AIC 2011 Midterm Meeting of the International Colour Association (AIC)

Interaction of Colour & Light in the Arts and Sciences

Conference Proceedings

Much interest is devoted to the interaction of colour & light in today's scientific and artistic research communities. New technologies, materials and media are now being deployed to enhance and stimulate our experience of daily life in real and virtual, permanent and ephemeral environments. The aim of the AIC 2011 conference is to explore how the interaction of colour & light plays a crucial role in the perception, conception and realization of spaces and platforms in different fields from both theoretical and practical points of view. Using terms and concepts such as appearance, interaction, performance, event, and by privileging the materiality, mediality, and the interactive dimension of colour & light, the conference presentations demonstrate how productive the theme of the INTERACTION OF COLOUR & LIGHT IN THE ARTS AND SCIENCES is. The fields of inquiry include education, design, art, media, lighting, architecture, theatre, dance, as well as psychology, colour science and technology. The AIC 2011 Midterm Meeting aims to further discussion and nurture the latest findings in these various fields.

The International Colour Association – Association Internationale de la Couleur (AIC) or Internationale Vereinigung für die Farbe – is a learned society whose aims are to encourage research in all aspects of colour, to disseminate the knowledge gained from this research, and to promote its application to the solution of problems in the fields of science, art, design and industry on an international basis.

pro/colore
Schweizerische Vereinigung für die Farbe

AIC
International Colour Association
Internationale Vereinigung für die Farbe
Association Internationale de la Couleur

ISBN 978-3-033-02929-3

AIC 2011 ZURICH · 7-10 JUNE SWITZERLAND

Interaction of Colour & Light
in the Arts and Sciences

Midterm Meeting of the
International Colour Association (AIC)
7–10 June 2011
Zurich, Switzerland

Conference Proceedings

Editors: Verena M. Schindler, Stephan Cuber

Please use the following format to cite material from the AIC 2011 Conference Proceedings:
Author(s). "Title of paper". AIC 2011, Interaction of Colour & Light in the Arts and Sciences, Midterm Meeting of the International Color Association, Zurich, Switzerland, 7–10 June 2011: Conference Proceedings, edited by Verena M. Schindler and Stephan Cuber. Zurich: pro/colore, 2011, page number(s).
The Conference Proceedings contain the full papers of the technical programme cited in the cover and title page of this volume. They reflect the author's opinions and are published as presented.
The abstracts from the technical programme are published in the AIC 2011 Book of Abstracts, ISBN 978-3-033-02929-3.

Editors: Verena M. Schindler, Stephan Cuber
Design: Florian Bachmann, Zürich
Layout: Stephan Cuber, Bern
Produktion: CD-Fabrik, Zürich

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AIC President's Message

It was here in Switzerland where it all started! In 1965 the first International Colour Meeting was held in Luzern. "They carried out their task with great success. The only thing they forgot to order was fine weather" as Gunnar Tonnquist expressed it in "The early history of the AIC". General guidelines for the new international colour organization were agreed upon, and the task of drafting the statues was given to the Statutes Committee consisting of Dr Ganz from Switzerland and Prof. Tonnquist from Sweden. The AIC was then founded 1967 in Washington DC, USA.

It is with great pleasure that AIC is coming back to Switzerland. The first AIC Meeting held in Switzerland was the AIC Meeting 1988 in Winterthur. This year's meeting in Zurich has attracted a lot of interest, and we are looking forward to a very interesting program. I am sure we will all have a lot of colourful memories to bring home.

Today we are 24 regular members and within the AIC executive committee we have therefore emphasized on the agenda the question about attracting new AIC member countries. This is a really important matter to be able to strengthen the position of AIC. I think the five AIC Study Groups are a key to attracting new interest for colour science as well for AIC as a powerful colour organization.

The five Study Groups are: Color Education (CE) with Robert Hirschler as chair, Environmental Color Design (ECD) with Verena M. Schindler as chair, Visual Illusions and Effects (VIE) with Osvaldo da Pos as chair, Color Perception of the Elderly (CPE) with Katsunori Okajima as chair and the newest one is The Language of Color (LC) with Jin-Sook Lee as chair.

To introduce an international day of colour and light, the "International Colour Day" March 21st, is an idea that we hope that you all will contribute to. Just let your fantasy start and you will create memorable colour activities in your country and we are all doing these colour actions all around the whole world on the same colourful day! As we will need a logo to establish an image for the day of the international celebration of colour we will suggest the opening of a competition for its creation during this meeting.

After the very successful and memorable meeting in Mar del Plata Argentina we are now working on the coming meetings. The next meeting will be the 2012 AIC Interim Meeting in Taipei, Taiwan, September 28 - October 1 with the theme "In color we live: Color and Environment"; in 2013 the 12th AIC Congress will take place in Newcastle, Great Britain, July 8-12; the 2014 AIC Interim Meeting is still open; the 2015 AIC Midterm Meeting will be in Tokyo Japan in May 2015.

I would like to thank especially Verena M. Schindler with her organization and all the members of the pro/colore – Swiss Colour Association and Zurich University of the Arts for the great organization of this meeting, as well as the members of the international scientific committee who reviewed a big number of extended abstracts resulting in 45 oral presentations and 150 poster presentations.

I am sure that the members of the organizing committee have done their best to ensure that this meeting will work out under the best possible conditions, that the proceedings will be interesting and that it will be exciting to learn about the latest developments under the theme of "Interaction of Colour & Light in the Arts and Sciences". I hope that we will all be enriched with increased knowledge and good friendship among our colour colleagues from around the world.

Stockholm, April 2011

Berit Bergström, AIC President

AIC
International Colour Association

AIC Executive Committee
President: Berit Bergström | **Vice-President:** Prof. Dr. Javier Romero | **Secretary/Treasurer:** Nick Harkness | **Committee Members:** Prof. Lindsay MacDonald | María Luisa Musso | Verena M. Schindler | Prof. Shoji Tominaga

Member Countries
Argentina: Grupo Argentino del Color | **Australia**: Colour Society of Australia | **Brazil**: Associação Pró-Cor do Brasil | **Bulgaria**: Colour Group of Bulgaria | **Chile**: Asociación Chilena del Color | **China**: Color Association of China | **Finland**: Suomen Väriyhdistys Svy Ry | **France**: Centre Français de la Couleur | **Germany**: Deutscher Verband Farbe | **United Kingdom**: The Colour Group (Great Britain) | **Hungary**: Hungarian National Colour Committee | **Italy**: Associazione Ottica Italiana | **Japan**: Color Science Association of Japan | **Korea**: Korean Society of Color Studies | **Mexico**: Asociación Mexicana de Investigadores del Color | **Netherlands**: Nederlandse Vereniging voor Kleurenstudie | **Portugal**: Associação Portugesa da Cor | **Slovenia**: Drustvo Koloristov Slovenije | **Spain**: Comité Español del Color | **Sweden**: Stiftelsen Svenskt Färgcentrum | **Switzerland**: Pro Colore | **Taiwan**: Color Association of Taiwan | **Thailand**: The Color Group of Thailand | **United States**: Inter-Society Color Council

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AIC Study Groups
Colour Education (CE): Dr. Robert Hirschler, chair | **Environmental Colour Design (ECD)**: Verena M. Schindler, chair | **Visual Illusions and Effects (VIE)**: Prof. Dr. Osvaldo da Pos, chair | **Colour Perception of the Elderly (CPE)**: Dr. Katsunori Okajima, chair | **The Language of Colour (LC)**: Prof. Dr. Jinsook Lee, chair

www.aic-colour.org

aic ZURICH · 7-10 JUNE 2011 SWITZERLAND

Preface

The beginnings of the AIC 2011 Conference in Zurich, Switzerland, occurred during a visit to the Alhambra for the 10th AIC Congress in Granada Spain in 2005. A small Swiss group began discussions there and then successfully prepared – together with the members of the AIC 2011 Organising Committee – an exciting programme on the theme of the 'Interaction of Colour & Light in the Arts and Sciences.' At AIC 2011, June 7–10, a total of forty-five oral papers, three invited lectures and one Judd Award lecture will be given. As well, 150 posters will be presented in two successive poster exhibits and discussed during the poster sessions.

I would like to thank the members of the AIC 2011 International Scientific Committee for reviewing the 325 submissions. The devotion and hard work of the AIC 2011 Organising Committee ensured that this adventure has turned out to be a great success. It is perhaps the first time that an AIC Midterm Meeting has been fully booked by the early registration deadline with 290 participants from almost forty countries working in many different research fields.

The venue at the Zurich University of the Arts is renowned for colour theory and its creative atmosphere. A prominent director was Johannes Itten who served in that position from 1938 to 1954. Today the ColourLight Center (CLC) serves to carry on this tradition, conducting important research projects and producing significant publications. The CLC research team Ulrich Bachmann, Ralf Michel, Florian Bachmann and Marcus Pericin will give the AIC 2011 opening lecture on the topic 'From Colour-Light Research to Colour-Light Teaching.' The NCS invited lecture will be given by Lino Sibillano on 'The Colour Space of Zurich. An Exemplary Research on Colour, Texture and Light in Urban Space,' and the Philips invited lecture by Markus Reisinger will be on 'Facilitating Surface, Colour and Lighting Choice.' On Thursday, June 9th, Prof. Dr. Lucia Ronchi, winner of the prestigious AIC 2011 Judd Award, will speak on 'Experimentation in Colour Vision.'

As for the social programme, a welcome reception at Zurich University of the Arts (ZHdK) and conference dinner at the 'Zunfthaus zur Meisen' provide an opportunity for the participants to get to know each other and develop an exchange and network. As well, an excursion exploring new urban development and colour planning in Zurich that has been organised by Haus der Farbe Zurich is an optional event open to all AIC 2011 participants and accompanying guests. Further a walking tour to experience the historic city core and its plan lumière has been organised by NCS Colour Centre Schweiz, one of our main sponsors.

I would like to extend my warmest thanks to our partner, sponsors and supporters for their generosity; their precious support has made this conference a successful endeavour.

I wish you all a captivating AIC 2011 Midterm Meeting and an exciting time in Zurich!

Verena M. Schindler,
AIC 2011 General Conference Chair

www.aic2011.org

pro/colore
Swiss Colour Association

The Swiss Colour Association pro/colore is an independent, non-profit colour association that aims to serve as a general and professional platform for dealing with colour design, dyes, colour reproduction and colour communication. pro/colore is actively dedicated to promoting more conscious ways of understanding and dealing with colour, not only in the way it is used creatively, but also in terms of its production and reproduction.
Collective and individual membership is open to affiliates of trade unions and companies, educational, public and professional organisations and institutions, as well as private persons. Currently pro/colore has more than 300 members.
pro/colore organizes colour events four times a year. On these occasions it sends out a letter including a whole range of information on colour and colour events to its individual and collective members.

The main goals are to further the exchange of experience, spread information and support cooperation between members of different specialization. A further aim is also to encourage international cooperation and exchange with other colour associations, e.g., the German colour association Deutsches Farbenzentrum. As well, pro/colore is a member of the International Colour Association (AIC) being one of the signatories of the founding act of the AIC in 1967.

www.procolore.ch

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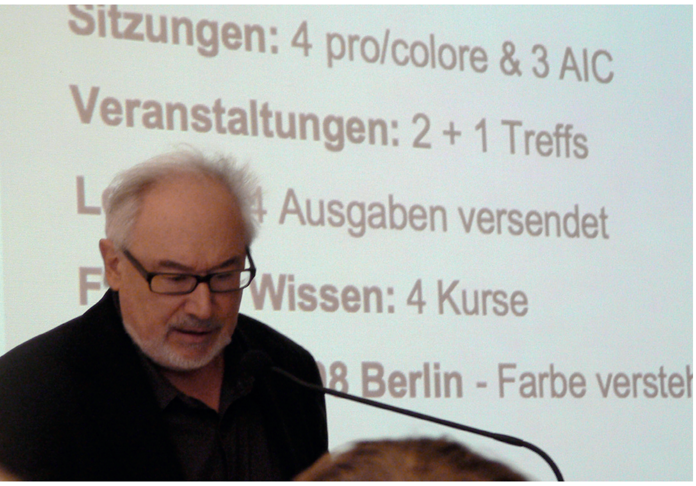

Interaction of Colour & Light in the Arts and Sciences

How do coloured surfaces change their appearance with coloured light? How does light interact with materials? How does light interact with colours in our environment, on stage, on digital screens and in daily life? Do we have tools to teach about the interaction of colour and light? How can we best explore the effects of the interaction of light and colour in relation to people? The fields of inquiry include education, design, art, media, lighting, theatre, architecture, urbanism, and landscaping as well as psychology, colour science and technology. The AIC 2011 Midterm Meeting in Zurich, June 7–10, aims to further discussion and nurture the latest findings in these various fields from both theoretical and practical points of view.

The AIC 2011 conference presentations demonstrate the productive nature of the theme of the Interaction of Colour & Light in the Arts and Sciences. The papers explore these important topics in today's scientific and artistic research communities. New technologies, materials and media are now being deployed to enhance, alter and improve our experience in real and virtual environments.

Conference Topics and Sub-Topics
Submissions were accepted for consideration in any of the topics mentioned below.
1. SPACE: a. visual culture; b. photography; c. design; d. lighting; e. interior architecture; f. architecture; g. urbanism; h. environment; i. landscaping; j. visionary projects
2. STAGE: a. performance; b. art; c. museography; d. scenography; e. techniques of staging; f. theatre, performing body; g. dance, movement; h. music, sound; i. virtual projects
3. EDUCATION: a. teaching aids; b. methodology; c. theory; d. terminology; e. static and electronic media; f. multimedia
4. PSYCHOLOGY: a. colour perception; b. harmonious interactions; c. emotional interactions; d. illusions resulting through light and colour interaction
5. SCIENCE & TECHNOLOGY: a. colour science; b. physiology and psychophysics; c. colour appearance and measurement; d. materiality, texture, surface; e. transparency and translucency, reflection and glossiness
6. COMPUTER GRAPHICS: a. colour in computer vision; b. colour in graphic design; c. multimedia in colour imaging; d. computer graphics scene rendering; e. Virtual Reality (VR) and Augmented Reality (AR) environments

Committees

AIC 2011 Organising Committee

General Chair: Verena M. Schindler, Art & Architectural Historian, Zollikon and Atelier Cler Etudes Chromatiques, Paris | **Technical Chair:** Prof. Ulrich Bachmann, ColourLight Center, Zurich University of the Arts, Zurich | **Publications Chair:** Stephan Cuber, Architect & Designer, Bern | **Publicity Chair:** Florian Bachmann, ColourLight Center, Zurich University of the Arts, Zurich | Stephan Cuber | **Financial Chair:** Daniel Pfeffer, pro/colore and CRB and NCS Colour Centre Switzerland, Zurich | **Social Events:** Eveline Staub, pro/colore Head Office and Event Manager and Colour Designer, Zurich

AIC 2011 Scientific Committee

Programme Chairs: Verena M. Schindler | Prof. Brian Funt, School of Computing Science, Simon Fraser University, Canada

Papers Committee: Prof. Sabine Süsstrunk, School of Information & Communication Sciences, Ecole Polytechnique Fédérale de Lausanne | Dr. Stefanie Wettstein, Haus der Farbe, Zurich | Verena M. Schindler | Dr. Marcus Pericin, ColourLight Center, Zurich University of the Arts, Zurich | Prof. Brian Funt

AIC 2011 International Scientific Committee

Berit Bergström, Swedish Colour Centre Foundation and NCS Colour Academy AB, Sweden | **Prof. Roy S. Berns,** R. S. Hunter Professor in Color Science, Appearance, and Technology, Munsell Color Science Laboratory, Rochester Institute of Technology, USA | **Prof. Axel Buether,** Colour Light Space Fundamental Studies, Burg Giebichenstein University of Arts Halle, Germany | **Prof. José Luis Caivano,** University of Buenos Aires and National Council for Research, Argentina | **Michel Cler,** Architect, Colour Consultant, Atelier Cler Etudes Chromatiques Paris, France | **Prof. Osvaldo Da Pos,** Department of Applied Psychology, University of Padua, Italy | **Prof. Maria João Durão,** LabCor-Colour Laboratory, Faculty of Architecture, Lisbon Technical University and APCOR-The Portuguese Colour Association | **Prof. Brian Funt,** School of Computing Science, Simon Fraser University, Canada | **Dr. Paul Green-Armytage,** School of Design and Art, Curtin University, Australia | **Prof. Rudolf Gschwind,** Imaging and Media Lab, University Basel, Switzerland | **Nick Harkness,** NHPL, Australia | **Prof. Roger D. Hersch,** Computer & Communication Sciences, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland | **Dr. Robert Hirschler,** SENAI/CETIQT Colour Institute, Brazil | **Prof. Jinsook Lee,** Department of Architectural Engineering, ChungNam National University, Korea | **Prof. Tien-Rein Lee,** Graduate Institute of Informationn Communication, Chinese Culture University, Taiwan | **Prof. Lindsay W. MacDonald,** London College of Communication Elephant & Castle, UK | **Prof. Manuel Melgosa Latorre,** Department of Optics, University of Granada, Spain | **Maria Luisa Musso,** Architect, Consulting Professor, University of Buenos Aires, Argentina | **Prof. Katsunori Okajima,** Research Institute of Environment and Information Sciences, Yokohama National University, Japan | **Frank Rochow,** Adviser, Licht- und Farbmesstechnik, Germany | **Prof. Javier Romero,** Departamento de Óptica, Universidad de Granada, Spain | **Prof. Lucia Ronchi,** Fondazione Giorgio Ronchi, Italy | **Prof. Emerita Lois Swirnoff,** The Cooper Union for the Advancement of Science and Art, New York, NY and University of California, Los Angeles, USA | **Prof. Shoji Tominaga,** Graduate School of Advanced Integration Science, Chiba University, Japan | **Prof. Françoise Viénot,** Muséum National d'Histoire Naturelle, Centre de Recherche sur la Conservation des Collections, France | **Prof. Stephen Westland,** School of Design, University of Leeds, UK | **Prof. Sanford Wurmfeld,** Phyllis and Joseph Caroff Professor of Fine Art, Department of Art, Hunter College, City University of New York, USA | **Prof. Guanrong Ye,** Institute of Optical Radiation Technique (ORT), Zhejiang University Hangzhou, China | **Prof. Libero Zuppiroli,** Laboratory of Optoelectronics of Molecular Materials (LOMM), Ecole Polytechnique Fédérale de Lausanne, Switzerland


Florian Bachmann


Ulrich Bachmann


Stephan Cuber


Brian Funt


Marcus Pericin


Daniel Pfeffer


Verena M. Schindler


Eveline Staub


Sabine Süsstrunk


Stefanie Wettstein

Judd Award citation

Citation for the 2011 Deane B. Judd Award Presented to Prof. Lucia Ronchi

Manuel MELGOSA
Department of Optics, Faculty of Sciences, University of Granada (Spain)

Ms President, Committee Members, Colleagues, Ladies and Gentlemen:

It is a great pleasure and an honour to introduce to you Prof. Lucia Ronchi, the recipient of the 2011 Judd Award given by the International Colour Association (AIC).

Prof. Lucia Ronchi ~ 1970

Since 1973, when Betty Judd proposed to establish an AIC award in memory of her husband, to recognize outstanding work in the field of colour science, the AIC has been carrying out the process of selection of the recipients for this award every two years. Up to date the recipients of this highly prestigious award, the highest AIC distinction, have been 22 famous colour scientists, including only 2 women: Dorothy Nickerson (Judd Award in 1975), and Dorothea Jameson (Judd Award in 1985, together with Leo M. Hurvich). Today we have the great pleasure to add the name of a third woman, Prof. Lucia Ronchi, to this important list of colour scientists. They generously dedicated a very important part of their lives to the progress of colour science, allowing most of us to develop our current professional activity in this exciting scientific field.

Lucia Ronchi (widow Rositani) was born in 1927 in Florence (Italy). She was graduated in Physics at the University of Florence in 1948 with a Ph.D. Thesis in Astronomy, on the Milky Way. During the first five years after the doctorship she continued attending part time the Institute of Experimental Physics, in the section of electrical and electronic laboratory, passing from voluntary to "extraordinary" assistant, but devoting her main involvement at the National Institute of Optics, active in optical design and in the organization of a visual laboratory. In 1955 she became "Libera Docente" in Physiological Optics, which just in 1950 was becoming officially a self-standing branch of science, and the National Institute of Optics was given the task of spreading it in Italy, by emphasizing its optical component. In 1956, Lucia became full time assistant at National Institute of Optics, responsible for the Visual Laboratory, where the psychophysical and electrophysiologial experimental activity started, and continued, uninterruptedly, until her retirement in 1992. Thereafter, she is pursuing experimenting in a private small laboratory, yet representing Italy in some sections of CIE and AIC, attending international meetings, as President of the Fondazione Giorgio Ronchi, and performing some tasks in the Associazione Ottica Italiana. In particular, she is involved in divulgating the "scientific revolution in visual science" at the turn of the Millennium and its implications in the advanced research in a visual laboratory.

Since 1949 Lucia Ronchi has published 293 papers of the Atti Fondazione Giorgio Ronchi (http://ronchi.isti.cnr.it) and she is also author of many other contributions in scientific Journals (see references, conferences, technical reports, etc.) In summary, it means a service to science community. Thank you and congratulations for your hard work.

Lucia Ronchi's publications concern on one side the results of her personal experiments, on the other side a continued bibliographical up-to-dating on the progress of colour science. The booklets illustrating her AIC activity and contributions to the advanced research are available on Google. The multidisciplinarity of visual research led Lucia Ronchi to the enlargement of her interest in a number of collateral fields, where vision is involved in one or another form. An abridged report on some specific cooperations is displayed below.

Colour Science

She was called by Verriest to contribute to his International Research Group on Colour Vision Deficiencies IRGCVD, from its foundation, in the early seventies, with the specific task of spreading in Italy the interest for that growing discipline. She has been attending yearly the International meeting of that group, and has been invited speaker in various Italian meetings on colour vision deficiencies. She is "member for the life" of the Colour Group of Great Britain. Lucia links Italy, as regular member of AIC, since 1975. She started attending the AIC meetings in 1982 (Budapest), and continued in the subsequent decades. In 1988 she was nominated Vice-President of AIC and acted as AIC President from 1983 to 1997. Lucia Ronchi is taking care of the Journal Luce e Immagini, the voice of the Associazione Ottica Italiana dealing with colour vision under various respects. She closely followed and contributed to the activities of the AIC Study Group on Environmental Colour Design (ECD). At the Sydney 2009 meeting, she presented at the AIC EC a proposal for a new Study Group, entitled "Language of Colour", flanked by a bibliographical review of the papers concerning colour in architecture since 1982.

Lighting Engineering

In 1975 Lucia Ronchi entered as member the Commissione Italiana di Illuminazione, started attending the national meetings of AIDI (Associazione Italiana di Illuminazione) since its origin in the sixties, and contributing to its journal LUCE. She was invited to teach the recurrent courses devoted to lighting design, up-to-dating in visual research related to lighting, organized by the AIDI at the Politecnico di Milano. She has been member of the Foreign Advisory Board of "Lighting Research and Technology" up to 1991, as well as member of the Foreign Advisory Board of the journal "Light & Engineering" (and Svetotekhnika) since 2002. She has been regularly attending the quadrennial meetings of LUX EUROPA (the last in Berlin, 2005).

CIE Activities

On behalf of the Italian Commission of Illumination (linking Italy to CIE) Lucia Ronchi started being interested in photobiology and related applications to lighting. In 1969 she was invited speaker at the NATO Advanced Institute on Biological Effects of Visible Light, a meeting held in Sassari (Italy). Prof. Ronchi has been Italian delegate first for CIE Division 1, next for CIE Division 6 (and yet nowadays). In 1975 she was nominated Italian representative in the CIE Study Group on Actinic Effects of Optical Radiation. In 1975 Prof. Ronchi first attended a CIE meeting at the Imperial College (London). Her attendance has continued, uninterruptedly, including the

CIE Expert Symposia (among the most recent 1999 Cambridge, UK; 2002 Versprèm, Hungary; 2006 "Visual Appearance" in Paris; 2009 "Lighting & Lighting Conference" in Budapest; 2010 "Lighting Quality & Energy Efficiency" in Vienna. From 1979 to 1983, Chairman of TC1-7, Visual and Non Visual Actinic Effects of Optical Radiation. From 1983 to 1991, for two quadrennial terms, Prof. Ronchi was Division Director of CIE Division 6, Photobiology and Photochemistry (Visual and non-visual effects of optical radiation on man, animals, vegetables and materials). During the course of decades, she served as member of various CIE Technical Committees: TC1-26 Heterochromatic brightness matching; TC1-59 CIE ten degree photopic photometric observer, V10 (lambda); TC1-72 Measurement of appearance network MApNet, etc.

Ophthalmology

Lucia Ronchi was involved for 25 years (up to 1980) in an experimental and educational collaboration with opthalmologists in the Lab. and at the School of Specialization. She has been regularly attending international meetings as member of a number of associations, like IRGCVD (inherited and acquired colour vision deficiencies); ISCERG (International Society of Electroretinography, subsequently devoted to cortical visual evoked potential), IPS (visual perimetry).

Educational Activity in Visual Optics

As member of the staff of National Institute of Optics in Italy, she regularly lectured at this institution up to 1992. In 1982 she started a collaboration with the Italian Society of Nuclear Medicine, and was invited speaker at their 1st National Meeting (Gargonza, Arezzo, Italy, 1982) dealing with advanced imaging techniques. She had a continued collaboration with the Faculty of Medical Physics culminating in 2002 as invited speaker at their meeting on Visuo-Motor Reaction Time. She has also acted from time to time as coordinator in doctorship theses at the Faculty of Physics, dealing with computational visual modelling as well as at the Faculty of Architecture.

Architecture

In 1975 Lucia Ronchi was invited to collaborate to the journal "Technical Bulletin of the Union of Architects and Engineers Free Professionists of Tuscany". She has been invited at the meetings of UIA (International University of Arts, Florence, Italy), lecturing in the section Colour in the Landscape, and Colour Planning.

Along many years Prof. Lucia Ronchi has achieved the highest scientific appreciation and friendship of a large number of researchers in colour science around the world. For me and many other colleagues in the colour community it is a great pleasure to meet her in new scientific meetings. We highly appreciate Lucia's wise guidelines and answers to the scientific questions on colour and light raised in our everyday work. In particular, I feel really proud of her friendship since we met first at AIC meeting in Budapest in 1993, and one year later when she was invited at the II National Colour Meeting of Spain. May I introduce to you my friend and highly respected colleague Prof. Lucia Ronchi who will speak on: Experimentation in Colour Vision.

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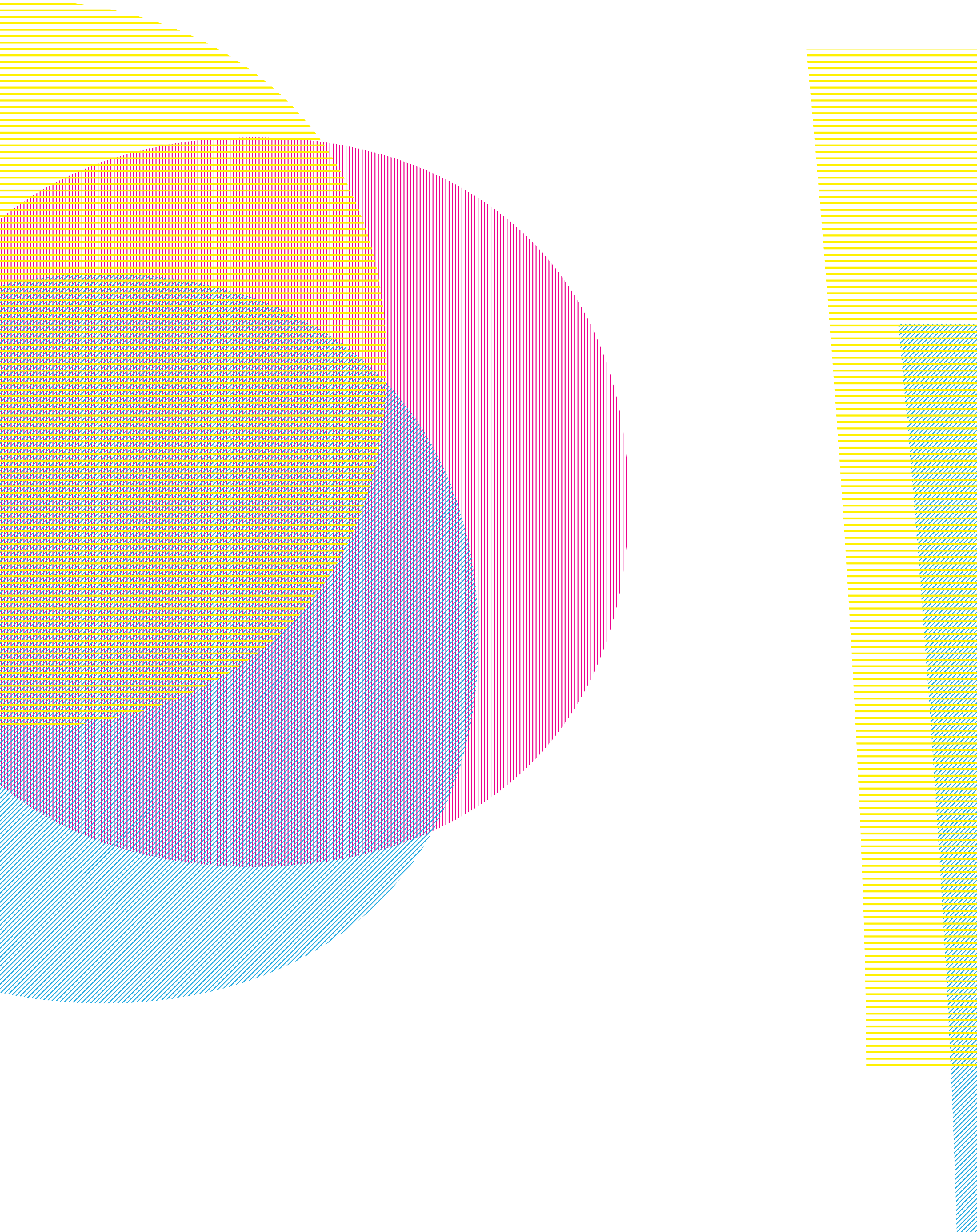

Judd Award lecture

Experimentation in colour vision

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Abstract
According to Valberg (2005), "neurophysiological research has brought major advances in our understanding of underlying mechanisms of color vision, but much remains to be discovered… we have no complete physiological model of color vision". In turn, according to K. De Valois (2003), "the basic function of color is not yet agreed". The present paper deals with a problem yet under discussion: the prediction of the global response to complex real and natural test objects. Much is expected from the present experimental task force on feature interactions. An intriguing fact is that the color, although conjoined with every stimulus feature, does not always obey to the same rules of the conjunction as the other features.

1. Introduction
The research on vision, and on colour vision in particular, is very old, and it is documented in the editorial efforts appearing, for instance, around the mid XX century, like the three volumes by Y. Le Grand, entitled *Optique Physiologique*. Briefly, a lot of research had been made, but, at that point, an intense exchange of ideas among authors was needed Therefore, in 1950 a world task force was activated to raise the Physiological Optics to the official level of a branch of Science, in a multidisciplinary context. In the present paper we are considering, in particular, the inclusion of Physics through Optics. In each country an Institute was charged with the task of locally spreading up-dated informations, of exchanging researchers, and organizing periodical meetings. In line with it, in 1954, the INO (National Institute of Optics, of Arcetri), in conjunction with the ICO (International Commission of Optics), organized a meeting in Florence, entitled "Problems in Contemporary Optics", dealing, among the highlights, with the introduction of the Fourier Analysis to assess the spatial frequency content, and hence the quality of the images formed by the optical instruments. This tool was soon adopted in visual science, for instance by de Lange, for the flicker response, and by Robson and Campbell for the transfer of spatial contrast. The related concept of electrical analog in terms of cascade of filters, amplifiers and feedbacks was thus adopted in visual modeling, where achromatic vision was found to be band pass, and chromatic vision, low pass and the concept of multichannel modeling of vision was becoming popular.

From the stand point of experimental psychophysics, two parallel approaches were activated: the "classical" approach, in strictly controlled conditions, defined as "captivity"; the parallel approach, devoted to an alternative, more realistic research mode, that opened the way to the study of vision in real and in natural environments ("the jungle").

2. The two simultaneously active approaches of experimental research
Let the visual sensory system be considered like a physical system, in the form of a "closed box", governed by laws, defined as the relation between the input signal (the light stimulus) and the output signal (the observer's response, recorded psychohysically).

The chromatic vision is elicited by a narrow band monochromatic stimulus or by spectral bands of appropriate width, their "spectral composition". The achromatic vision is elicited by stimuli of sufficiently wide bands, or by the mixture of pairs of particular monochromatic stimuli. In either case the world of stimulation is multidimensional. Various tasks are requested to the observer and various responses are recorded. Moreover, the good connection of colour vision with colorimetry should be taken into account, as well as the relation with the century lasting research on Colour Order Systems, culminating in the recent precious Farb-Systeme (Spilmann, 2009).

2.1 The classical experimental approach

The goal of this experimental mode consists in recording the basic laws of visual functionality under particular constraints The stimulus related factors are varied each at a time, the others being frosted, and named parameters. The same holds for observer related factors. The small test objects, comparable in size to the retinal receptoral units . are dots, patches, simple geometrical forms spatially uniform uniformly illuminated. The same holds for the background, while the surround is black or kept at a low level, to avoid contextual effects. Eye fixation is rigidly maintained. The top-down effects are minimized, as far as possible. The responses depend on the particular visual task in course. In the case of the detection threshold, three response categories are allowed, Yes, No, Doubtful.

From the experimental viewpoint, colour vision is an interplay of threshold and supra-threshold situations. The photochromatic interval is of interest, in particular, because it shows that the difference between the chromatic and the achromatic thresholds is high in the central regions of the visible spectrum, but it drop to nearly zero at the red and blue extremities. The problem of color differences is a matter of threshold, and it is traditional highly debated, not last because of its industrial relevance. However, from the general stand point, colour vision is regarded as a suprathreshold fact, typical of photopic vision. The question is often raised whether colour vision is superior or not achromatic vision, and in any case under what respect. As an aside, the assessment of suprathreshold responses is debated by pure psychophysicists, in favour for a matching method, while others are in favour of visual scaling.. In this latter connection, according to K. De Valois (2003), the relative superiority of colour vision, compared to achromatic vision, is that luminance is an unidimensional continuum and its perceptual aspect is not easily categorized beyond bright, dark and medium. On the other hand, color is three-dimensional, thanks to its perceptual aspects: brightness, saturation and hue…" each susceptible of scaling. At last, let us note that the functionality laws, emerged from the classical experimental approach, were transmitted to applications. In particular, the spectral sensitivity data and their complicacies have been deeply considered by the CIE, while the data of normal observer have been utilized in Ophthalmology and related instrumentation Moreover colour vision screening applies in various professions.

2.2 The alternative, non classical, experimental approach

In the fifties, another approach started operating, in parallel with the classical approach, but on an alternative position. In fact, the growing availability of the computer facilities allowed the generation of non uniform test objects, with variable degrees of complexity. It opened the way to the research on vision in the real world, and even in the natural world, where illuminance is rarely uniform, and spatial uniformity is the exception, since texture is ubiquitous. Now, in real situations, several stimulus factors are co-varying. The resultant visual effect cannot be calculated by combining the, single variable laws emerging from classical experiments, because the combined stimulus features interact and the related laws are yet unknown laws. It was imperative to find new ways.

Therefore, Julesz, with Barlow, Caelli, et al. undertook experiments by creating test objects of variable complexity thanks to the just emerging computer facilities. Starting from aggregates of random dots, random textures were created by manipulating various filtering procedures. By using filtered noise and noise masking a syntaxis of complexity emerged, by interpreting the observations in terms of the complex and ipercomplex features extracted from the images and by establishing the related hierarchies. In this way, the way to the advanced research of the 3rd Millennium was open. The path was not easy and various problems were solved decade after decade. Also new responses were needed, to pass from simple to complex, from local to global. Colour vision was involved by using the anaglyphs as targets. More recently, the various Gabor's test objects became popular in visual laboratories, very appreciated because they can cope with the pre-receptoral individual differences. However, their instrinsic structure is such that their, perception related, luminance contrast is difficult to be assessed, since the traditional photometry refers to uniform surfaces.

3. The recent experiments on colour vision

A recent task force in visual laboratories is devoted to the "interactions" as a basic ingredient of visual processing. We owe to K. De Valois (2003) the solution of an old question, whether color and luminance are processed independently from one another or not. The classical experiment resulted in ambiguous responses. Therefore K. De Valois organized a non classical experiment, a step toward the globality. That is, instead of varying a single variable at a time, she introduced an additional variable by recording the spatial response in cases where the luminance was kept constant and the color was varied, and viceversa, where color was constant and luminance was varied. In this way she demonstrated the hue specificity of luminance variation. Anyhow, the above conjunction of three features confirm the statement that there is no color without form.

The responses to complex test objects may be described also by the help of computational modeling (Ellemberg, 2004). Briefly, in the 1st order vision the extracted features are colour, luminance and orientation. They are processed independently from one another, until they process passes to second order vision, where other features are extracted, like the contrast of features and the texture, and all the features are conjoined and interact. The intriguing fact is that there are various kinds of even contradicting interactions, implying facilitation or suppression; subadditivity or superadditivity; counteracting or compensating; assimilation or contrast, as well as various possible degrees of perceptual constancy. The observer's responses may vary from case to case, depending on the task. However, there may be also responses of general use, like the manual visuo motor reaction time (RT), the semantic differential scaling (SD) and he visual balance, that is the matching of visual weights or of the information contents of Test and of Reference. An important fact, susceptible of future experimentation is that the color conjoins with every other feature, but it does not obey to the same laws of conjunction as the other colours: it does not lose its identity in the conjunction as the other features do; it attracts the attention, and its capture is automatic even when it is not salient.

4. A report about some personal experimentation

4.1 A global response: the visual balance used for the textured Purkinje effect

During the past decade (Ronchi, 2002 a) we have been devoting our research to the study of the visual balance, that is the match of the visual weights of a test sample (of given size, e.g. 10°x 10°) and of a reference sample, juxtaposed in a display, hence sharing the same height, 10°, but of variable width wref. The conjoined features are color, lightness, intradisplay luminance contrast c, and relative size. Once fixed the Test object, e.g. a red cardboard, and the reference, e.g. a grey of given reflectance factors, and hence, once fixed the value of c, let us apply the constant stimulus method. For each value assigned to wR, the allowed response categories are: Yes, balance, No balance, doubtful and the balance condition is thus attained. In the case where Test and Reference are spatially uniform, the psychometric functions are sigmoidal. However, if the Test is increasingly textured, the psychometric function shows and increasingly complex shape.

Since 1826 it is known that as adapting luminance decreases during sunset, the lightness, of a red sample decreases faster than the lightness of a blue sample. Laboratory experiments have shown that this Purkinje effect depends on the fact that the maximum of the spectral efficiency function shifts to shorter wavelengths when crossing the mesopic range. Now, even if the "Purkinje shift" (from 555 to 505 nm) is the most relevant factor, a typical description of this effect is not yet available, as far as we know. The reason might be that it is complex, because of the conjunction of various factors, such as the size of the sample, their saturation, the SPD of the source (varying under natural sunset) and the experimental method used. Some examples of these dependencies, shown in Figures 1 to 3 are obtained by using a red cardboard (NCS notation S 05 80 - Y 90 R) and a blue cardboard (S 10 60 - B), both spatially uniform. Now, as it is for instance the case of bilateral symmnetry.

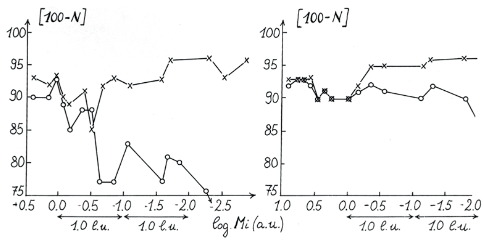

Figure 1 - Purkinje effect recorded at sunset. Abscissae, log illuminance, arbitrary units, mesopic range, decreasing from left to right. Stimuli: square cardboards, left, 2° side; right, 10° side, on a black background. Circles, red; crosses, blue. Ordinates: estimates of lightness, by match with the NCS grey scale placed between the samples.

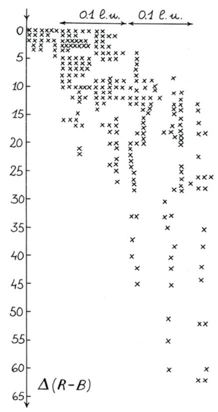

Figure 2 - Horizontal axis: log mesopic illuminance, decreasing from left to right. Data points: responses of one observer, stimulus size ranging from 1° to 10° and various sources, natural, warm (x=0.510; y=410), and cool (x=402; y=0.377). Vertical axis: differences of the estimates of red and blue lightnesses.

The models representing a given effect, designed to fit the data obtained with spatially uniform samples, fail when the texture is an additional feature. When using cardboards on which a line square grating is printed, the assessment of relative lightnesses becomes increasingly difficult. One of the reason may be the eye chromatic aberration. The variability of the responses is unacceptable. Therefore we decided taking profit of a global response like the balance is (Figure 4). The test object is red, the lines of the alternating red and black grating are oriented horizontally.

The juxtaposed reference grating (also with horizontal lines) is blue, of variable length wref. According a Munsell rule, small areas of large chroma will balance large areas of low chroma. Hence, the greater the lightness, the smaller the weight. Therefore, the fact that when illuminance decreases the (fixed) red sample is balanced by a blue reference of increasing length, means that the visual weight of red increased more rapidly than that of blue. In addition, the red increases in saturation (re: chroma) as its lightness decreases, while the opposite occurs for blue, probably because of the increasing participation or interacting rods. Note that Figure 4 also show the transition from assimilation to simultaneous contrast. In conclusion, it seems to us that the use of a global response like the balance is, is somehow advantageous.

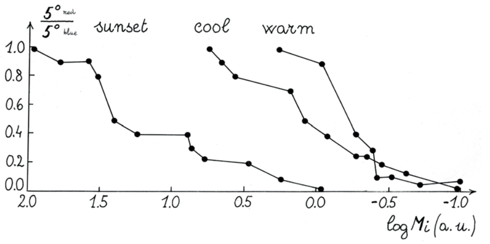

Figure 3 - Abscissae: log illuminances across the mesopic range. Size of the stimul, 5°. Ordinates: estimated ratio of red and blue lightnesses. Note the effect of the SPD.

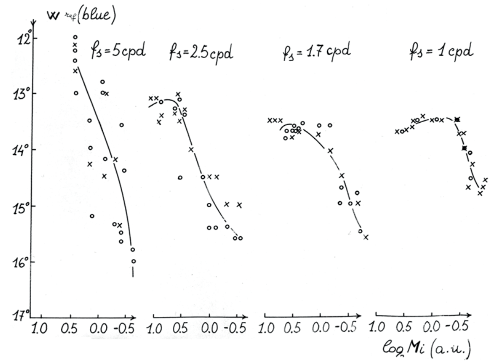

Figure 4 - Abscissae: log illuminance in the mesopic range. Ordinates: width of the blue reference sample balancing the red sample of fixed size (10°x10°); fs, the spatial frequency of the red. black and blue-black, square line gratings printed, respectively on the red and the blue samples.

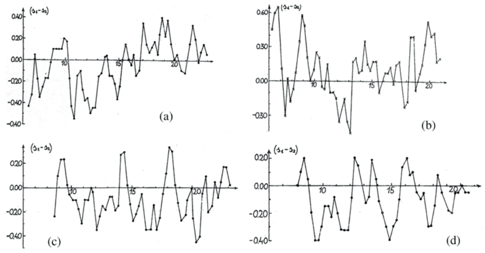

Figure 5 - Abscissae: time of day, in hours. Ordinates: difference between the slopes of the plots of estimated lightness versus retinal eccentricity, in the ranges 10°-20 and 20°-30°, respectivey.*

4.2 About the long, linking bridge

Being respectful of the space availability, let us synthesize now two of our experiments concerning the basis of the transition from local to global and from simple to complex.

The former is of physiological flavour. The enthusiasm evoked by the discovery of the microelectrodes and the related recordings of the single cell responses decayed rapidly because the laws of combination, leading to the behaviour of the related organ were not available. Nowadays, an important research channel has been activated by the discovery of the ipGRC variety of ganglion cells in the mice retina (frequency of occurrence 4%) linked to the non-imaging brain centers mediating the physiological rhythms. It seems that such cells are present also in the human retina, and the action spectrum of melanopsin contained by the said cells has been tentatively related to the SPD (re: color of light) of a source for general lighting, capable of optimizing the human biological rhythms (metabolical, hormonal), in turn linked to the visual performance rhythms. However, the influences of daylight and of the social factors are yet a matter of investigation. Some data, e shown in Figure 5, were obtained (Ronchi, 2009 b) in typical days spent partly under controlled illuminance, partly under uncontrolled exposure. Circadiancy is found to be partially disrupted by a free running 4 hour oscillation. The dependence on SPD is weak, at the limit of significance, but further work is neede.

The latter channel of research concerns both the extent of the range where vision is uncertain and the related response variability. Both increase when passing from the detection threshold of a simple uniform patch to the visibility threshold of increasing deviation from the spatial uniformity (the modification of a simple geometrical figure, the compound gratings, the clusters appearing in arrays of Random Dots, etc). We have been considering as limiting case (Ronchi, 2005 c) that is wool knitted samples, where two threads of different colors where paired, flat or rough, according to the stitch. By increasing the viewing distance, numerous effects were perceived, ascribable to the interlacing of complex cortical cells and to the irregularities at the site of the formation of retinal images. Now, apart from shimmering, jitter, vibrating, pulsating, speckle-like boiling animation, the most important event is the resistance to fusion, the repulsion, the non validity of Ricco's law, for pairs of colors belonging to different categories. Seurat created non identifiable colors. His secret, was that randomness prevents categorization. Recently (Mausfeld, 2002) computer generated "Seurat stimuli" have been presented. In a research in course we are exploring the possible counterpart of the above effects in the grainy arrays of LEDs, in particular to those labeled RBG.

To conclude, let us note that the concept of linking and bridging is not a prerequisite of particular cases, but it is intrinsic to the nature of the color process. For instance, because of the Principle of Univariance the single cone cannot be defined as "colour receptors" in the strict sense of the word. The colour message leaving the retina is not per sé perceptual but is represented by the sum and difference of the action spectra of the three types of cones (De Valois, 2003). However, the extent and location in the brain of a specific, localized color centre is still a matter of debate. In turn, the trichromatism theory itself has been released from the ancient demand that it should account for how colours look (Mollon, 2003).

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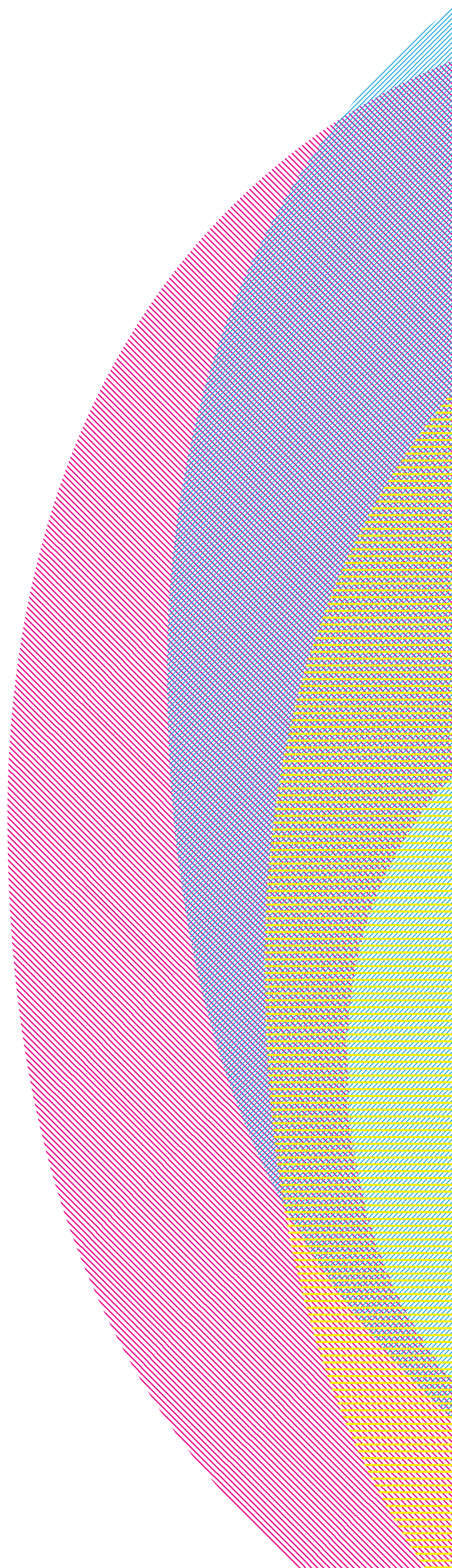

Invited lectures, oral papers

in order of presentation

From colour light research to colour light teaching

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Abstract

Colour and light go together and the many different interactions represent very important research topics towards new teaching developments as well as new practical applications in art, architecture, design and performing arts. Our aim was to develop a combined approach for colour and light teaching for basic education, its evaluation and didactic implementation. Our main questions were:

– How are the colours influenced by dynamic lights?
– What are appropriate elements for teaching the complex interactions of colour and light and how do they have to be designed?
– What is the relevance of the developed materials for teaching and practical use and the suitability as individual learning tools?

The above aim was achieved by practical, design driven experiments and specific evaluation methods (questionnaires, interviews, participatory observations) following the idea of research through design (Archer, 1995). In close relationship with our teaching activities we developed three different kinds of didactic materials based on a multimedia approach: room installations, interactive physical and digital tools. They enable the understanding of the complex interrelations between colour and light by own experiments in a sensual way. The results show in particular:

– The relevance of hue, saturation and brightness shifts using coloured or different white light sources
– The suitability of using differentiated materials in colour and light teaching such as room installations, interactive physical and digital tools
– The relevance of the developed materials in the field of colour and light teaching and as individual learning tools

Based on the relevance of our research results we should be able to develop in the near future instruments and methods also for practical use in design, stage design and interior design.

1. Colour light research

The approach to the research of the inseparable elements of colour and light has emerged from the experience that previous instructional and practical methods have not adequately recognized the connection between these two factors. Neither in the theory nor in the practice of design do comprehensive methods or models exist for the controlled use of colour and light that extend beyond theoretical explanations or a compendium of empirical values. Furthermore, the development of new light technologies, most importantly of dynamic and coloured LED lights, increase the necessity to investigate and teach the enormous potential of the many different interactions between colours and light.

Our research is focusing on the interaction between colours and light in spatial, temporal and virtual contexts. It strives to innovate instructional content and form, and to advance the practical application of design. It is achieved by simulation and evaluation in experimental settings in form of prototypes which are evaluated with respect to teaching applications in design studies (Bachmann et al. 2009; Bachmann 2006, 2011). The method follows the idea of research through design, which was expressed by Bruce Archer in 1995 as research through practice (Archer, 1995).

In our teaching activities we use the same approach. We combine the acquisition of knowledge with the assessment of the relevance of this knowledge for instructional projects. New knowledge is not an end in itself but is directly communicated, even in the earliest phases, before it has been confirmed. Students thoroughly test this knowledge in their projects, criticize it, utilize it and in doing so examine its substance.

2. Colour light teaching

Within our current research project *Colour and Light* (Bachmann 2011) we developed a new and combined approach towards colour and light teaching. We developed three different types of experimental materials that encourage users to creatively examine and experiment with phenomena related to colour and light on their own: installations, interactive physical and digital tools. They show central phenomena, such as the dynamic correlations between surface colours and light and between dynamic lighting conditions in spatial, temporal and virtual contexts. Some of these materials are based on our previous research projects *ColourLightLab* (Bachmann 2006), and *LED-ColourLab* (Bachmann et al. 2009). All these materials and additional theoretical background information, such as a compendium can be found on the multimedia publication *Colour and Light* (Bachmann 2011).

2.1 Installations

We use the term installation to refer to all materials that allow various perceptive phenomena related to light and colour to be illustrated and experienced in a spatial context. The installations have been developed from observations that can be made in everyday situations. They illustrate the interdependence of colour and light: *colour-light-pattern (Figure 1)* and *colour-light-keyboard (Figure 2)* (Bachmann et al. 2009). Furthermore, the large influence of the spatial and temporal context in colour perception can be observed within the *colour-light-cabin* showing various phenomena, such as *contrast of light and dark (Figure 3)*, *simultaneous contrast*, *colour shadows (Figure 4)*, and *successive contrast* (Bachmann 2011).

Figure 1. Colour-Light-Pattern

Figure 2. Colour-Light-Keyboard

Figure 3. Colour-Light-Cabin: Contrast of light and dark

Figure 4. Colour-Light-Cabin: Colour shadows

Figure 5. Colour-Light-Playground

2.2 Interactive Materials

Interactive materials are referred to as tools that allow a playful and experimental approach to different perceptual phenomena about light and colour. These include both physical and digital tools and encourage independent or guided experimentations, thus allowing the acquirement of knowledge and experience in individual learning processes.

The physical tools show the same phenomena as our room installations in a model situation. Additionally, they allow the direct manipulation of and experimenting with following phenomena: Interaction of surface colours and light, such as hue shifts, hue increase, brightness changes and greying of colours (*colour and light playground,* Figure 5), additive and subtractive colour mixtures (*intermediate colours*), and the interdependence of colours in a spatial and temporal context (*colour-light box*, Figure 6). The programmable *colour-light box* shows the same contrast phenomena as the afore mentioned room installations.

With the digital tools following colour-light phenomena can be simulated: subtractive mixing/combining/arranging of colours based on a simple colour system for painting (colour dimensions), additive colour mixing (RGB/HSB tool), experimenting with colours in context (simultaneous contrast and Bezold spreading effect). Additionally, various colour-light experiments can be performed within a virtual 3D environment in a similar way as with our installations or physical tools (*colour-light-toy*, Figure 7).

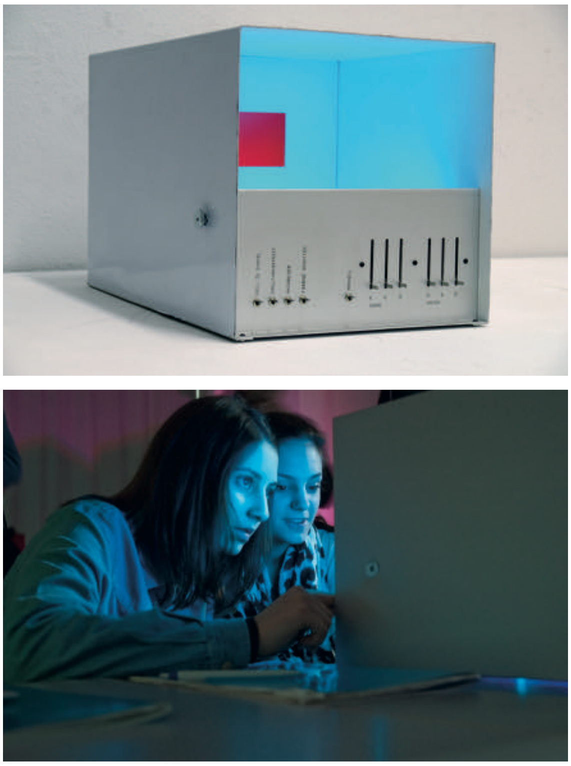

Figure 6. Colour-Light-Box

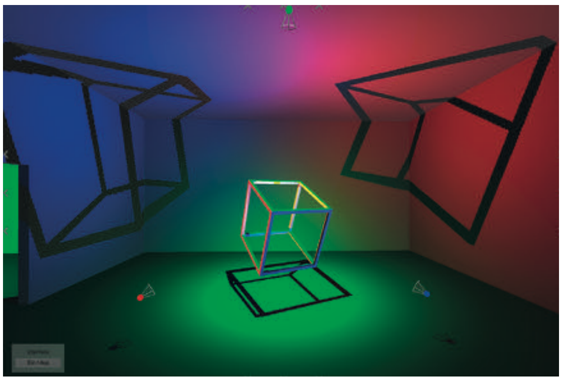

Figure 7. Colour-Light-Toy

2.3 Evaluation

The evaluation process of our didactic materials included following steps. First, we presented our prototypes in the context of an exhibition (Bachmann et al. 2010) in order to receive a first feedback. We used standardized questions for students and experts in the field of colour teaching. In addition, we used participatory observations and interviews with selected experts. In a second step, in order to receive a practical feedback, we implemented and evaluated the adapted materials in a pilot project at a high school in Zurich and at the Zurich University of the Arts (ZHdK). In summery, we found that more than 60% of the students were interested in the phenomena of colour and light as presented at the exhibition in Halle (Bachmann et al. 2010), and more than 75% of teaching experts would like to work with these phenomena in the context of teaching. In the evaluated teaching project with BA in Design students at the ZHdK we received a more detailed and qualitative feedback in terms of the practical use of the physical and the digital tools. Most importantly the interface design and the intuitive approach were highlighted.

2.4 Instructional projects

The presented instructional projects were created at the ZHdK in various modules by students of the BA in Art Education and the BA in Design. The student projects provide insights into individual design approaches towards the topic of colour and light. Basically such an approach is suitable for other school levels as well. In addition to theoretical inputs in order to enable the understanding of the different phenomena and relationships of colour and light, the approach is primarily concerned with the perception of students awareness in dealing with light, colour and space.

2.5 Conclusion

Together with the research and instructional projects on perceptive phenomena, the collection of materials on the Theory of Colour and Light presented here offers a new perspective of visual phenomena and events involving colour and light. With a focus on the visual, the open-endedness of the materials, such as installations, physical and digital tools, allow new spaces for experience and learning to be created and expands the field of colour theories and systems, which is already sufficiently comprehensive. The intent was to awaken the kind of curiosity that lies at the root of all experimentation. Subsequently we showed the suitability and relevance of our developed materials towards teaching and learning in questionnaires and pilot projects. Based on the relevance of our research results we plan to develop in the near future instruments and methods for practical use in design, stage design and interior design.

Acknowledgments

This work was supported by the Swiss National Science Foundation's (SNSF), DORE, Zurich University of the Arts (ZHdK), Burg Giebichenstein Kunsthochschule Halle, Deutsches Farben-zentrum.

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Interaction of colour and light: Simulation and assessment under artificial and natural light

Leonhard OBERASCHER

Abstract

The interaction of sunlight and colour is observed and analyzed in architectural models in the open under natural light conditions. The equipment and method developed allows systematic observation and detailed description, particularly of temporary light transitions and subtle colour transformations. The apparent colour in the fields observed is determined largely by the position and movement of the sun, and is a combination of local surface colour, direct and indirect lighting, clouding and coloured reflected light.

1. Introduction

The interaction of colour and light is a complex and far-reaching topic. Art, architecture and design are interested primarily in aesthetic and psychological aspects. In my studies and projects to date, I have focused on the complex interactions of colour, material, surface and artificial light in the context of architecture (Oberascher, 2002). My current studies concentrate on the question of how to systematically analyze and describe the interaction of sunlight and colour (a) in outdoor settings and (b) under the conditions of an "Artificial Sky" – a sunlight simulation laboratory at the Department for Building and Environment at the Danube University, Krems, Austria. This paper deals with the first question and analyzes the effect of sunlight in architectural models in the open under natural light conditions.

2. Observations in the open under natural light conditions

In order to make observations in various places in the open under natural light conditions, I constructed a kind of modular "laboratory", which enabled me to carry out several studies based on different models and in different places. A detailed list of apparatus and techniques used follows.

2.1 Apparatus and construction

(2.1.1) Observation table: a stand with circular boards 60cm in diameter; fixed wooden base, revolving cover with goniometer, in the centre axis of which different gnomons can be inserted to measure the horizontal angle (azimuth); an additional vertical goniometer can be fitted to measure the solar altitude. (2.1.2) Model: plywood box (12 x 12 x 3 cm), 6 open cells (52 x 22 x 28 mm), colour: natural wood (NCS 1010-Y05R). Colour of lateral surfaces inside the cells: upper (narrow) and right (broad) face of all cells: natural wood (NCS 1010-Y05R); lower (narrow) face in cell 1: natural wood (NCS 1010-Y05R), in cells 2-6: yellow (NCS 0070-G85Y); left (broad) face in cell 1: pure white (NCS 0400-N), cell 2: yellow (NCS 0070-G85Y), cell 3 red (NCS 0285-R), cell 4: green (NCS 1078-G20Y), cell 5: blue (NCS 2075-R80B), cell 6: magenta (NCS 0575-R30B). (2.1.3) Camera 1: DSLR-camera (Canon EOS 7D), timer remote control (JJC TM-A) for serial and interval exposures, tripod. Camera 2: DSLR-camera (Canon EOS 350D), hand-held. (2.1.4) Experimental setup: observation date: 2011.02.03, observation period: 11h00m-16h40m (UT+1), climatic conditions: cloudless, except slightly overcast around 12h33m and 15h33m-15h38m (UT+1). Sun path: sunrise: 6h55.8m (UT), azimuth 111.1°; sunset: 17h10.7m (UT), azimuth 249.1°; transit: 12h02m59s (UT), altitude 33.7° Cap, (local correction -60,4 min.; equation of time -11,2 min.); day length: 10h14.9m. Geographical position: Lat: 39º46'37.39''N, Long: 2º41'43.09''E, (in decimal degrees: +39.777041, +2.695338); elevation 43m AMSL. Alignment of model: north-south; lower (narrow) sides of cells facing south, left (broader) sides facing west. Position of fixed camera: east (90º), viewing direction west (270º, inclination ca. 45º). Exposure: focal length 47mm; aperture f/11,3; exposure time 1/256-1/395; chronological series, interval 5 min.

2.2 Observation and Analysis

Concurrently with the chronological series (one picture every 5 minutes) I took additional photos with the hand-held camera from different perspectives and distances. Furthermore I observed the model (isolated and in relation to the surroundings) both with the naked eye and with binoculars. The colours and their transitions (occurring inside the model) throughout the day, I assessed visually with reference to NCS (atlas and index). Exact ephemerides of the sun were obtained from astronomical programmes (CalSKY, *source: Arnold Barmettler, www.calsky.com*), and sun path charts (polar, Cartesian) were plotted by means of special software (Autodesk Ecotect Analysis). Since all photos are time-coded, for each image the exact azimuth/altitude values at the moment of exposure can be given (see figure 1). All images were analyzed on a colour-calibrated monitor as a whole and in detail, individually and in animated succession.

3. Results

The overall colour impression of the fields observed is formed by the combination of local surface colour, direct and indirect lighting, clouding and coloured reflected light. Depending on the position of the sun and the number and colour of the reflecting surfaces, a large range of subtle colour overlapping and distribution results.

The (apparent) movement of the sun causes a constant change in the appearance of the colours. This does not happen gradually, however, but very differently, and in phases. As the solar altitude increases, the sun appears to move faster, so that at midday, when it passes the zenith, the direction of light and shade changes more quickly. Thus in the experiment described here (alignment of model and camera), the more "dramatic" changes in light, shade and colour took place in the relatively short interval between 12.30 and 13.30 local time (UT + 1). Columns 3 - 6 in figure 1 show how, in cells 3 - 6 of the model, the dominant hue changes within an hour and the hard shadow, through chromatic reflected light, gradually passes into lighter clouding. Figure 2 shows an extract from column 6 (or cell 4, yellow NCS 0070-G85Y, green NCS 1078-G20Y), which gives a good rendering of the subtle colour transformation, clouding and chromatic lightening.

Analogously with the classical theory of harmony in music, I would suggest the term "*light alteration*" for this modulating overlapping of diffusely clouded areas of colour through coloured reflected light. While columns 3, 4 and 6 show a more or less harmonious progression of hue, the colours in column 5 (or cell 5, yellow NCS 0070-G85Y, NCS 2075-R80B) – in which the selected pair of hues are almost diametrically opposite in the chromatic circle – do not appear to "*merge*" properly. The result is a vibrant rivalry in which the (reflecting) colours have a mutually "*polluting*" effect. I would call this phenomenon "*colour-light contamination*".

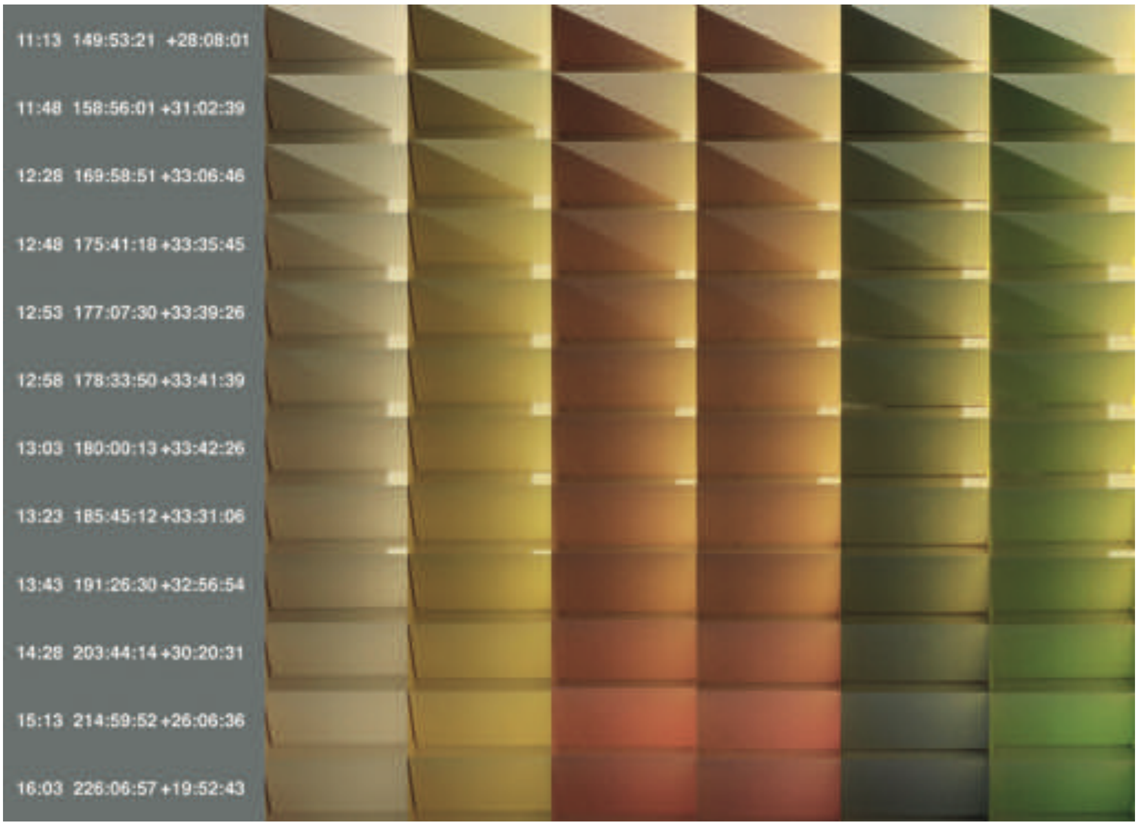

Figure 1: Selection of 12 photos with time code, azimuth, altitude; columns 1,2,3 correspond to cells 1,2,3, columns 4,5,6 to cells 6,5,4. Figure 2: Detail from column 6 (in the model: cell 4)

4. Discussion

Under a clear sky, the apparent colour of an object or a section of space is determined largely by the angle of light incidence, depending on the position of the sun. This changes continuously during the course of a day and over a year. In addition, the band-width and frequency of the light incidence in different places varies, sometimes considerably, with the latitude. In her book *The Color of Cities* (2000), Lois Swirnoff puts forward the theory that the distinctive image of a town comes less from the topography, urban planning and architecture than from the specific quality of the prevailing (natural) light conditions there. Taking a wide variety of photographs, she compares various towns, and demonstrates that their characteristic appearance and colours are related to the angle of incidence and the intensity of light in any particular location. The determining factors are latitude and altitude, the quantity and quality of the light being additionally modified by climatic conditions. I agree that the influence of a region's specific light conditions on the choice and preference of colours – particularly in architecture (façades, awnings, etc.) – should not be underestimated, forming as they do the way local inhabitants have, over generations, come to see them – especially before the extensive spread of artificial light sources, which represent determinative physical conditions governing visual perception (Oberascher, 2008). One might object that local light conditions change greatly in the course of the year, so that similar light situations can arise in places at different latitudes. Although in, for example, Narvik or Vienna, the sun can never stand as high as it does in Malaga, due to the axial tilt all three locations will see an angle of between 0° and 45°. Thus in the northern hemisphere, even in temperate latitudes, during winter we have more northerly conditions in respect of the quality of the light and the variable dynamics of the sun's course. Therefore, when drawing conclusions from observation of the interaction between (sun)light, colour and shadow in different places, we should take more account of the dynamic aspect. In general, the following conditions apply: 1) The lower the sun path, the more constant the change of direction, and the converse (in relation to the azimuth). 2) (Apparently) accelerated change of direction up to the culmination, thereafter (apparent) deceleration. 3) Greatest dynamism around the zenith; thus around midday the direction of light and shade changes rapidly, but the length of shadows changes slowly. 4) North of the tropic of Cancer, the horizontal angle changes evenly in winter and in the north, unevenly in summer and in the south. I am convinced that these dynamic yet cyclic changes in light, shade and colour, in different places and at different times, had originally a considerable influence on our sense of time and our rhythm of life. In industrial societies, with their pressures and obsession with performance and success, the natural world retreats increasingly into the background. Who today has the patience – and the leisure – to observe the daily and seasonal changes in light, shade and colour? Our age has little time for "*true time*", for natural "*light and colour time*", for a flexible, dynamic time, uneven yet cyclically consistent, and probably also better suited to our inner clock.

5. Conclusion

The equipment and method described above allows systematic observation and detailed description of the interaction of sunlight and colour in the open under natural light conditions. In particular, temporary light transitions and subtle colour transformations can be accurately monitored and documented. Dynamic yet cyclic changes in light and shade are more important than the angle of light incidence, for colour appearance. The subtle beauty and creative potential of sunlight-induced "*colour cadences*", however, seem hardly to be recognized, and are rarely if ever used in contemporary architecture.

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Coloured light sequences based on human perception: The case of a lit sculpture in an urban open space

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Abstract

A research regarding coloured light sequences was conducted on the occasion of the author's design of a pyramidal sculpture lit by RGB LED uplights inserted into the base. The goal of this inquiry was to develop design strategies and methodologies that meet the requirements and specificities of spatial-temporal sequences by means of coloured lights. In this way, four aspects such as light, colour, space and time were studied respectively in order to identify priorities for any further research. First, the RGB light source values were assessed in regard to their visual sensation. Second, the colour palette was observed, assessed and altered as a whole, in order to render this colour palette seemingly more continuous. Furthermore, previously determined relative luminance sensation values were used in order to redesign the RGB coding. On site experiments hinted towards the avoidance of the feeling of repetition and showed the importance of observer's point of view in relation to the spatial organization and segmentation based on the visual scenes. In conclusion, both, empirical and theoretical research alluded to the importance of design methodologies of coloured light sequences based on the user's visual perception in relation to the temporal and spatial context.

1. Introduction

A research regarding coloured light sequences was conducted on the occasion of the author's design of a coloured lit pyramidal sculpture, including the design and integration of multi-coloured lights as well as their spatial and temporal dynamic aspects.

In 2009, on the occasion of the 5th edition of the Festival des Sapins in Liège (BE), the author designed a sculpture of light and colour to be erected on the city's main piazza, the Place Saint-Lambert [Figure 1]. The total height of the sculpture is 6 meters, fixed on a faceted circular base with a diameter of 3,72 meters. It is composed of 44 "V" shaped moduli made of two welded semicircular steel plates, painted white matte and tilted. Each module is individually fixed on a thin cylindrical steel pole. The poles are fixed on top of the base, along a mesh of interlaced spirals. The moduli, staged on 8 levels, are lit by 20 RGB LED uplights inserted into the base. [Figure 2].

From the very first sketches, the strategy was to consider the user as the origin and purpose, affecting both the physical structure of the sculpture, and lighting and colour choices. In order to design an urban object that would be seen by the pedestrian from different point of views, numerous proposals were designed using computer simulations.

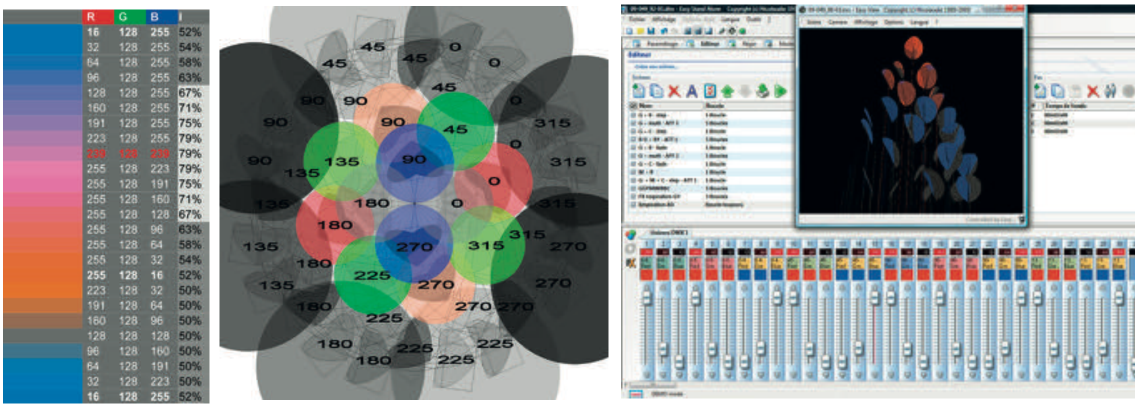
At the end of the process, the sculpture is perceived as fragmented and homogeneous at the same time. And the play of coloured lights on the staged modules, set along a maze of spiral whirls, swaying in the wind, generates a dynamic effect [Figure 3].

Figures 1-2-3. The "presence" of the multi-coloured light sculpture – Staged modules set along a maze of spiral whirls – Diffuse reflection of the coloured lights on double titled modules

To maximize the light-colour effects made possible by Philips Lighting LED projectors, the author developed novel colour palettes especially for the occasion. The characteristics of each colour component light sequence are weighted by perceptual data. After validation of colourful lighting effects on a full-size module, dynamic lighting scenes were made using a DMX software interface [Figure 6].

2. Discussion

An anthropocentric design of a 3D object, combining light and colour, considers the eye the starting point of a virtual line that connects secondary emissive surfaces - the modules - and light sources - the spotlights. In terms of coloured lighting, the process is defined by the physiological characteristics of human vision under mesopic conditions (Purkinje effect, cone sensitivity, ...), how objects are illuminated in space, as "secondary emissive surface" (colour reflectance, …) and finally the characteristics of light from the light sources (optics, luminance levels, colour temperature, …).



Figures 4-5-6. Temporal continuous flow - Spatial organisation and temporal dimension - DMX transposition of the spatio-temporal dynamic

The goal of this inquiry was to develop design strategies and methodologies that meet the requirements and specificities of spatial-temporal sequences by means of coloured lights. In this way, four aspects such as light, colour, space and time were studied respectively in order to identify the priorities for any further research.

First, the RGB light source values were assessed in order to define the specific codes for the three primary colours on a 0-255 level scale. Subsequently, these were altered based on the assessment of the colours on a sample modulus of the final structure, manipulating each of the RGB components respectively.

Second, the colour palette was observed as a whole. Noticeable discrepancies were noticed among the subsequent colour gradients. Consequently, the RGB codes were critically assessed and altered in order to render this colour palette seemingly more continuous. Furthermore, previously determined relative luminance sensation values were used in combination with the cube-root chromatic adaptation in order to redesign the RGB coding.

On site experiments hinted towards the avoidance of the feeling of repetition. By accentuating the perception of primary colours, an illusion of a temporal continuous flow is induced. The experiments also showed the importance of observer's point of view in designing 3D coloured light sequences in relation to the spatial organization and segmentation based on the visual scenes.

To sum-up, the following technical aspects are of importance:

- Selection of the white coating and its application. The application of a matte paint provides a finish that diffuses the reflection of the coloured light on the surfaces of the module and prevents high level of external reflection.
- Quick tests of the RGB light flux values. Illuminance measurements [1] of the selected light source gives non-homogeneous results for the RGB sources, with the values for blue equal to about one third of red and green, and their spatial repartition.

As the characteristics of coloured lights have to be selected and adapted on the basis of human perception, the following aspects are of importance:

- Definition of perceived primary colours. Mock-up perception assessments [2] tend to indicate that on an RGB 0-255 scale, a portion of about one twentieth of one of the other basic hues should be added; for example 255/0/12, 0/12/255, 0/255/12. Even more satisfactory results were reached by combining the hues in proportions such as 255/16/128, 128/255/16, 16/128/255 and 16/255/128, 128/16/255, 255/128/16, as complementary.
- Avoidance of discrepancies in temporal succession of colours. As established during the aforementioned assessment tests of perceived colours, a perceived continuum of colours gradient may be improved by steps of sixteen, or so [Figure 4]. This also gives hints for avoiding a feeling of repetition, by attenuating the perception of colours as primary, thus, giving the illusion of a more continuous flow.
- Perceived homogeneity of dimmed coloured light. On-site experimental attempts by means of the square law curve (IESNA 2000: 27-4) and relative perceived luminance values in regard to the attractiveness of chromatic light (Kort *et al.* 2009; Reisinger *et al.* 2008) suggest promising results. It clearly helps to create with gentle shifts in tone colours and harmonious perception of the lit surfaces spatial arrangements.
- Spatial organisation of the lit modules. Rhythmic lighting sequences [3], with themes such as “breathing”, “flicker”, “continuum”, … emphasise the third dimension [Figure 5].

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1 Measurements made with the students of the course Light in the built environment.
2 Assessments made with Marie-Hélène Huysmans of the former Hic et nunC a.s.b.l.
3 Some sequences were designed by students of the course Colour in the built environment.

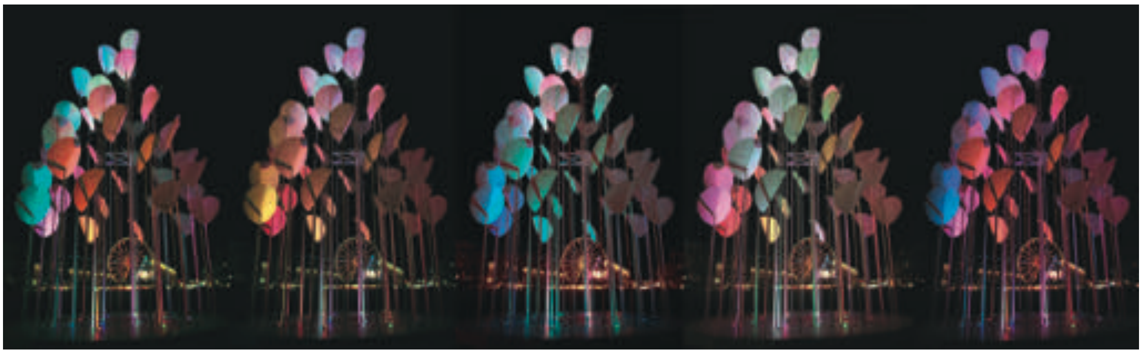
Figure 7: Coloured light sequences

3. Conclusion

Both, empirical and theoretical, research allured to the importance of design methodologies of coloured light sequences based on the user's visual perception in relation to the temporal and spatial context. Considering the temporal aspect, further improvements could be done by integrating colour remanence, both in discontinuous phases and in continuous gradients. Regarding the spatial dimension, further inquiries should be conducted on visual attractiveness of hues under mesopic conditions with a non homogeneous vision field, referring to the Esterman grid, for instance (Decuypere *et al.* 2009: 1178). The last area of inquiry is strongly connected to an ongoing personal research concerning the aspect of visual scenes in an urban environment.

The design prize awarded to this sculpture of light and colour affirms that projects using an anthropocentric approach are intrinsically positive for the built environment and its components. It demonstrates how festive lighting based on rigorous design strategy and combining scientific data can meet poetic sensibility.

Acknowledgments

This research and the design was sponsored by Yvan Paque s.a. (groupe Eiffage) and Hic et nunC a.s.b.l., with the cooperation of the City of Liège and Wallonie Design.

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oral paper

RGB colours, kinetic traces, body, and space: An exploration of the narrative potential of the interaction of light and colour in the performing arts

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Abstract

Performing artists, such as dancers and actors, will greatly benefit from the understanding of the science behind the systematic effects caused by the interaction of luminous and pigment-based colours in the conception and execution of their works. The change of the colour appearance of red and green outfits worn by dancers was examined in the context of interaction of additive and subtractive colours. This paper suggests that such interaction can be used to build metaphors and has an impact in building a performance narrative. A technique called *Kinetic Traces* was used in the study and in the performance of *Kinetic Traces: Dreamscapes, 2010* (video documentation is available online). The authors argue that the understanding and systematic manipulation of the interaction of luminous and pigment-based colours has the potential to impact the development of a new set of expressive tools for the performing arts, such as dance and theatre.

1. Background Information

Computer colours specified in RGB values, custom-built software, and digital projectors have increased a palette of opportunities and the production of innovative tools of expression. At Purdue University, we have been investigating the potential of computer-generated colour palettes (RGB colours) and graphics projected directly onto dancers using a technique titled *Kinetic Traces.* More recently Bendito started an examination of the interaction of additive and subtractive colours on costume design. Bendito is developing *Kinetic Traces* in collaboration with choreographers, dancers and musicians.

Bendito's early interactive art installation *Digital Habitat* in 2004 and collaboration with the dance company Project IN Motion motivated the further development of *Kinetic Traces*, which can be described as a digital toolset to perform live drawings on the stage and dancers. For *Projections*, a performance that took place during *Dances We Don't Know Yet* at Purdue University in 2005, both dancers and environment had a white base (costumes and backdrop). Dancers as well as the set design were "painted" with projected colours from the computer. The colours were specified in RGB values (i.e. magenta = 255,000,255 and green = 000,255,000). The vibrant colour palette for *Projections* took into account a systematic method of selection based on the geometric configuration of the RGB colour model. By choosing colours numerically in relationship to their position in the RGB cube, it was assured that the most vivid RGB versions of these hues were employed.

Kinetic Traces gained a new dimension in 2009: Dancers continued to be "painted" live, but this time using brushstrokes "infused" with algorithmic graphics created in *Processing*. A programmed keyboard triggered different brushstroke methods and was also used to select colours and to deploy fading effects and transitions.

In a later stage of using *Kinetic Traces*, by analyzing video footage of rehearsals and actual performances, parameters of interaction between dancers, environment, and the drawings were identified and used to guide the development of other performances, such as *Yellow-Green* (2010) and *Dreamscape* (2010).

2. Additive and Subtractive Colour Interaction

In the context of design education that favoured direct experimentation, it has been demonstrated (Bachmann, 2007) that there is a wide range of effects produced by the superimposition of subtractive and additive colours, or as Bachmann puts it: coloured light and material colours. Essentially additive colours have the potential to change the appearance of subtractive mixtures when superimposed. From the standpoint of the performing arts, an important application of this understanding is to explore how such transformative power may lead to the development of a palette of expression. It was under this framework that in 2010 a new variable has been introduced to a *Kinetic Traces* dance project, namely the interaction of additive and subtractive colours and its expressive potential.

In 2010, Bendito presented lectures and conducted a three-day workshop at the III Seminário de Poéticas Tecnológicas hosted by the Federal University of Bahia in Brazil. The workshop explored the intersection of dance and digital technologies. Participants were mostly graduate and undergraduate students. Under the guidance of Bendito, participants choreographed a demonstration of the results of the workshop. The demonstration was titled *Dreamscape* and was performed at the Teatro Sesc Senac Pelourinho, Salvador, Bahia on November 05, 2010. This workshop provided an opportunity for Bendito to examine the expressive potential of the interaction of additive and subtractive colours in the context of the performing arts. Two costumes—one red and the other green—were used.

The images below (Figure 1) show a sequence of additive colours specified in RGB values being projected on a vivid red costume. At one point, it was possible to notice how the red was transformed into a completely dark, almost black colour. This transformation became key in building an understanding of the interaction of additive and subtractive colours and suggested a metaphor of change: from colour to neutral colour values; from a dancer and her shadow; to the dancer "with" her shadow. It is this kind of transformation in real-time that choreographers may consider when examining the interaction of additive and subtractive colour systems, for this transformation has the potential to build metaphors, and consequently visual narratives.

3. Findings and Recommendations

Two costumes were produced and used to examine the interaction of additive and subtractive colours. During the workshop, from a data projector connected to a computer, different light wavelengths were projected and manipulated via the *Kinetic Traces* software. The colour palette was defined based on RGB values. Two costumes, a red and green, absorbed or reflected the wavelengths of light to varying degrees. The colour that the audience saw was impacted by the costume's potential for reflecting or absorbing the light being projected onto it.

Figure 1. Studies conducted at the III Seminário de Poéticas Tecnológicas , hosted by the Federal University of Bahia in Brazil, 2010. Here the effect of additive colours is examined when projected over a given subtractive colour red (images captured from a video camera).

When RGB 102,000,255 was projected onto the red costume, the costume became a dark, almost black. Taking into account different light wavelengths, a similar effect has been addressed in the literature (Bachmann, 2007) and is confirmed in this experiment. Essentially, we realized that by experimenting with RGB colour values it was possible to achieve subtle and abrupt colour changes in the costumes. Because colour has different connotative meanings and associations, how the audience experiences the change from one colour into another can be manipulated with such a degree as to become part of the narrative being created in a performance. This potential was suggested in the *Dreamscape* performance and needs further investigation.

4. RGB Specification and Study Limitations

Because RGB colours are hardware dependent, specifying colours in terms of RGB values has limiting factors. However, during the workshop, when trying to determine the overall impact of additive colours on a given pigment, it was effective to start the experiment numerically; for example, with a colour R=255, G=000, B=000 and progressively decreasing R using a custom-built software, rather than picking a hue using the colour picker of a standard Graphical User Interface (GUI). For artists and designers using digital projectors with access to a calibration system, RGB values provide a starting point in identifying which specific effects that light wavelengths may have on certain pigment-based hues.

5. Implications and Conclusion

There has been an increasing interest in and use of digital projectors in museums, art galleries, and outdoor art installations, to name a few. We've seen an increasing use of digital projectors in dance and theatrical performances. Consequently, digital projectors have become another tool for self-expression. Artists not only are painting with RGB-defined additive colours, but are also projecting these colours on subtractive colours, most of the time without considering the "science" behind such juxtapositions. Based on informal assessment (Bendito) it is surprising that many new media artists are not aware of how colours can be systematically controlled to achieve systematic effects in terms of RGB values. This deficiency needs to be addressed in art and design academic programs.

New media artists could greatly benefit from the understanding of the interaction of additive and subtractive colours. The performance *Dreamscape* suggests that the red colour of a costume metamorphosing into black on the stage is embedded with a wide range of metaphorical associations and can be deliberately explored to build meaning. This type of experiment needs further development in the performing arts. It is critical for performing artists operating in the 21st Century to investigate systematically the impact of the interaction of digitally manipulated additive colours and the colours of the body, costume and set design elements.

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Altered space: The transformative capabilities of colour and light in the architecture of Steven Holl and UN Studio

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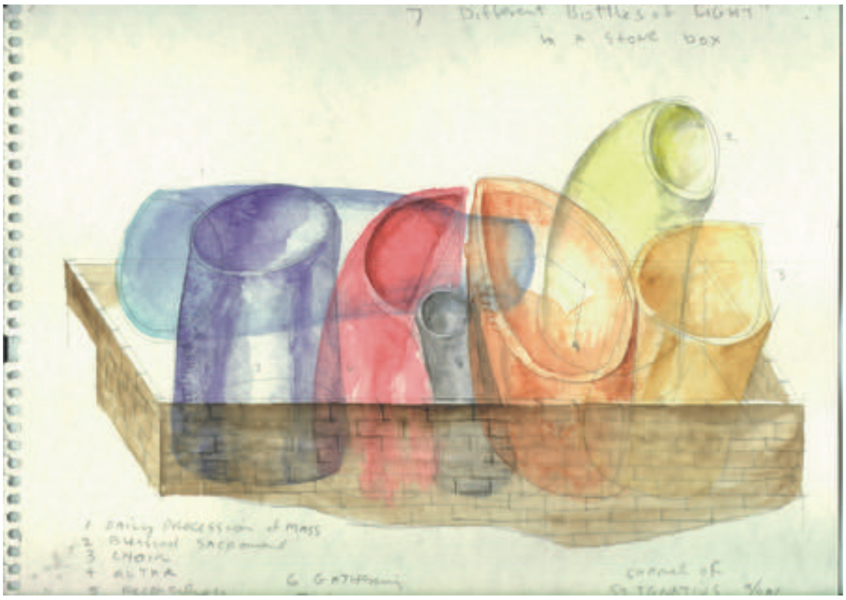
Abstract

The paper will explore the transformative capabilities of colour and light in architecture through selected projects of two contemporary architectural practices. Colour, which is generated through the play of light, is never static and has the capability to be used as an instrument to tune and transform architectural space. Coloured glass has been used for centuries, although with the symbolism embodied in the window design as the primary intent and the interaction of the cast colours largely a secondary effect. Drawing on an interview with Ben van Berkel and Caroline Bos of UN Studio, based in Amsterdam, and considering the work of the American architect, Steven Holl, the paper argues that the metaphysical properties of reflected colour can be seen as instrumental to the synergic design of architectural space.



Steven Holl : Chapel of St Ignatius, Seattle
(Watercolour: Steven Holl Architects)

Two buildings within the oeuvre of the New York based architect, Steven Holl, particularly epitomize his use of colour and light and the interaction between them. The first, his chapel at St Ignatius, Seattle (1997) adopts white interiors, tempered by the use of roof-lit funnels, which gently tinge the internal surfaces as the external lighting conditions change. The perception of the space is transformed as light bounces against the curved surfaces, capturing the different qualities of light from north, south, east and west by a series of angled roof lights. The volumes are shaped to further modify the internal experiences as one moves through the church, and simultaneously correspond to specific aspects of Jesuit Catholic worship. Holl's analogy is of bottles acting as containers in which light is captured and stored, with each volume differentiated in form and reflected colour.

Steven Holl: Cranbrook Institute for Science (Photo: Paul Warchol Studio)

Holl's entrance hall at the University of Cranbrook Institute of Science (1998) uses no colour other than that produced by the effects of light distorted through many different types of glass. Here the constantly changing effects are of sunlight and shade, of streaks, informal patterns and the occasional spectral projection through prisms built into the façade. These work in concert to animate the space as part of a highly experiential series of internal and external spaces. This is a subtle colour palette, the same base wall is modified in appearance solely by the instrument of light and the passing of time.

A key principle of Steven Holl's architecture is the "spatial energy" generated by the interaction of the body moving through space.[1] Central to this is his use of colour and light that allows each work to be open to interpretation by the mood and perception of the user. The experience is therefore not entirely predictable or under the control of the architect as would be the case using pigmented surfaces. Colours generated in this way while still entirely relative to light conditions, context and material surface are, by comparison with coloured light, essentially more stable.

A further condition employed in one of Holl's best known small buildings in the Sarphatistraat, Amsterdam (2000), is the use of reflected light from a pigmented surface or filter which is deliberately concealed, and activated by the play of light. Such devices project tinted light that moves across both space and surface. The colour attracts the eye, and obliquely reveals a hidden space beyond that which is immediately experienced, adding a layer of ambiguity. Holl further celebrates this element of doubt by using layers of different materials, some being perforated, some solid, some translucent and some clear. The layers seldom entirely align, and are sandwiched in different combinations, to distort the surfaces and indicate depth. Colour and light are therefore employed as part of an experiential, multi-sensory architecture, the architect deliberately abdicating a degree of authority to natural phenomena.

There has been a recent growth in the use of coloured light to transform architecture externally, spurred on by the ability to programme complex lighting combinations digitally. The Dutch architectural practice, UN Studio, has completed two department stores, the Galleria in Seoul, South Korea (2004) and Star Place, Kaohsiung Taiwan (2008).2 In both, projected light is used directly to distort and modify the appearance of the building by day and by night through timed pulses. Ben van Berkel relates the changing colour to the seasonal pulse of fashion in clothes, using the same metaphor of dressing for a proposed apartment building wrapped in

1 Holl, S. Taken from his lecture for the Jencks Award 2010 at the RIBA, London. 'Spatial energy being one of his five 'axioms' on architecture

2 UN Studio is led by Ben van Berkel and Caroline Bos

ribbons of steel in New York. In the case of the department stores however, the pulse is much faster than any seasonal variation in clothes. Through the constantly changing light, the authority of the building image is placed in some doubt. Who is in control of the image? Architect, or computer programmer?

Van Berkel admits that they had not entirely understood how easy it would be for the client to change the appearance, and so for the second building, the practice constrained the lighting design through a tighter contractual agreement, effectively legislating the colours and thereby ensuring their authorship.[3] There are inherent dangers for architecture in this drift towards brand and image over substance and materiality. Taken to its limits, architecture becomes mere lifeless surface by day, and by night, a "brandscape" for projected colour and light.[4] It may still be experiential, but only in a cinematic sense and easily open to manipulation. These technologies introduce opportunities, but also bring new dilemmas for architects more accustomed to permanence, durability and stability.

UN Studio has also employed the reflective properties of light and colour in a collaboration with adhesive manufacturer 3M (the originators of yellow stickies). 3M had developed a product originally intended for wrapping perfume bottles, but it had not turned out as expected, and was lying idle in their laboratory.[5] The architects used the material embedded into layers of glass, to wrap the courtyard surfaces of a new office development in the new town of Almere, north of Amsterdam. The film shimmers like the wing of a butterfly. Further, and most notably, the perception of the reflected colour is altered dramatically depending on the angle of the viewer and the ambient light conditions. While the surfaces of the buildings at the perimeter of the urban block are clad in a shiny but plain grey aluminium, the plan form uses oblique slashes across the centre of the urban block to reveal a highly colourful series of voids snaking through the centre of the site. The building appears inside out, bland and homogenous on the outside, vibrant and astonishingly dynamic on the inner faces. The entrances to most of the individual buildings are set inside the block, forcing the visitor to penetrate the exterior and discover the colours within.

The building skin is a pure experiment into the interaction of colour and light. Walking through the exterior courtyard, the surfaces appear to change from vivid red to blue, green, orange and yellow, utterly transforming the appearance of the building within a few paces. Viewed perpendicular to the skin, a clear deep red may change to a green, yellow or blue when seen obliquely. It is hard for the mind to accept that this is all one material. The reflected light from the panels is itself so intense that it is diffuses across the pavements and internal courtyard surfaces, heightening the transformative effect.

Without the material, and the resultant colour, one could argue that this is a fairly soulless perimeter office building. The courts are barren, without any form of softening landscape. It is a disconcerting experience to dwell in the voids, feeling as if being constantly observed by acres of mirrored sunglasses. Inside the buildings, now occupied by Social Security and Tax offices, the coloured light bounces around the faces of the courtyard and into the edges of the rooms. The reflected colour completely transforms the appearance of the building, through the movement of clouds, light and the position of the viewer. Unlike the examples in Seoul and Kaohsiung, the joy

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3 Taken from an interview with Ben van Berkel and Caroline Bos and the author, Amsterdam, September 2009

4 The term 'Brandscapes', is thought to have been introduced by John Sherry, in 1986 conference of the Association for Consumer Research, in Toronto, Canada. Subsequently used by Klingmann, Anna (2007) *Brandscapes: Architecture in the Experience Economy*.

5 The material now known as *3M Radiant Colour/Light Film*

UN Studio, La Defense Offices in Almere, Netherlands (2004) Photo: Author

of this colour is that it is generated entirely by daylight. Although concentrated, it is more subtle, less controlled, not programmed but utterly contingent on the vagaries of natural light.

Gilles Deleuze considered this to be entirely the role of space. (Pavoni, 2010 : 9). Space is more than fixed geometry, more than simple built form. Architecture is multi-dimensional, although stable, it is experienced in a transient way and should allow multiple subjective readings and experiences. In these examples, colour generated as light activates and transforms space and surface. Here, architecture is moving, rather than static, constantly changing, contingent, de-materialising and re-constituting.

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Architectural glass colour palette

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Abstract

The colourmetry has various methods of measuring colour. All those methods permit to define the qualitative and quantitative characteristics of colour with different levels of accuracy and completeness; however each of them has certain shortcomings restricting their broad practical use.

Compared to nontransparent materials glass differs considerably in terms of its colour and physical properties. They include light reflection, light transmission, colour, solar radiation transmission, shade factor, heat transfer factor and others. The presentation demonstrates the spectrophotometric method for measuring colour coordinates and a glass reflection coefficient. This method enables us to simulate different ways of illumination and different types of perception. The measurement results are converted into alphanumeric codes (formulas).

Using the obtained formula one can select a glass with necessary optical properties using the database as well as define the formula and optical characteristics of the colour. Thus, using the improved colour formula, one can accurately identify a specific glass specimen, that is available on the market, and develop new glass specimens meeting necessary requirements (lighter, darker, more transparent etc.) Alphanumerical codes (formulas) can be used for glass identification in different databases, electronic systems and devices used when selecting a façade glass.

1. Introduction

Each time period puts forward new challenges for architects. Emergence of new building materials used by architects reflects the evolution of production and society in general. Today new buildings, mostly made of coloured glass with a supportive metal frame, appear in all cities in the world. You can see them in Paris, Berlin, Shanghai, Tokio, London, Dubau, etc. However, nowadays it is impossible to use one and the same glass everywhere as it was before when it was only used for windows. Today we see the extensive use of multicolored glass. An architect has to explain to a manufacturer in detail which particular glass fitting his design he wants to buy from him. Often glasses with quite similar colour and other characteristics have absolutely different names. This led to a need to identify digitally a glass colour as well as its reflective and light transmission characteristics with a mathematical formula which could be easy to use. Such formulas are available for non-transparent materials. For example, customers in Moscow can easily order any paint from Finland, Sweden, Spain and other countries using a catalogue where each colour is identified by a specific formula. They only have to name this formula. We have decided to do the same for glass. Thus, there will be no need for using its descriptive name.

2. Colour coding systems

When working on the palette of the architectural and construction glass, we analyzed the main colour coding systems. These systems include: RGB, CMYK, HSB, HSV, NCS, CIE XYZ, PCCS, CIE L*a*b*, MNIITEP (a colour catalogue) and others. Some of them are used to describe the colour on a colour screen., others are applied in printing and computer graphics, and some are used to describe nontransparent colours with special codes. A large group of systems, developed to study human vision, makes inductive colour perception possible.

The 1981 MNIITEP (colour catalogue) model is represented with a colour circle of ten colours and ten tables of a conventional “colour solid”, where all the colours are arranged in a certain sequence depending on their physical characteristics. This made it possible to reproduce the necessary colour based on the numerical values of its parameters.

The review of a big number of colour systems and models to study transformation and colour designations has shown that they cannot be applied for defining and measuring the chromatic and other optical characteristics of transparent objects, for which optical parameters characterizing light and colour interaction are of particular importance. The matter is that the glass differs considerably in terms of its colour and physical properties as compared to nontransparent materials. They include light reflection, light transmission, colour, solar radiation transmission, reflectiity, shade factor, heat transfer factor, heat-transfer resistance, emission factor, etc.

The mathematical L*a*b* system gives the most accurate and full description of the colour space perceived by a human eye. In the L*a*b* system the non-linear nature of colour perception by a human is adjusted mathematically. Thus, the L*a*b* model most fits for developing a palette and identifying architectural glass.

The L*a*b* is used in theory for colour coding of transparent materials, glass in particular,. However, it doesn’t consider transmission coefficient which makes it impossible to control the glass colour. It was necessary to adapt the L*a*b* system, so that to improve accuracy and reliability of measurements and numerical definition of colour of painted transparent objects and to enable practical measurements and numerical definition of colour in codes or numerical values.

3. Identification of glass colour

3.1 Optical characteristics of glass.

Light transmission is an important optical characteristic of glass. Travelling through transparent, painted glass structure, the colour of light interacts with the colour of glass structure. The colour field of chromatic colours, produced by reflection, absorption, and bending of light, varies from achromatic colour field - white, black and grey.

The main issue is that it is difficult to predict, which part of the spectrum the glass will transmit in the natural light. Besides, glass can change its colour depending on the colour of light inside a building. It is obvious, that the architect needs an opportunity to select a glass with a necessary hue not only experimentally, as it is currently done, but by relying on scientific methods. It is necessary to adapt designer’s vision of colour scheme of the entire project to real materials and have a procedure that would help architects accurately select a tinted glass with due consideration of its exterior perception. To this end, it is necessary to express glass parameters in the universal coded form available for use by architects, and then convert them into digital codes. The parameters must be easily identifiable with the chromatic characteristics of a glass.

To improve the accuracy of measurements and numerical designations of colour of transparent objects the spectrophotometric analysis is done within the visible spectrum with the wavelength from 380 to 770 nm (which includes all the seven colours in regular connection of the solar spectrum colours: red, orange, yellow, green, blue and purple) with due consideration of a reflection index and a lightness index of a specimen and then the measurement results are converted into alphanumeric codes using a certain mathematical model.

GVG palette algorithm.

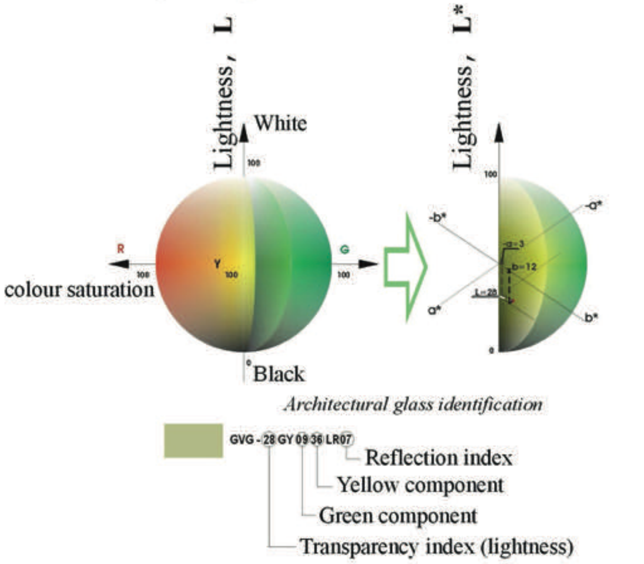

Figure 1.

3.2 Spectrophotometric method

The spectrophotometric method for measuring colour coordinates and reflection index of glass simulates different ways of illumination and different types of perception. Achromatic spectrophotometer uses a source of light to illuminate the measured specimen. The light reflects from the object, passes through the optical grating that breaks it down into the spectrum. The spectrum falls on the diode grating, where the amount of light at each wavelength is measured. The obtained experimental data are then transferred to the processor, where they are processed together with the tabular data for a CIE light source and a standard observer in order to get the values X, Y and Z. The spectrophotometer is connected to a computer, the data is processed and shown in a specialized software application. (Figure.1)

Using the selected procedure, we have measured the main chromatic parameters of glass: external and internal reflection indices, light transmission of architectural glasses varied in colour, thickness, light and thermal transmission properties.

The analysis of the obtained experimental data has shown that colour, transparency (lightness) and reflection index (light transmission) are necessary parameters for visual identification. To develop a facade glazing palette, we needed to define the colour spectrum range and identify specific glass characteristics such as reflection index (light transmission) and transparency (lightness).

The visible spectrum was divided into 18 colours, which quite fully reflect the colours perceived by a human eye. Considering the chemical composition and the requirements of the contemporary architecture, blue, green, red, yellow and gray range of the spectrum was expanded. (Figure 2, 3, 4, 5) However, pure colours may be achieved only by applying paint (lacquer) or a colour film on the glass surface. It is clear that when developing a facade glazing palette, first of all, it is necessary to study transparent non-painted glass. Today, the so called smart glass having energy-saving, sound-proofing, sun-screening properties and a mirror effect is used in the architecture. All those properties require special additives in the body or a specific sprayed coating on the glass surface, which changes its reflective power and transparency and inevitably leads to the shift from clear glass to the grey area. In this context, we adjusted the palette to the perception of colour by a human eye in different areas of the colour field.

Blue colour spectrum

Figure 2.

The measurement of the optical characteristics were made on the spectrophotometers Colour Quest

Green colour spectrum

Figure 3.

XE, Pelkin Elmer and Ultra Scan. The glass colour was defined depending on the position of the point in the colour space. The reflection index was defined using measurements on a spectrophotometer. The lightness was measured in units from 0 to 100. To combine all the basic parameters into a single formula, we developed the coding system, which implies the following. A GVG code, depending on the colour area the studied specimen is in, is denoted by a successive specification of the main parameters: lightness (L), saturation (blue B, green G, yellow Y and red R), and the reflective power of a glass (LR). As the system, in general, describes the colour with figures showing the amount of basic colours and the reflective power, this method за measuring the colour of objects can be a universal tool to enable quantitative measurements of the quality of chromatic characteristics of any transparent object and to convert the obtained data in digital codes.

Red colour spectrum

Figure 4.

Yellow colour spectrum

Figure 5.

The proposed palette and colour identification codes for architectural and construction glass, comprising of 372 colours in various colour areas, is a result of the three year collaboration between the Moscow Colour City Centre and the Asahi Glass Company Russia . This palette most fully corresponds to the market needs and meets the preference of most demanding designers and customers.

4. Conclusion

Being easy to read, the colour designation formula makes it clear for a person who does not know the physics of glass. It is designed both for architects and a wide range of specialists. Looking at the alphanumerical codes, one can easily imagine the appearance of the glass. The research-based glass colour identification code makes the developed palette a certain communication language between producers, architects and investors.

Acknowledgment

The author would like to acknowledge the Asahi Glass Company (Glaverbel-Vostok) Russia. for valuable assistance in development of architectural glass colour palette.

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Interstices of colour and light in the architectural and pictorial space of Venice

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Abstract

This paper analyses the interstices of colour and light when part of the architectural and pictorial space of Venice, in search of potential phenomena existent in space-light-colour dynamics. Using qualitative research techniques and field data gathering procedures, the phase of research presented indicates 'embryonic clusters' to be used in the analysis of interconnecting factors. In Middle Ages and Renaissance, the Republic of Venice was a maritime-mercantile power and crossroad between East and West. Exposed to an exchange of a multiplicity of ideas, a cultural fusion is exemplified by harmonious cohabitation of Byzantine, Islamic, Gothic and Renaissance architectural designs. Positioned as one of the most significant trading ports and with the expansion of commerce, *Serenissima* was influenced by technological, artistic and scientific developments and accessed materials used for architectural and pictorial art chromatic exuberance: pigments, marbles, mosaics, tiles, glass and textiles, that added opulence and luxury to a place without territorial expansion possibilities. These conditionings interact with the pluri-dimensional liquidity of Venice that simultaneously determines the overall environmental fluidity of the city and its architectural design. Affected by actions of light, the liquid membrane expands spatial fields of colour and feeds the creative imagination of Venetian *colorito.*

1. Introduction

The content of this paper addresses the results of the first phase of the research on architectural and pictorial space of Venice for which exploratory approach was used in data gathering techniques such as observation, the production of sketches drawn *in situ* over time, as well as iconographic sources, photography and film. The skeleton of the 'embryonic clusters' was construed through interconnecting factors that ground *spatial constituents* and their interactions with the *dynamic agents* of colour and light, in the following contexts: a) city's environment and composition; b) traces of structure, organization and surface of architectural settings; c) representation of space, colour and light in a selected group of paintings that represent the Venetian *colorito* and where parallels between pictorial space and architectural space are found: Jacopo and Gentile Bellini; Tintoretto, Veronese; Canaletto; Titian, Carpaccio; Mantegna, Giorgione, Mansueti and Guardi; d) consequences of light on matter when part of either architectural or pictorial space; e) physical and cultural grounds for interrelations of light-colour-space; f) illumination of the 'liquid space' and consequences on solidity and space of imagination.

2. Embryonic clusters

Figure 1. Basilica of San Marco. Photo: Maria João Durão

2.1 Following the red brick road

In the middle of a lagoon and in a city with no walls, *case* and *palazzi* of marble were built on mudbanks, and their construction materials brought in to the city by sea. There are hardly any art works of the sixth century in the Veneta and lack of archaeological evidence of residential architecture before the twelfth century, joined by lack of credible written testimony make it difficult to be precise as to what perishable construction materials were used before brick and stone.

Originally brick walls were protected with a thin layer of *intonaco,* and when stuccoes began to peel off, a varied gamut of textures and hues were revealed. Very light brick walls tied with lime mortar have the porosity required for evaporation. Prosperous merchant classes opted for stone to prevent recurrent fires. Environment was tinged with the Venetian pairing of white Istrian stone and red Verona, accentuated by the red terracotta and burnt sienna clay from the roof tiles. From the Renaissance onwards, brick facades were often clad in a veneer of Istrian stone. The latter was used in the renaissance Venice of Codussi and Palladio as did Longhena on the opulent barroque of *Santa Maria della Salute.*
With Istrian stone, Sansovino lent Roman style to the Piazza San Marco altering the pre-existing Byzantine, Islamic and Gothic polychromatic Basilica of San Marco and the Palazzo Ducale. To Ruskin, veneering with marble is a sensitive and sustainable use of very precious material and cladding is the incrustation of brick with more precious materials. Here we find the medieval power of colour that Ruskin identifies in San Marco, whose effects also depend on the "most subtle, variable, inexpressive colour in the world,-the colour of glass, of transparent alabaster, of polished marble, and lustrous gold". (Cook and Wedderburn 1913: 115)

In Venice, the marbles of walls, balustrades, stairways, or alcoves harmonize with green and purple porphyry, the marble and mosaics of the Basilica of San Marco, its Pala d'Oro panels of translucent blue enamel with golden borders, as with terracotta reds and stuccoes of yellow ochre, coral, salmon, magenta, orange, crimson, smoky pink, rose, marble greens and purple-the blue sky harmonizes with all -and the waters of the canal and lagoon intermingle with the former as an orchestrated ensemble.

2.2 Apertures and passages of light

Like Peter Pan's inconstant shadow stitched to his body, in Venice, architectural bodies are linked to the overall surrounding water, blended with the smoothness of a watercolour reflection. Buildings don't seem to grow from the plane of the ground, mainly along the Grand Canal, where colour and light flow between liquidity and solidity, and for functional purposes, palaces have a landing stage

Figure 2. Apertures of light, Basilica of San Marco. Photo: Maria João Durão

on the waterside for access, and long arcade windows to enable the passage of light into their deep interiors.

Affecting concepts of spatial visualization, stained-glass was considered the most beautiful medium, through which light penetrates but does not break. But with purified glass, through which unchanging colours could be seen, sixteenth century telescopic optics altered conceptions of space and expanded the vanishing point, influencing the way reality was depicted. In Venice every house had glass windows due to the existence of its raw material-sand. They were made of bottle glass discs set in lead, affecting the view of the outside space that looked like mosaics, bright in contrast with the darkness of recesses, passages, and narrow ways.

Figure 3. Liquid mirrors. Photo: Maria João Durão

2.3 Specular and glass effects: fluidity on solidity

Confined by the lagoon, it is also beyond it that Venetians perceive the vastness permeated by exchanges in the East and the Mediterranean. Since Venice was the wealthiest city in Europe, it allowed for luxuries in the construction of palaces, churches and houses. In the fabric of the city, the use of precious stones is enough to establish its unique character. Architectural colour dematerializes with the presence of water, more or less so depending on the incidence of light in conjunction with body movements and the visual field.

Liquid membranes of lilac, jade, brown, heliotrope, act as mirrors where walls and skies are multiplied by the 'scissors' of a passing gondola or boat. Water reflects light upwards, so facing a waterfront were introduced portals, balconies or gutters as architectural elements while narrow facades hold tightly on to each other, struggling for a bit of space and exposure to light and colour.

Dwellings were built to capture light so even on the flooring of houses the stone and lime was polished with oil for reflection. Adrian Stokes (Gowing 1978) admired the flooring tones affected by light and shadow on Quattro Cento art, he most appreciated in Venice.

Figure 4. Titian-Presentation of Virgin at Temple (detail) Public image.

2.4 Colour and pictorial representation

Linked to the *disegno* versus *colore* debate, an episode shows one of Titian's discoveries: the relation between the eye and movement (Durão 2008). When Vasari visited Titian in 1566, he considered the broad and bold strokes and smudges could not provide a clear image of the paintings when closely viewed, whereas from a distance they seemed perfect. These paintings *had to be viewed from a distance.* Furthermore, Hills (1999: 11) argues that since Venetians are seafarers, they would 'feel more at ease with representations that allow for a moving eye', in

Figure 5. Carpaccio- Sermon of Saint Stephen at Jerusalem (detail) Public image.

opposition to the static Florence, the birthplace of Brunelleschi's one point of view perspective. This would account for the uniqueness of the Venetian School.

The influence of trade with the East impacted both Venice's architecture- distinctive for integrating divergent cultures- and art. Painters had access to the finest orpiment and realgar, red pigments from silver or sulphur, lead white, vermilion and the semi-precious lapis lazuli that Bellini and Titian used to transform painting. Architectural colour had such impact that some paintings by Carpaccio, Mansueti and Gentile Bellini, overshadow the human figure as part of the architectural *tessitura.*

The exuberance and harmonious interactions of pictorial space are distilled from the perceived environment, a confirmation that Venetians possess perfection of *colour-instinct* justly acknowledged by Ruskin. Therefore, it is not surprising that painters should find a way to represent the poetry of light with labyrinthine strokes of colour that transform matter by emitting light, and invite entrance to a space of *reflected reality*.

Acknowledgments

Research project supported by Faculdade de Arquitectura, Universidade Técnica de Lisboa

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The colour space of Zurich. An exemplary research on colour, texture and light in urban space

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Abstract

What are the colours of Zurich? This simple question, raised by the city's department of urban planning in order to establish a well-founded basis for colour decisions in urban settings was the beginning of a five-year research, conceived and directed by Haus der Farbe in co-operation with the municipality of Zurich and CRB – NCS Colour Centre Switzerland. Considering the city's participatory policy in decision-making the purpose of the project was to increase the competence of all actors dealing with colour in the urban space rather than to establish regulating instruments such as chromatic charts or a colour master plan.

Hence working tools both for the public authorities as well as for architects, colourists, craftsmen, property developers and home owners were to be developed. Colour planning should remain a lively process, but should henceforth be based on a better comprehension of the numerous factors to be considered in careful colour decisions.

After defining these specific targets, genuine research methods and instruments had to be designed in order to adequately grasp the complexity of the urban colour space and provide reliable empiric data. Therefore, a comprehensive study was conducted considering six different points of view.

1. The general urban-planning view: a summary inventory of the colours and materials used for facade design considering every single building of the city

To provide an inventory of the facade colours of the city a Zurich specific colour fan was developed including 117 colours, which were divided into 12 colour families: beige, grey, white, brown, okra, orange, yellow, green earth, green, blue, pink/lilac, red. In addition each colour received three attributes defining its level of saturation, brightness and its striking effect in the urban context. With the help of this fan a main and a secondary colour of the facades of every single building of Zurich was determined considering also the material of the facade such as plaster, stone, brick, wood, fibre cement, concrete, metal, glass. Other parameters collected were the colour of the shutters or blinds, the form of the roof, the size and the urban context (square, street, housing scheme, nature) of the building. Subsequently all the data were incorporated into the database of the Geographic Information System of Zurich, and therefore connected with additional information on each building such as use or year of construction.

On the base of this nearly 41'000 data sound colour and material profiles of the entire city, as well as for the 34 neighbourhoods of Zurich could be determined and accurately described. The results are available as a colour plan of the city of Zurich as well as commented charts showing various aspects and correlations. (Figures 1-2)

2. The focused view: detailed colour portraits of selected outstanding buildings

In addition to the area-wide chromatic compilation detailed colour portraits of 130 selected outstanding buildings were created, in order to focus on more subtle qualities in colour design. (Figures 3-4) The buildings were selected according to different criteria. First of all the quality of the chromaticity of the building was decisive. Furthermore we were interested in the use of bright and dark colours, in the chromatic use of materials and in the aging of surfaces, as well as in carefully renovated buildings. Finally we have chosen buildings which have preserved their genuine chromaticity and so helped to detect the characteristic colours of the various decades of the last century. A series of essays dedicated to each of the topics are included in the Book "Farbraum Stadt", and give a deeper insight into the aspects illustrated.

Therefore many quality criteria for colour design can be described and discussed alongside our selection. Moreover, the portraits capture the rich variety of subtly composed colour harmonies and provide an ample collection of colours. Thus the chromatic portraits become useful in the fine-tuning of shades and in the draft of colour concepts, and they may be also helpful in the communication with clients and building committees.

3. The tactile view: a sample collection of structures and materials used in architecture surface design

It is crucial to consider the properties of materials and surfaces in the process of colour planning, given that these affect the quality and effect of a determined colour shade and contribute to the characterisation of the urban space too. In order to acknowledge this fact five years ago Haus der Farbe established a workshop under the guidance of Matteo Laffranchi, in which since then design oriented material research has been conducted. The findings of this ongoing project contribute to the building of a sample collection dedicated to the design of surfaces in architecture.

The samples illustrate the different characteristics of surfaces and serve as an inspiration for architects and designers searching for specific surfaces. An accurate description of the single samples considering the three aspects mentioned will furthermore provide planners, craftsmen and purchasers with the specific information and vocabulary for a professional communication among each other. (Figure 5)

4. The time-specific view: chromatic charts of period-typical colours used in architecture through the decades of the 20th century

Another issue of the project was to analyse the historical development of the colour space of Zurich in the 20th century and to detect colours, which were characteristic for certain periods. An essay analyses and comments the results in their specific cultural and historical context. Although a typical chromaticity and specific use (e.g. distribution and quantity) of colours could be defined for each single decade of the 20th century, the predominant colours of Zurich's architecture remain the same throughout the century. These are nuances of the colours beige, white, grey, okra and brown, which are found in more of eighty percent of the buildings.

The encountered colours have been compiled in a colour fan with 100 typical architecture colours of the last century. The fan was produced together with CRB – NCS Colour Centre Switzerland. An additional peculiarity of the fan is, that every single colour refers to a specific building and its colour portrait contained in the Box. So one can grasp at one glance the chromatic context of the colour and get further particulars on the building. So the colour fan, just like the colour portrait cards can be a source of inspiration for architects, designers and craftsmen in their colour planning but turns useful in the analysis and communication of colours too. (Figure 6)

5. The dynamic view: video renderings of urban interstices, of changing or mobile colour elements such as light, weather, seasons, advertising, traffic or people

The colour space of a city is more than just the colours of its built structures. Many other chromatic elements, which often have a dynamic and/or temporal character, affect the quality of an urban colour space as well. Urban interstices for example parks, squares, streets or a lake, provide a permanent colour context and therefore alter the appearance of the colours chosen for the buildings. Furthermore it is important to consider the impact of dynamic factors such as changing light, weather and seasons on the colours of a building and of its context. And finally there is a variety of temporary and mobile chromatic elements that bring an additional and peculiar chromaticity into the urban space and which planners have to be aware of.

Thus it was important to us to make these elements visible and we decided to collaborate with the artist Erik Dettwiler to achieve this issue. Erik Dettwiler produced three videos, which can be watched on www.farbraumstadt.ch.

6. The subjective view: a survey on the perception that Zurich's inhabitants have of the colours of their city

Finally we wanted to grasp the colour image Zurich's inhabitants have of their city. Being asked the question what colour Zurich has, most of the people answered with “blue” or “green”. Only on the third place we find the colour “grey”. This shows that the colour image of Zurich is not primarily defined by its architecture (which actually is predominantly beige), but by other characteristics such as the lake, the colour of its flag and public transportation, parks or the surrounding woods.

Most of the people did not remember the colour of the building they defined the most important for them in their neighbourhood. And even though the majority of the interviewed people wish more bright colours for architecture, the same people are usually bothered by buildings with vivid hues. So the survey reveals, that there is not a high awareness of colours in architecture. On the other hand we see, that the demands people have often are very spontaneous and emotional. Therefore they certainly have to be taken into consideration, but need to be analysed carefully. In the mean time we see the necessity to increase the general awareness of the impact of colours on our environment.

The six described views have been conceived as complementary ways how to perceive and analyse the urban colour space, and only a comprehensive view makes it possible to portray a differentiated and multi-layered picture of its chromaticity. By considering all the layers, results and tools colour decisions can be taken that meet the complex requirements of a lively and manifold colour planning of high quality in urban space.

Acknowledgments

The project “Colour Atlas Zurich” was lead by Lino Sibillano and Stefanie Wettstein (Co-Directors Haus der Farbe) and Jürg Rehsteiner (until 2009 Director of the Building Consulting office Zurich, now City Architect of Lucerne). We want to thank our project partners for their generous support: Department of urban planning Zurich, CRB – NCS Colour Centre Switzerland, Fontana&Fontana, Holcim Switzerland, Sax Farben, VASP knowledge visualization.

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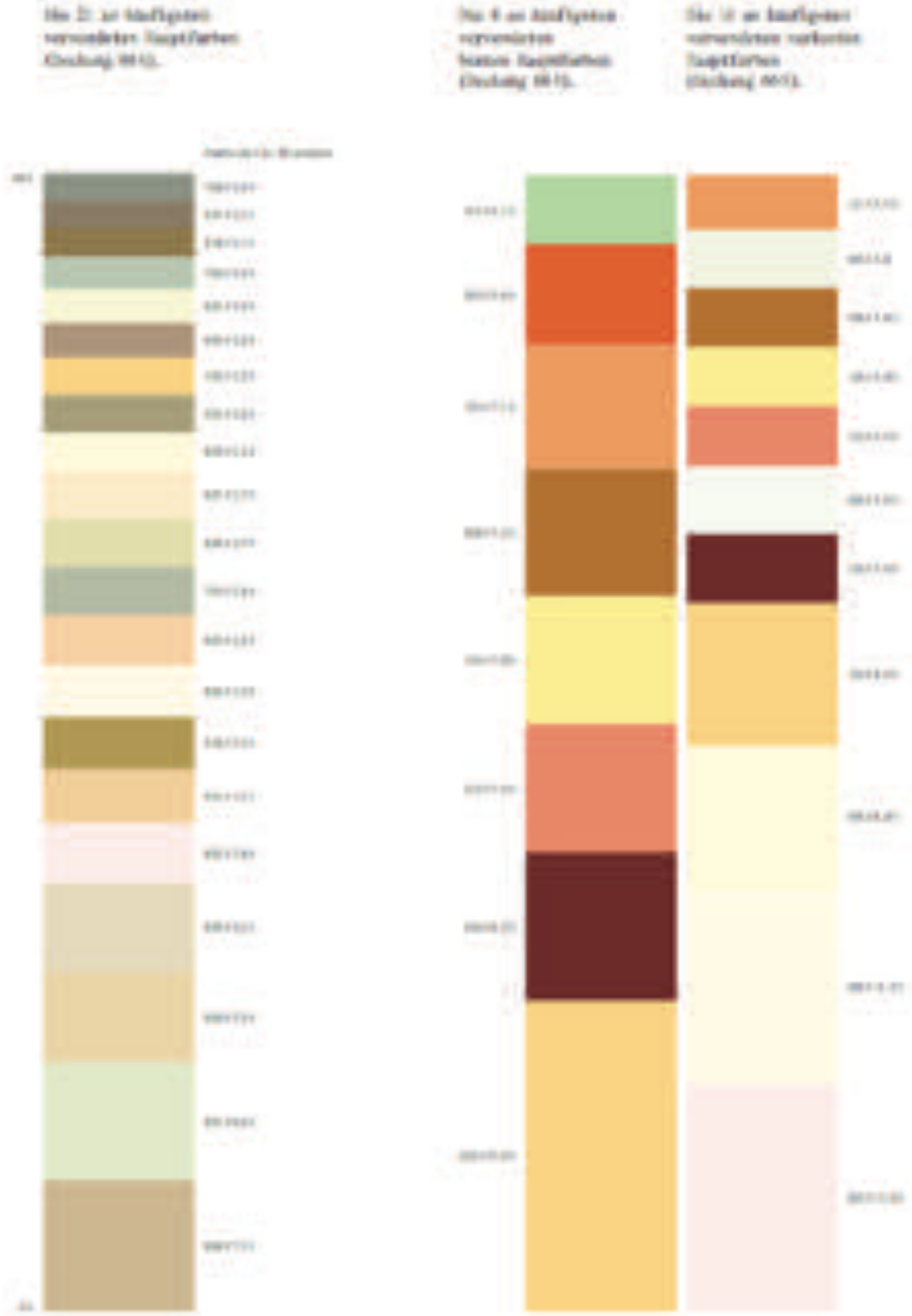

Fig. 1: a) The 21 most used main colours for facades (covering 66 % of the buildings). b) The 8 most used saturated colours for facades (covering 66 % of the buildings with a saturated facade colour).*
c) The 11 most used striking colours for facades (covering 66 % of the buildings with a striking facade colour). (Farbraum Stadt. Box ZRH, p. 70, fig. 1-3)

** The main colour describes the predominant colour of a facade.*

Fig. 2: a) The 25 most used secondary colours for facades (covering 66 % of the buildings). b) The 15 most used saturated secondary colours for facades (covering 66 % of the buildings with a saturated secondary facade colour). c) The 17 most used striking secondary colours for facades (covering 66 % of the buildings with a striking facade colour). (Farbraum Stadt. Box ZRH, p. 71, fig. 4-6)*

** The secondary colour describes a second colour used to distinguish parts of the facade.*

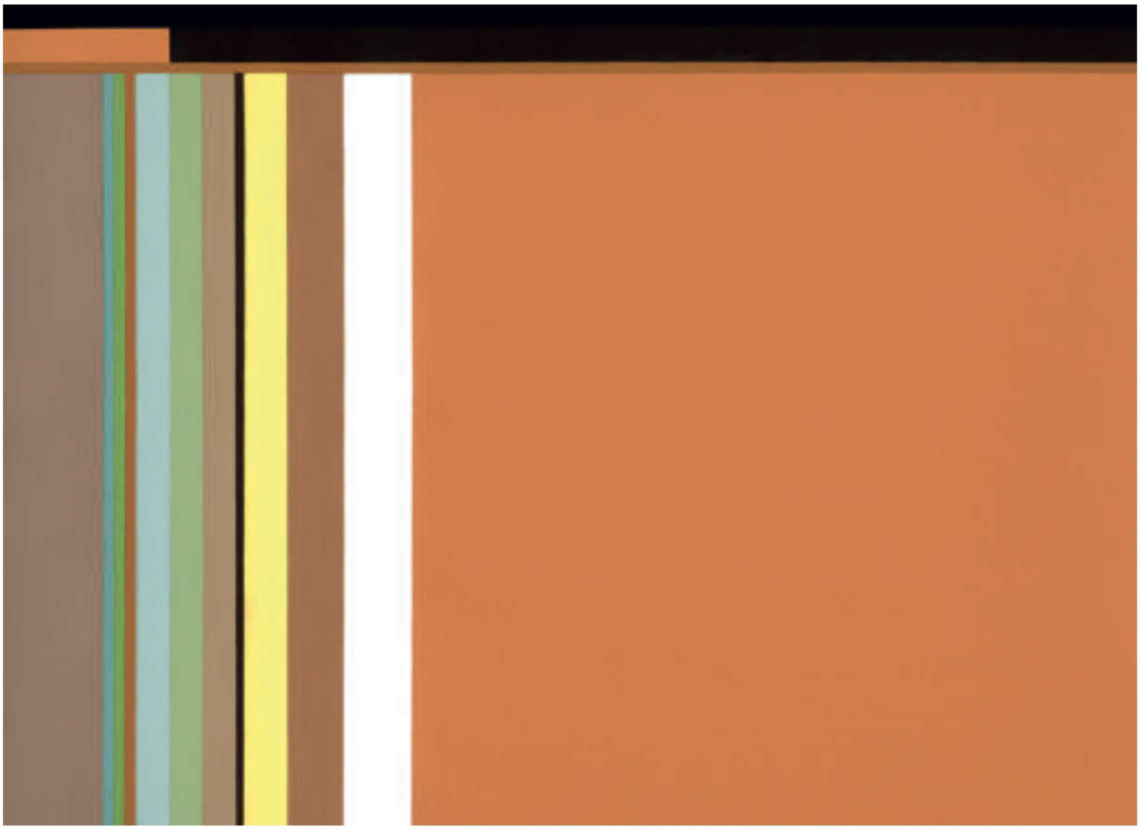

Fig. 3: Colour portrait of Kino Radium, Mühlegasse 5, Zürich. Colour design 1928. (Farbraum Stadt. Box ZRH, FAP 58)

Fig. 4: Colour portrait of Schoolhouse Letten, Rousseaustrasse 43, Zürich. Adolf and Heinrich Bräm, 1913–15. (Farbraum Stadt. Box ZRH, FAP 69)

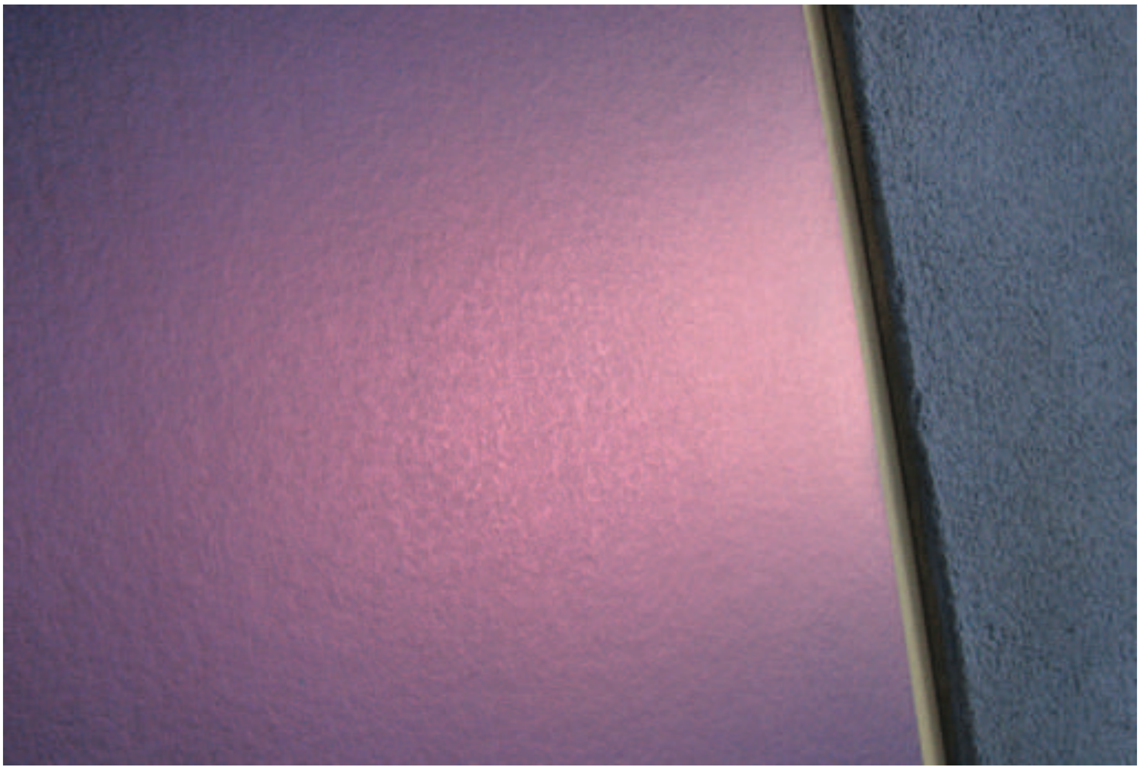

Fig. 5: Sample collection of structures and materials used in architecture surface design at Haus der Farbe Zurich. The collection provides technical information and examines the phenomenological and esthetical qualities of surfaces. (Samples made by Matteo Laffranchi, Haus der Farbe Zurich)

Fig. 6: Colour Fan with 100 typical architecture colours of the 20th century. Produced in co-operation with CRB – NCS Colour Centre Switzerland. (Farbraum Stadt. Epochenfächer 100)

Photoshop as a tool for museum lighting design using apriori colorant optical data

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Abstract

A variety of light sources with a range of correlated color temperatures and optical radiation risk potentials are now available for museum lighting applications. Simulating a work of art's appearance under such lights would be useful for lighting design. This is generally performed using either spectral imaging or computationally-intensive image processing and a priori assumptions about an artist's palette. In this research, ICC abstract profiles were produced for the second approach enabling nearly real-time processing. This was tested using a palette or five acrylic dispersion paints: cadmium yellow medium, phthalocyanine green (blue shade), cobalt blue, quinacridone magenta, and titanium white. An abstract painting made from these paints was used to evaluate this approach. When compared with spectral imaging, the abstract profile produced encouraging results.

1. Introduction

Museum lighting design is a balance between preventative conservation, curatorial aesthetics, architectural constraints, and adhering to the artist's intent (when known) (Thomson, Cuttle) Historically, these conditions have favored tungsten lighting. With the introduction of solid-state lighting and novel filters and lamp design for tungsten, there are more choices of CCT and spectral power distribution. Both impact a work's appearance and there are two approaches to evaluate this inter-relationship. One is to observe the work under the proposed lighting condition. This may not be possible when designing a new environment or seeking alternate lighting options. The second approach is to image the work spectrally; using colorimetry and a chromatic adaptation (CAT) model, the work can be rendered for a given test light (Berns 2008). Unfortunately, very few works of art have been imaged spectrally. If we make assumptions about likely pigments used by the artist, it is possible to estimate a work's spectral properties, enabling lighting comparisons (Zhao). However, such computations are too expensive computationally for routine usage. This research used Photoshop as a method to facilitate these visual comparisons.

2. Methodology

ICC profiles were produced where the input to the profile was the colorimetric-based encoding of a reference illuminant and the output was similar encoding for a test illuminant including chromatic adaptation. By using Photoshop's "convert to profile," the effect of the change of lighting was simulated.

The profile required colorimetric coordinates for the pair of illuminants. The most direct approach would be to produce a sampling of color mixtures for a set of artist materials and measure their spectral reflectance factor, followed by calculating their color for the pair of illuminants. Using a CAT, corresponding colors are calculated from each illuminant to D50 (the

ICC reference illuminant). The set of coordinates is used to build a table-based profile. The artwork is assumed to be composed of this set of materials and by profile conversion, its appearance is rendered for a test illuminant. This is a multi-dimensional interpolation and the quality of the rendering depends on the sampling density and local linearity between measured values. Although this approach is effective for color printing where sample production and measurement is trivial, it would be formidable for artist paints requiring thousands of color mixtures. Thus, a model-based approach or some form of PCA or ICA is required to produce an appropriate sampling.

For this experiment, we used the opaque form of Kubelka-Munk theory (Berns 2007). Tints and masstone samples were painted onto a paper support for the following acrylic dispersion paints: cadmium yellow medium, phthalocyanine green (blue shade), cobalt blue, quinacridone magenta, and titanium white. At this stage of our research, we wanted to limit the number of colorants to minimize the complexity of such an over-determined system caused by colorimetric redundancy. This unusual pigment set can represent paintings by Vincent Van Gogh where phthalocyanine green is a modern "emerald green," quinacridone magenta is a lightfast modern "geranium red lake," and cadmium yellow is similar to chrome yellow. The absorption and scattering data were used to estimate a spectrum at maximum chroma and from this sample, unit k/s was calculated. We observed that the color gamut was small, a consequence of the paints having diffuse surfaces. Since many images are mapped to L*=0 – 100 and enhanced in chroma, there would be a large number of out-of-gamut colors following profile conversion. This was minimized by exponentiating the unit k/s spectra, e.g. $(k/s)_{\lambda}^{2}$, to expand their ranges to greater and smaller values without changing their spectral properties appreciably. Images were also pre-compressed in L* as part of the profile as a second approach to minimize out-of-gamut colors.

CIELAB was divided into a uniform sampling of 33x33x33 nodal positions. For each node, L* was compressed and non-linear optimization was used to find a set of non-negative concentrations that matched a nodal value. From these concentrations, spectral reflectance was calculated, then CIELAB for the test illuminant, L* was expanded, and CIECAT02 (CIE) was used to convert the test illuminant to D50. The final profile was an abstract profile, LAB to LAB (requiring Photoshop CS5).

The tint ladders and an abstract painting made using these paints were imaged using an experimental camera system that estimated spectra, colorimetry, and geometry using a Sinar eVolution 75H and Broncolor strobes. Diffuse images, collected using cross-polarization were calibrated for Ills. D50 and A using our multi-filter approach (Berns 2008B). The Xrite ColorChecker Classic and the tint ladders were used as calibration training data.

3. Results and Discussion

The camera accuracy is listed in Table 1 where the average CIEDE2000 values for the tint ladders were 1.2 and 1.6 for Ills. D50 and A, respectively. A synthetic tint ladder was created using the measured values and converted to corresponding colors using the profile and compared with the corresponding colors calculated using the spectral measurements. The average error was 1.2. Since these particular colors are not LUT nodes, they give an indication of interpolation error.

The average color inconstancy indices (CII in units of CIEDE2000) of the tints determined spectrophotometrically, using the camera calibrated for Ill. A, and using the profile are also listed in Table 1. It was unexpected that the green samples had the greatest color inconstancy, followed by magenta, blue, and yellow. We expected cobalt blue to exhibit the greatest change in appearance. Similar to other research, it seems that the CIECAT02 is a poor predictor of appearance changes for cobalt blue (Berns 2010). The camera produced very similar results to the spectrophotometer. The profile had good performance for the magenta and green tints and poor performance for cobalt blue.

The corresponding images for the abstract painting are shown in Figure 3. Because the color gamut of the painting exceeds the color ramps, the change in appearance is easily observed where the oranges become more vibrant (due to the magenta), the yellows reduce in chroma, and the blues take on a reddish caste. The profile generates an image intermediate to the Ills. D50 and A renderings, tracking the performance metrics listed in Table 1.

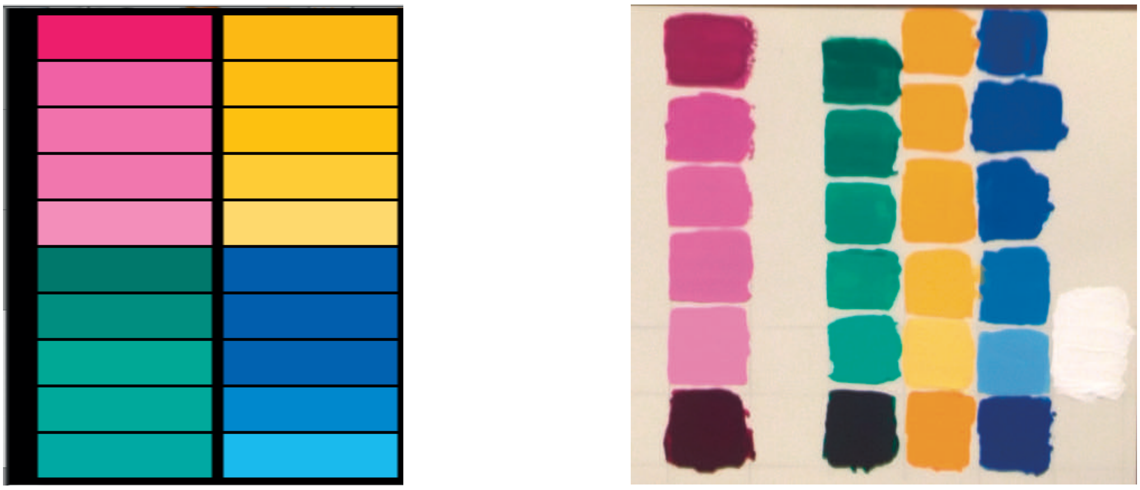

Figure 2. Left: synthetic tint ladders for cadmium yellow medium, phthalocyanine green (blue shade), cobalt blue, and quinacridone magenta, excluding masstones; right: image rendered for D50.

Table 1. CIEDE2000 values for each listed quantity. CII = color inconstancy index.

Tint Ladder	Camera Error D50	Camera Error A	Profile Error	Measured CII	Camera CII	Profile CII
Magenta	1.1	2.1	0.9	3.7	3.4	3.7
Green	1.1	0.9	0.7	4.7	4.5	4.3
Yellow	0.7	1.3	1.8	1.6	1.5	2.3
Blue	1.8	2.3	1.6	2.5	2.3	0.9
Grand Ave.	**1.2**	**1.6**	**1.2**	**3.1**	**2.9**	**2.8**

Figure 3. Abstract painting: left – appearance under D50; center – appearance under Ill. A based on camera Ill. A calibration; right – appearance under Ill. A based on ICC abstract profile. Colors in black are out of gamut of profile.

oral paper

4. Conclusions

This approach to simulating the effects of lighting on color appearance was demonstrated successfully. A profile was produced that simulated the color change between Ills. D50 and A for a set of artist paints. There are still areas requiring improvement including image compression, gamut mapping, color separation for sets of colorants with more than three chromatic materials, and improving the sampling within the MLUT.

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Acknowledgments

This research was supported by the Andrew W. Mellon Foundation and the Richard S. Hunter Professorship in color science, appearance, and technology.

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Optimal wavelengths of colour laser scanners

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Abstract

The reflectance spectra of the NCS colour atlas were analysed to determine the combination of laser wavelengths that would minimise the mean colour difference between the laser illumination and D65. The optimum wavelengths were found to be 460, 535 and 600 nm, close to Thornton's 'prime wavelengths of vision'. The results were compared with the colorimetric performance of a commercial 3D colour laser scanner.

1. Introduction

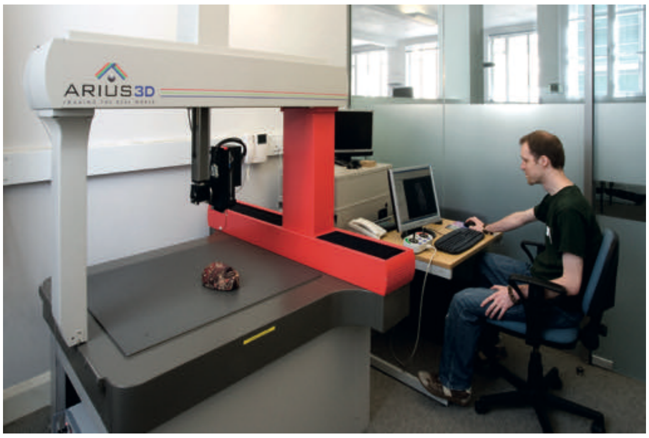

Figure 1. Arius 3D colour laser scanner at UCL

Laser scanners pose a colorimetric challenge for the digitisation of reflective objects because, unlike the human visual system and digital cameras with broadband sensitivity, they sample the spectrum at single wavelengths. More properly, they illuminate the sample at one or more monochromatic wavelengths, and sense the intensity of the reflected light. For a colour scanner with red, green and blue lasers, the RGB triplet at each pixel position depends only on the wavelength of each laser and the surface reflectance of the object at those three wavelengths (assuming a Lambertian surface and linearity of the detector). Although this arrangement is highly metameric, it produces acceptable results for a wide range of media because the reflectance spectra are broadband and can be sampled with sufficient accuracy at three widely-spaced discrete wavelengths. The question then arises as to which specific three wavelengths would be optimum for trichromatic imaging of typical colorants?

2. Method and results

The Natural Color System (NCS) dataset of 1950 samples was used, with spectral reflectance recorded at 5 nm wavelength intervals over the range 380-730 nm (a vector of 71 reflectance factors for each sample). The data had been measured by a Gretag *Spectrolino* spectrophotometer with 45-0° geometry. Tristimulus values X,Y,Z were calculated for each sample under D65 and under multi-laser illumination, using the Judd-Vos (1978) modification of the CIE 2-degree standard observer. These were converted to CIELAB values using the respective spectra of D65 and equal unit power of the lasers as reference white, and the colour difference ΔE^*_{ab} was calculated. The median and mean values were calculated over all the samples in the dataset. By exhaustive search, the combination of laser wavelengths at 5 nm intervals was found that would minimise the mean colour difference between D65 and laser illumination over the pigment set. The search space was limited to all combinations of laser wavelengths, at 5 nm intervals, in the three ranges: blue 380-495 nm; green 500-565 nm; and red 570-650 nm.

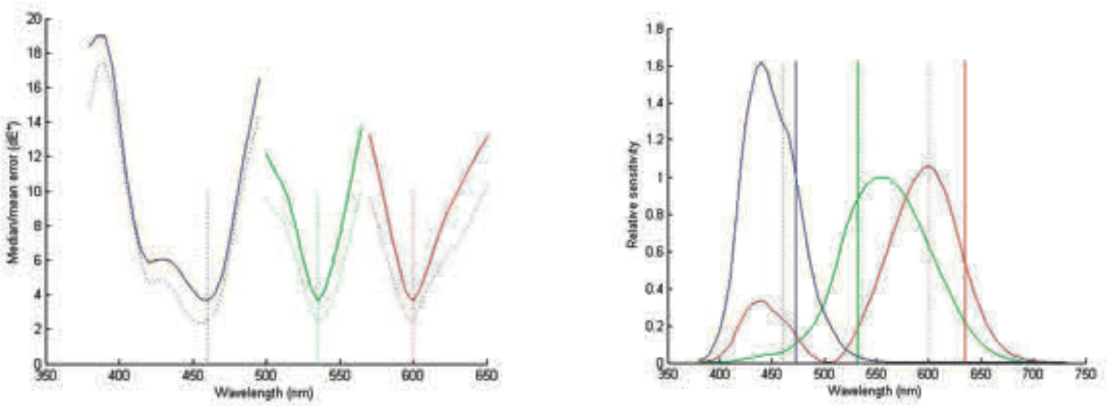

Figure 2. (left) Mean (solid line) and median (dotted line) values of colour difference for 1950 NCS reflectance spectra; (right) CIE standard observer (Judd-Vos modification) with wavelengths of Arius scanner (solid lines) and optimum (dotted lines).

The results are shown in the three curves of Fig. 2 (left), which represent one-dimensional sections through the three-dimensional distribution of mean ΔE^*_{ab} values for the complete dataset. The global minimum point was well defined with respect to all three variable laser wavelengths, and both mean and median measures of error distributions gave the same result. The optimum wavelengths were 460, 535 and 600 nm.

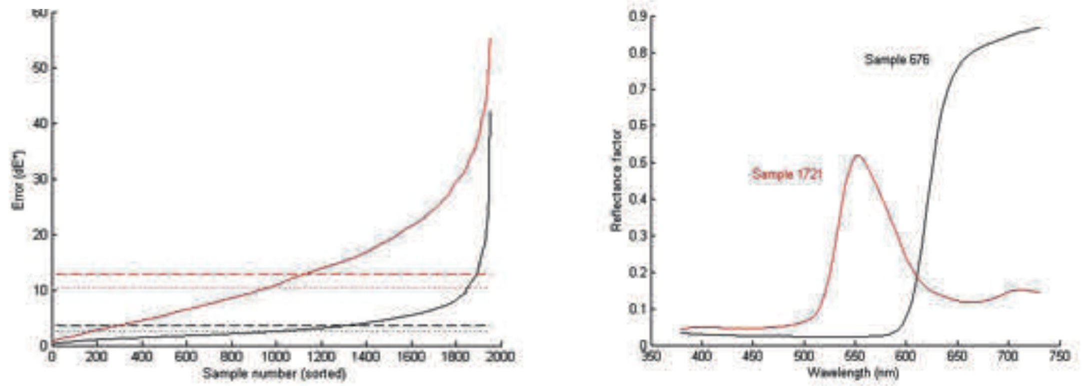

Figure 3. (left) Colour difference values for each of 1950 spectra, sorted into ascending order, with median (dotted line) and mean (dashed line). The black line shows the errors for optimum laser wavelengths and the red line the errors for approximate Arius wavelengths; (right) reflectance spectrum of colour samples giving the largest error for the optimum wavelengths (black) and for the Arius wavelengths (red).

The optimum results were compared with the colorimetric performance of the Arius 3D colour laser scanner, approximating the actual laser wavelengths of 473, 532, 635 by 475, 530, 635 the nearest 5 nm increments (Fig. 2 right). The mean error ΔE^*_{ab} = 12.97 of the Arius scanner for the patches in the combined dataset was 3.6 times greater than the mean error ΔE^*_{ab} = 3.65 of the optimum (Fig. 3 left). The maximum error for the optimum wavelengths was produced by sample 676 (1580-R), a vivid red, which has maximum slope in the reflectance spectrum between 610 and 620 nm (Fig. 3 right). The maximum error for the Arius scanner wavelengths was produced by sample 1721 (2070-G50Y), a strong yellow-green, with maximum slope in reflectance between 540 and 550 nm.

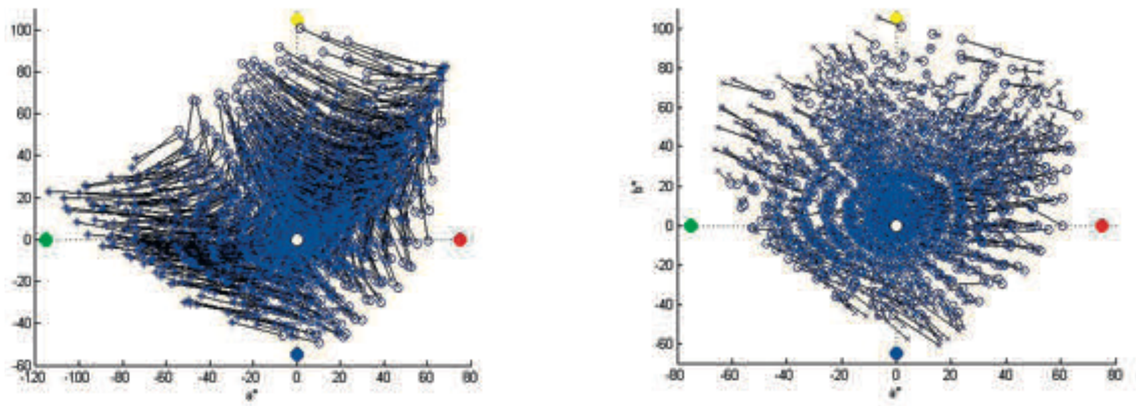

Figure 4. Error vectors in CIELAB a-b* plane between samples of the NCS dataset under D65 (o) and laser (*) illumination: (left) Arius scanner laser wavelengths; (right) optimal three scanner wavelengths.*

The difference in colorimetric accuracy between the Arius scanner and the optimum laser wavelengths can be seen clearly in the distribution of error vectors between the *a*-b** coordinates of each sample under D65 and its corresponding coordinates under the laser illumination (Fig. 4). For the Arius laser wavelengths there is a large displacement of colours in the hue range from magenta to yellow-green towards orange (+*a**) and a lesser opposite displacement of greens and blues towards green (–*b**). For the optimum laser wavelengths the displacements are much smaller and their directions rather random.

3. Discussion

The optimum three laser wavelengths identified in this study of 460, 535, 600 nm are close to the 'prime colors' of approximately 450, 530, 610 nm identified by Thornton (2000) as the wavelengths of peak visual sensitivity. Thornton (1993) also showed that fluorescent lamps with concentrations of light at the prime wavelengths had superior colour rendering properties and maximal visual efficiency. The prime wavelengths are those at which unit-power monochromatic lights induce the largest tristimulus gamut (in terms of the volume of the parallelepiped spanned by the tristimulus vectors of these lights) and are therefore optimal as the dominant wavelengths of display

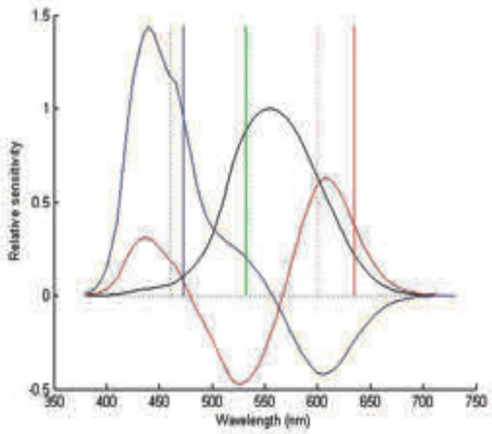

Figure 5. The Y tristimulus function and two orthonormal vectors, with Arius (solid line) and optimum (dotted line) laser wavelengths.

primaries. They are also the wavelengths at which natural metameric reflectance spectra tend to cross (Brill *et al*, 1998).

The relationship of optimum wavelengths to the tristimulus functions can be shown by Gram-Schmidt orthonormalisation, starting with the luminance (Y) function as the first basis vector and then projecting the X and Z functions onto it. The resulting orthogonal functions (Fig. 5), which correspond closely to the decorrelated luminance and chrominance neural channels in the visual pathway, have an obvious red-green and blue-yellow formation. The optimum wavelengths can be seen to lie close to the peaks of second and third orthonormal functions (colour opponent signals).

The improved visual efficiency of the optimal laser wavelengths can also be seen in the CIE general colour rendering index, which increases from 48.6 for the scanner wavelengths of 475, 530, 635 nm to 75.4 for the optimal laser wavelengths of 460, 535, 600 nm. This is largely due to the reduced shift of colorimetric values toward red (Fig. 6).

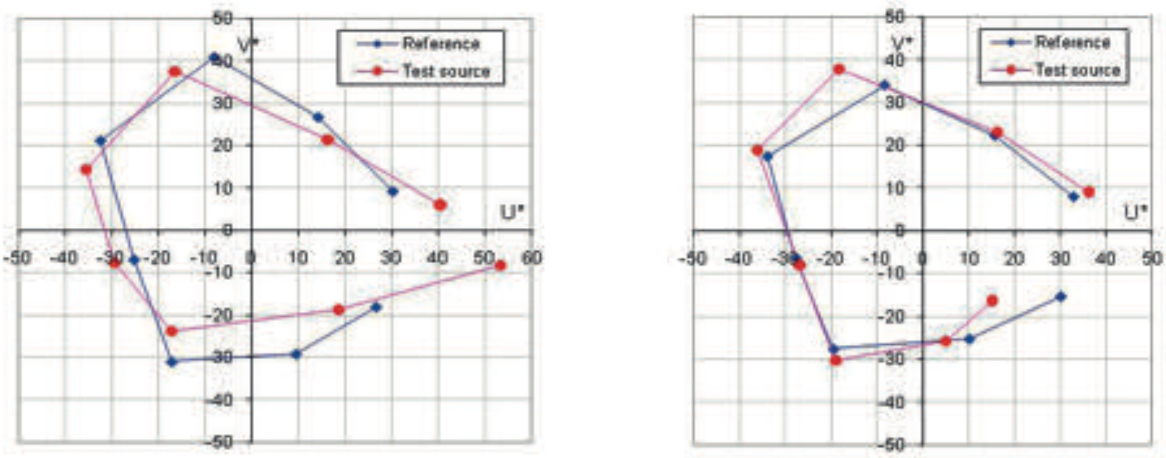

Figure 6. Colour rendering calculations of the eight CIE test colours: (left) under the Arius laser wavelengths; (right) under the optimal laser wavelengths.

This study has confirmed the significance of the prime wavelengths of colour vision as the optimal wavelengths for three monochromatic lasers in a colour laser scanner. Greater colorimetric accuracy is obtained in trichromatic images from the digitisation of 3D objects when the optimum laser wavelengths are used.

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Text segmentation in natural images robust to photometric effects

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Abstract

In this paper, we propose a novel method for detecting and segmenting text layers in complex images. This method is robust against degradations such as shadows, non-uniform illumination, low-contrast, large signal-dependent noise, smear and strain. The proposed method first uses a geodesic transform based on a morphological reconstruction technique to remove dark/light structures connected to the borders of the image and to emphasize on objects in center of the image. Next uses a method based on difference of gamma functions approximated by the Generalized Extreme Value Distribution (GEVD) to find a correct threshold for binarization. The main function of this GEVD is to find the optimum threshold value for image binarization relatively to a significance level. The significance levels are defined in function of the background complexity. This method is much simpler than other methods for text binarization and produces better text extraction results on degraded documents and natural scene images.

1. Introduction

One of the most challenging tasks for any computer vision system is to recognize the changes in an image which are due to a change in the underlying imaged surfaces from changes which are due to the effects of the scene illumination. The interactions between lights and surfaces are complex and introduce unwanted artifacts into an image. For example, shading, shadows, specularities and inter-reflections, as well as change to local variation in the intensity of color of the illumination all make it more difficult to achieve basic visual tasks such as text extraction or background extraction. As example, Figure 2 (b) shows that the colors distribution of the background of the image (c) of Figure 1 is not homogeneous and that in the background there is strong chrominance variations. Figure 2 (d) shows that the colors distribution of the background of the image (d) of Figure 1 is much more heterogeneous and that in this region there is greater chrominance variations than in Figure 1 (c). In order to attenuate these effects illuminant-invariant models have been proposed (see Tremeau et al. (2011)). Several studies have shown that these models greatly attenuate most of effects described above. In this paper, we show that these models suffer from limitations and do not perform well when addressing complex illumination conditions, such as those illustrated by Figure 1.

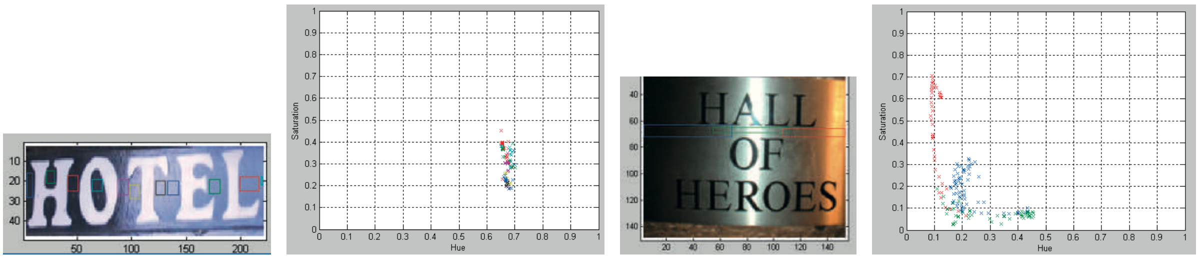
2. Text enhancement

Another challenging task is to enhance the image so that result is more suitable than original image for specific application such as segmentation. Several image enhancement techniques, often elementary or heuristic methods, have been proposed for improving the visual quality of images. Appropriate choice is greatly influenced by the imaging modality, task at hand and viewing conditions (see e.g. Maini and Aggarwal (2010)). As example, power-law transformations with a fractional exponent can be used to expand the gray scale range of dark images. Log

Transformation can be used for enhancing details in darker regions but at the expense of details in higher-level values, i.e. brighter regions. Histogram equalization can be used to stretch the contrast of an image by redistributing the gray-level values uniformly. Unfortunately these models do not perform well when addressing complex illumination conditions, such as those illustrated by Figure 1.

(a) (b) (c) (d)

Figure 1. (a) Color changes due to shading, (b) local variation in the intensity of the illumination, (c) specularities, (d) specularities and inter-reflections.



(a) *Windows analyzed* (b) *Saturation versus Hue* (c) *Windows analyzed* (d) *Saturation versus Hue*

Figure 2. Colors in (b) and (d) represent respectively color of corresponding windows in (a) and (c).

3. Text segmentation

Color image segmentation is another challenging task as solutions have to be effective against image shadows, illumination variations and highlights. Several approaches based on the computation of image invariants that are robust to photometric effects have been proposed in the literature (e.g. van de Weijer et al. (2005), Moreno-Noguer et al. (2007)). Unfortunately, there are too many color invariant models in the literature, making the selection of the best model and its combination with local image structures (e.g. color derivatives) quite difficult to produce optimal results. In specific applications, shadow, shading, illumination and highlight edges have to be identified and processed separately from geometrical edges such as corners, and T-junctions. To address the issue, Gevers et al. (2007) proposed to compute local differential structures and color invariants in a multidimensional feature space to detect salient image structures (i.e. edges) on the basis of their physical nature. Koschan and Abidi (2005) proposed a classification of edges into five classes, namely object edges, reflectance edges, illumination/shadow edges, specular edges, and occlusion edges to enhance the performance of the segmentation solution utilized. Shadow segmentation is of particular importance in applications such as video object extraction and tracking. Several research proposals have been developed in an attempt to detect a particular class of shadows in video images, namely moving cast shadows, based on the shadow's spectral and geometric properties (e.g. Salvador et al. (2004)). The problem is that cast shadow models cannot be effectively used to detect other classes of shadows, such as self shadows or shadows in diffuse penumbra suggesting that existing shadow segmentations solutions could be further improved using invariant color features. The main challenge in color image segmentation is since a decade the fusion of low level image features so that image content would be better described and processed. Several researches provided some solutions to combine color derivatives features and color invariant features, color features and other low level features (e.g. color and texture, color and shape), low-level features and high-level features. However, none of the proposed solutions appear to provide the expected performance to segment complex color images such as those illustrated in the image (d) of Figure 1. Most of existing text segmentation approaches assume that text layers are of uniform color and fail when this is not the case. The background may also be multicolor consequently the assumption according with it is the largest area of (almost) uniform color in the image does not necessarily hold (see e.g. Karatzas and Antonacopoulos (2007)). Lastly, most of existing text segmentation approaches assume that there is a high contrast between text and background in the image this is unfortunately not always the case in real images. Many approaches assume also that in segmenting the highest peak in the lightness histogram we can deduce if text layers are of lower or a higher lightness than the background region, this information may be helpful to segment text layers, but this is once again not always the case in real images.

In Tremeau et al. (2011a) we have demonstrated that none illuminant-invariant model is sufficiently robust to complex photometric effects to solve the issue of text detection in complex natural scenes. To solve this issue, in Tremeau et al. (2011b), we have proposed to use another strategy, more robust to photometric effects, based on the computation of the difference of gamma functions to detect text layers in complex scenes. The proposed method, introduced in Karaoglu et al. (2010), first uses a geodesic transform based morphological reconstruction technique to remove dark/light structures connected to the borders of the image and to emphasize on objects in center of the image. Next uses a method based on difference of gamma functions approximated by the Generalized Extreme Value Distribution (GEVD) to find a correct threshold for binarization. The main function of this GEVD is to find the optimum threshold value for image binarization relatively to a significance level. The significance levels can be optimized using relative background complexity of the image. This approach is based on a new concept of difference of gamma functions used to emphasize certain regions in function of to their intensity distribution.

4. Conclusion

From the results we obtained from ICDAR (2003) and DIBCO (2009) datasets we can conclude that the binarization algorithm proposed in this paper performs well on images with shadows, non-uniform illumination, low-contrast, large signal-dependent noise, smear and strain. Several experiments given in Tremeau et al. (2011b) showed this invariance. As example Figure 3 shows the color invariance of the proposed algorithm to different types of lighting changes. In comparison to other methods mentioned in DIBCO (2009) the proposed method is much simpler. Lack of noise in the threshold image, good and robust performance results (as recall, precision), and low complexity time are of paramount importance when performing optical character recognition (OCR) in degraded documents and text extraction from natural scenes applications. The experimental results that we have obtained show that the proposed method enables to reach this objective to greater extent.

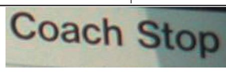
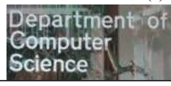
Invariance to	Lightness change(s) &/or shift(s) +	Color change(s) &/or shift(s) +	Color & Lightness change(s) &/or shift(s) +
Examples of image	 (a)	 (b)	 (c)
Results obtained	 (d)	 (e)	 (f)
Examples of image	 (g)	 (h)	 (i)
Results obtained	 (j)	 (k)	 (l)

Figure 3. Resulting images with uneven illumination, hue variations, specular reflections. Images (a), (b), (g) and (h) belong to the ICDAR 2003 dataset. Invariance to lightness &/or color change(s) &/or shift(s) is indicated with '+' and lack of invariance with '-'.

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Color naming experiment using 2D and 3D rendered samples

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Abstract

This paper describes a color naming experiment using 2D and 3D rendered color samples. In conventional color naming experiments using a priori clue, a 2D clue such as color patches were generally used. However, in the real-world scenes, most objects have 3D shapes which can generate illumination effects. We use both 2D and 3D rendering samples as a clue in the experiments, and analyze the relationship between color terms and object surfaces. We first develop a color term collection system which can produce 218 test colors. For each test color, we generate 2D and 3D rendered sample sets. Experimental results show that the number of color terms definitely change between 2D and 3D samples. For instance, the numbers of bright color names for representing 3D samples decrease. The average of response time for 3D samples is significantly faster than 2D color samples. The above results suggest that color naming to object surface can be specified stably not only by the matte surface color but also by the illumination effects of shadows and highlight.

1. Introduction

In the recent study of image science and technology, color names are the focus of the attention, because the language is intuitively easy for us to represent color information, compared with numerical representation such as the tristimulus values and the RGB values. One of the most important contributions to color naming is the study of basic color terms by Berlin and Kay (Berlin 1969). They claimed that there were eleven basic color terms found in any human language. This theory is widely verified and supported by many studies for a long time (Kay, 1978) (Boynton, 1987). In our previous study, we collected recall color terms for modern Japanese over several decade years (Tominaga 1985, 1987, 2010). Then we found out that a set of 15 color terms, including gold, silver, aqua, and yellow-green in addition to the Berlin and Kay's 11 basic color terms, is constructed stably as important color terms in Japanese daily life (Tominaga 2010). In conventional color naming experiments using a priori clue, a 2D clue such as color patches were generally used. However, in the real-world scenes, most objects have 3D shapes which can generate illumination effects such as glosses, highlights and shadows on the object surfaces.

In this paper, we use both 2D and 3D rendered samples as a clue in the experiments, and analyze the relationship between the 15 basic color terms and object surfaces. We first develop a color term collection system. Second, for each test color, we render 2D and 3D sample sets as CG images. Then we investigate the relation between 2D and 3D rendered samples, on the basis of the frequency of 15 color terms and the response time.

2. Color term collection system

We have developed a color term collection system as shown in Fig.1. A color sample with a diameter of 145 mm is displayed. When a subject selects and clicks a radio button of appropriate color name from the 15 terms, the system records the color name and response time. The display

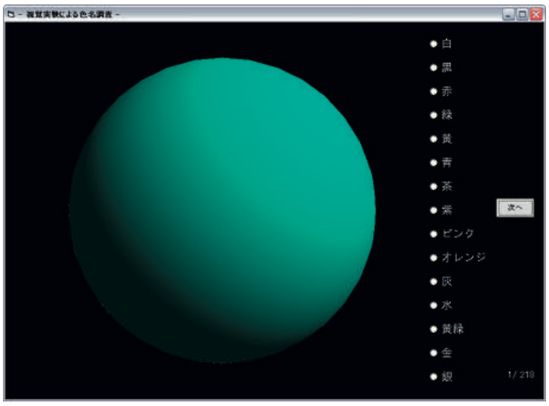
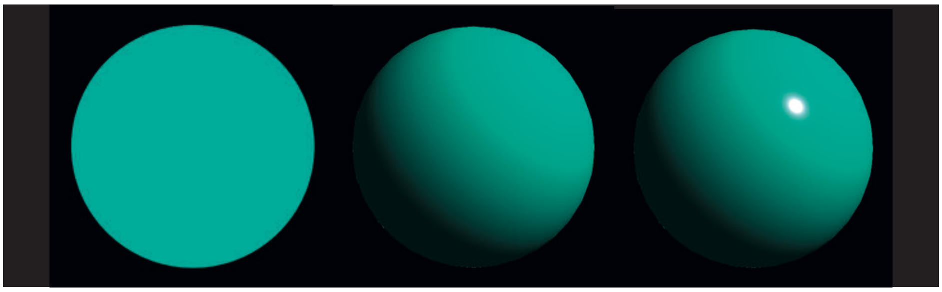


Figure 1. Color naming system.

device used in this study is an EIZO ColorEdge (CG221) with the Adobe RGB color gamut.

We generate the following set of three rendered samples: (Set 1) 2D disk patch painted by a uniform color, (Set 2) 3D sphere with shading effect by diffuse light reflection component, (Set 3) 3D sphere with all illumination effects of shading and specular by both diffuse and specular reflection components. The 3D sample sets in (Set 2) and (Set 3) are rendered by the Phong reflection model, and the illumination is D65 from the direction of 45 degrees to the surface normal. Figure 2 shows examples of rendered images. For each rendered image, the brightest area has the same chromaticity.



(a) Set 1 *(b) Set 2* *(c) Set 3*

Figure 2. Examples of rendered images.

This system can produce 218 test colors at grid points within the monitor's color gamut in CIELAB color space, where the grid point is sampled at the interval scale of 20. Figures 3(a) and (b) show the color gamut and LAB values of color samples, respectively.

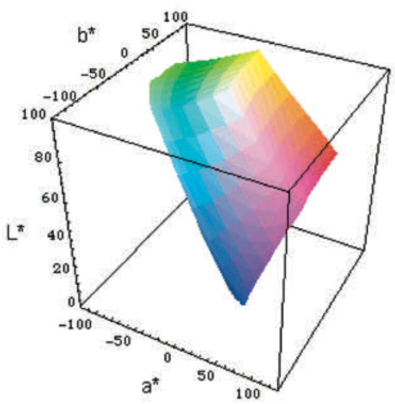
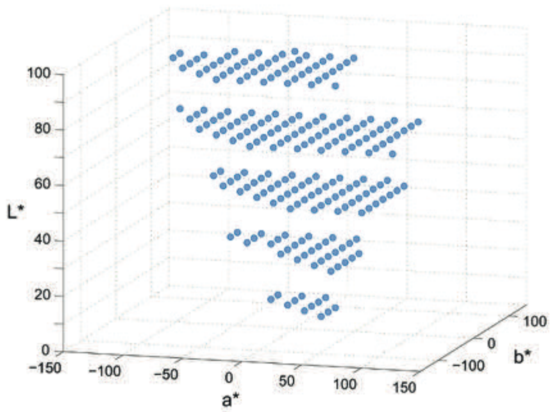


Figure 3(a) Display color gamut.



(b) Sampled colors.

oral paper

3. Experimental Results

Experiments conducted for ten normal subjects in the darkroom. In each sample set, 218 color samples were displayed at random. The distance between the monitor and a subject was about 700 mm. The subjects selected appropriate color name to each of the displayed color samples from the 15 terms. Our system then recorded the color name and the response time. Experimental results are summarized in Fig. 4: The number of color terms definitely changes between 2D and 3D samples. The numbers of such color names as black, red, blue, brown, gray, purple, and gold increase for the 3D sample sets, compared for the 2D samples. On the other hand, the numbers of pink, orange, yellow-green, and aqua decrease. The former color samples are darker than the latter color samples. In other words, the numbers of bright color names for the 3D samples decrease. The average of response time for 3D sample sets is significantly faster than 2D color samples.

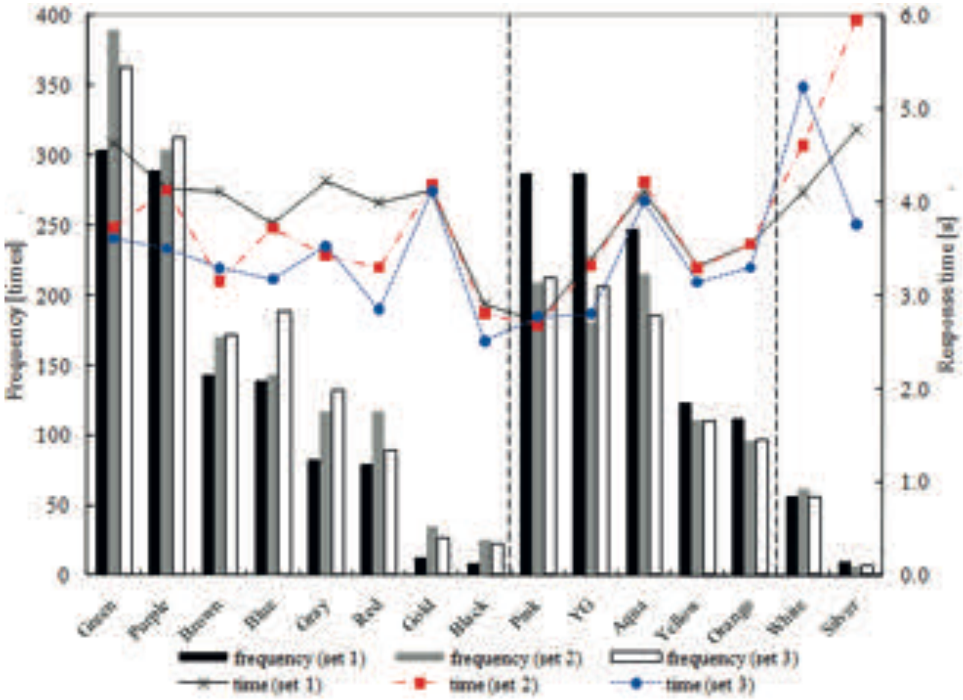


Figure 4. Frequency and Response time of each color sample.

There are some parameters to generate 3D color samples. As an example, we moved the illumination position at the direction of 0 degree to the surface normal. Then we generated an additional rendered sample set (Set 2') which was a 3D sphere with shading effect by diffuse reflection component illuminated from the front. Figure 5 shows an example in Set 2', where the 3D sphere has no highlight and weaker contrast by shading effect, compared with Set 2. Then we conducted the same psychophysical experiment. Table 1 shows the frequency of the color terms. We note that the answers to Set 2' are located between Set 1 and Set 2. In the first group from Green to Black, the answers using (Set 2') are almost larger than those using 2D images (Set 1), and smaller than those using 3D images of Set 2 and Set 3. In the second group from pink to orange, the answers using (Set 2') are almost smaller than 2D sets and larger than 3D sets. However, brown and orange exhibit peculiar behaviour as indicated by underline in Table 1. The two color terms seem exchanged. This may suggest that the contrast influences the color terms. Further consideration is necessary on this point.

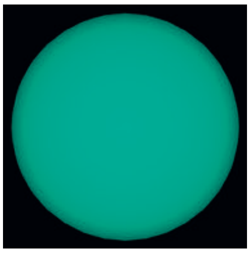


Figure 5. Additional 3D Color Sample.

Table1. Color Name Frequency

Color Name	In English	(1)	(2')	(2)	(3)
Midori	Green	304	293	390	363
Murasaki	Purple	289	297	304	313
Tya	Brown	143	113	170	172
Ao	Blue	139	162	143	188
Hai	Gray	83	108	117	132
Aka	Red	79	80	117	89
Kin	Gold	13	23	34	27
Kuro	Black	8	10	25	22
Pink	Pink	287	228	209	213
Kimidori	Yellow green	287	270	181	206
Mizu	Aqua	248	225	215	185
Ki	Yellow	123	128	111	110
Orange	Orange	112	141	96	97
Shiro	White	56	97	62	56
Gin	Silver	9	5	6	7

4. Conclusion

In this paper, we used both 2D and 3D rendered samples as a clue, and analyzed the relationship between color terms and object surfaces. As the result, the numbers of such color names as black, red, blue, brown, gray, purple, and gold increased for the 3D sample sets, compared for the 2D samples. On the other hand, the numbers of pink, orange, yellow-green, and aqua decreased. The fomer color samples are darker than the latter color samples. The average of response time for 3D sample sets was significantly faster than 2D color samples. As a future work, we will perform the other psychophysical experiments, using 3D color samples with more variations, to analyze the color naming mechanism.

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Validating large-scale lexical color resources

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Abstract

The use of the Web for crowd-sourcing lexical color data has succeeded in creating databases consisting of millions of color terms. Various researchers have demonstrated the value of this data, but questions related to the quality and reliability of the data remain, because each large survey is tainted by a small number of disruptive subjects. We report on a controlled experiment validating a very large database.

1. Introduction

Traditionally, color naming experiments—e.g., the World Color Survey—have used reflective samples such as chips from the Munsell Book of Color or OSA UCS color chips. There has been research in the use of additive displays for color naming (Post et al. (1986), Mojsilovic (2005), Benavente et al. (2005)) but that work is not based on large numbers of observers, especially compared to the thousands of participants in the World Color Survey.

Our motivation is the creation and use of very large lexical color resources specific to displays, and builds on a decade long effort to collect unconstrained color names on the World Wide Web by Moroney (2003). Recent results by Mylonas (2010) suggest excellent agreement for two different Web-based color naming experiments. A further result[1] published on the Web by Munroe and Ellis (2010) has increased the scale of data publically available for analysis from thousands to millions of participants. This has considerable promise for a detailed understanding of the use of color terms, but requires analysis and thought with respect to a systematic method to validate the data. Due to the data size, manual inspection of individual responses is not an option. Our objective is to effectively and efficiently perform a laboratory validation of this large scale uncontrolled Web data, following Zuffi et al. (2007). This is critical given the informal nature of the survey.

2. Experiment

The Munroe and Ellis (2010) color survey asked volunteers to name color patches on black and white backgrounds. Participants were free to name as many or as few patches as they wanted and were not constrained to which terms they could use. Full details of the survey can be found on the archived Web page. The result is a relational database consisting of over 3.5 million terms, or the size of the population of Berlin. The database also includes optional demographic data such as gender, which is not considered in this paper.

We processed the database using in the following steps. First, we applied minimal data cleaning, such as conversion to lower case. Next we queried the cleaned database for the basic

1 Munroe is the artist and writer of the Web-comic xkcd and Ellis implemented the software to conduct the survey. The survey was announced on Munroe's blog and data was collected for one week starting March 1, 2010. We refer to the data publically posted to the Web as Munroe & Ellis data to acknowledge their contribution in a format consistent with technical citations.

color terms, which are the subject of many laboratory studies. Only exact matches were recorded, yielding a monolexemic basic color term database of 1.3 million entries. This database consists of red, green and blue 8-bit values displayed during the survey and the elicited basic color terms. The next step was a 6×6×6 quantization of the red, green and blue values, providing a simple means to sort and cluster the data, such as the novel visualization scheme in which each participant is a pixel shown in Fig. 1. The color terms are shown as square regions arranged alphabetically from left to right. Each term is frequency-sorted from top to bottom, providing a useful representation of the database.

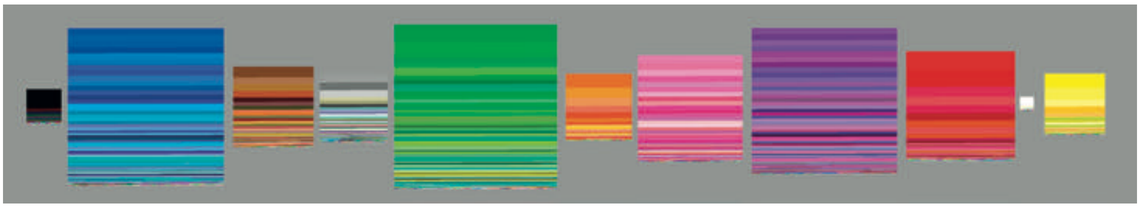

Figure 1. Sorted frequency visualization.

Our validation experiment was a multi-stimulus categorization task. Given a color term, observers were instructed to identify which color patches should be assigned to that category. A screen shot for the term green is shown in Fig. 2, which shows a screen with a summary of the instructions on the top and a 20 wide array of color patches of subtending roughly 2º. Each color patch had a check box; once observers selected the color patches corresponding to that term they progressed to the next term. The experiment was conducted on an HP Compaq LP2480zx display in sRGB conditions. A total of 16 color normal observers participated in the experiment.

Figure 2. Screen shot for color term green.

We avoid defining a disruptive participant. The sorted frequency images in Fig. 1 suggest that there are many types of observers. There are oranges of more frequent shades of brown than color normal observers might agree upon. However, there are also greenish browns that are probably the result of color deficient observers or systematic differences in display primaries. Finally, at the bottom are the colors that are clearly not on the dichromatic confusion lines and likely to stem from adversarial participants. In our instructions to the observers, we did not define what is normal or disruptive. We simply instructed, "select the color patches you might use with the color term."

3. Results and Discussion

The results for the experiment will be considered in three sets of graphs. Fig. 3 shows the CIELAB hue, lightness and chroma correlates. The CIELAB coordinates were computed averaging in RGB space all corresponding chromatic basic color terms. The graphs show the Berlin and Kay averaged centroids on the abscissa and the Munroe and Ellis averages on the ordinate. They also show a linear fit and the corresponding r^2 value. The hue values have the highest correlation, with $r^2 = 0.97$, and the chroma values have the lowest correlation. The hue results are comparable to previously published correlations of the Berlin et al. (1999) data with the studies by Sturges et al. (1995) and Boynton et al. (1987).

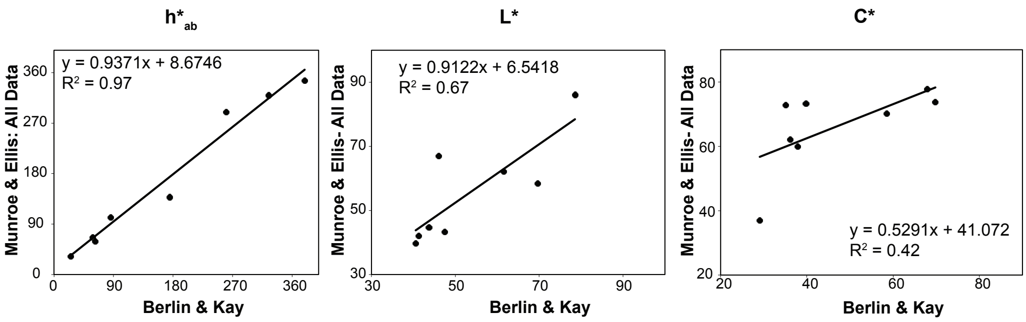

Figure 3. CIELAB hue (left), lightness (center) and chroma (right) correlations for the complete Munroe and Ellis data versus the Berlin and Kay data.

The results for the data validated in our experiment are shown in Fig. 4. The data was computed taking only the data elements selected for a given color term, averaged over all observers. The amount of data retained after validation is shown in Tab. 1. This a significant reduction in the amount of data used for calculation of the corresponding centroids.

Table 1. Percent color data retained after validation per color term.

Brown	*Purple*	*Pink*	*Orange*	*Blue*	*Yellow*	*Red*	*Green*
33%	*44%*	*49%*	*49%*	*53%*	*70%*	*73%*	*74%*

In Fig. 4 the ordinate is the validated Munore and Ellis data. The r^2 correlation values are comparable to those for the complete data set shown in Fig. 3. This raises the question: how comparable are the original and validated data sets?

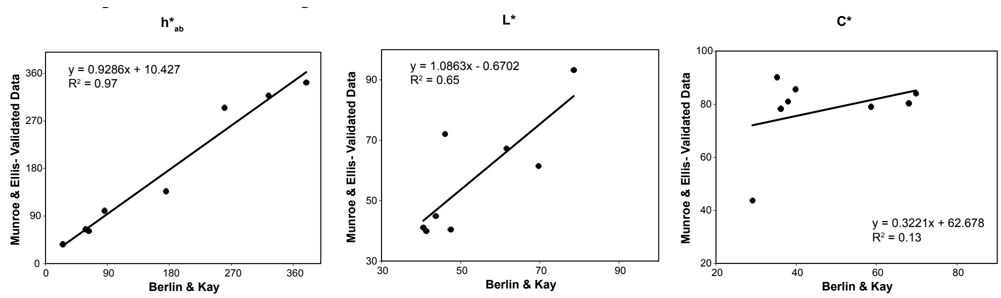

Figure 4. CIELAB hue (left), lightness (center) and chroma (right) correlations for the validated Munroe and Ellis data versus the Berlin and Kay data.

Fig. 5 shows the result of comparing the complete vs. validated Munroe and Ellis data sets. The original complete data is shown on the abscissa and the validated data is shown on the ordinate.

The results for the hue and lightness are $r^2 = 0.99$. Interestingly the results for the chroma are less correlated with $r^2 = 0.82$. We lack an explanation for this consistent shift to more chromatic centroids. The basic result however may ironically be that we have experimentally validated that validation may not be necessary for this data.

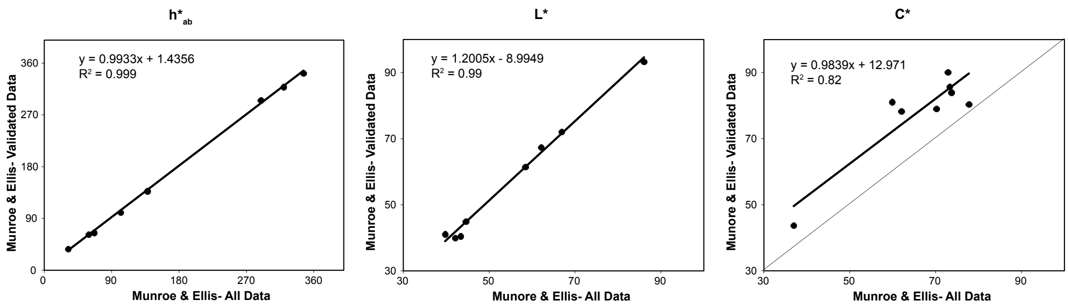

Figure 5. CIELAB hue (left), lightness (center) and chroma (right) correlations for complete Munroe and Ellis data versus the validated Munroe and Ellis data.

4. Conclusions

We have shown a means to use laboratory studies to clean large-scale uncontrolled data from the Web. The experimental subjects rejected from ⅔ of the uncontrolled data for brown to ¼ of the data for the color term green. The CIELAB hue correlation with the Web data (complete and validated) to Berlin and Kay is shown to be over 0.96. The correlations for lightness are less but still on the order 0.65. Finally the hue and lightness correlations for the complete and validated data sets is shown to be 0.99 suggesting that the scale and limited noise in this case may mean that validation is in fact not necessary.

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Color interaction as apparent luminosity in painting: How this is created and a history of its use in painting

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The physical nature of a painting is a flat opaque canvas of a particular size and shape on which elements of color are painted, but it is the emergent quality of a "picture" detached from this surface which is essential to aesthetic expression. This paper discusses how, through the systematic use of color in painting, an abstract work can achieve not only this picture quality, but also a sense of "apparent luminosity". Recent work has moved to a new level of complexity in creating such effects.

David Katz (Katz, 1911/1935) referring to earlier work by Ewald Hering differentiates color experiences according to various modes of appearance. Among many modes of appearance described by Katz, important to this discussion is his definitions of surface color, color seen as attached to an object, and film color, color seen detached from any surface and having a bi-dimensional frontal and indefinite spatial location with an apparent spongy texture. If an artist can stimulate an experience of film color from a painting, this can be primary to creating the sense of a picture quality because the viewer might temporarily lose the awareness of surface.

Katz describes an experience of "luminous film" from the focusing of a beam of light on one side of translucent paper and viewing it from the other side. The viewer "tends to have the impression that the light is shining through or that the paper…is self luminous"(Katz p.27). Katz goes on to say the "artist creates the illusion of a luminous object in a picture not so much by painting the object particularly bright colours as by distributing the light and shadow appropriately with reference to the object within the pictorially represented space" (Katz p.28)

Publishing in the 1960s, the color theorist Faber Birren building on Katz's work described rules to make areas of paintings appear luminous: "the area…must be relatively small in size,… must be higher in value or brightness than anything else in the composition,…must also be the purest colors in sight and have the strongest chroma,… the apparent light sources must seem to pervade the entire painting,…deep values must be avoided."(Birren 1969 p.73) Though this seems definitive, it doesn't always pertain to some great examples in the history of painting and so though important, it is too restrictive a set of rules.

Following on the work of her teacher Josef Albers, Lois Swirnoff credits understanding the phenomenon of additive mixture created from the assimilation of small, highly chromatic or saturated elements as the basis for experiencing apparent luminosity in paintings. Though she starts off her discussion of this with: "The close association of color with light is made visible in painting when color is formed as a gradient"(Swirnoff p.124), this statement is also helpful but doesn't clarify how the illusion is created in all cases.

What seems left out of these explanations is the possible role of color constancy in creating apparent luminosity in paintings. If the manipulation of color creates a sense of perceived color constancy - that what we are seeing in a painting is a single color, but in different quantities of light - then the viewer might experience apparent luminosity in a painting. By considering color constancy together with the technique of using additive mixture and Birren's rules of color sequences, one establishes a broader explanation of how we see such effects in painting.

In briefly reviewing the history of western painting we see that the early practitioners of perspective constructs wished to have the viewer lose awareness of the surface and hoped that a viewer would be able to "look through" the painting as a window on a scene. To this end they frequently emphasized the frame and created uniformed surfaces, varnished to make them even smoother, and with little or no surface articulation. This is an early and perhaps primitive attempt to accomplish what Katz in the early 20th century called film color. The 15c paintings of Van Eyck are a clear example of this approach. By the time of Leonardo's later work we see an artist rendering color in light and shadow to make the viewer sense they are seeing the same physical color in different amounts of light, but not to the extent of actually experiencing a sense of luminosity from the surface of the painting. This seems to occur more readily in 17th century work. George de la Tour mastered a sense of luminosity not only by depicting a candle light source, but by following some of the rules later described by Birren even though his work rarely evokes a sense of film. The subtle use of color to create a sense of luminosity by having a viewer feel color changes as a result of light changes – a kind of reverse color constancy – while also creating a sense of film color is more apparent in the work of Vermeer. Perhaps by drawing from a use of the *camera obscura* and mimicking on the canvas the effects of light he witness projected on the frosted glass of his instrument, he found clues to create such an experience for the viewers of his paintings.

Baroque ceiling painters used these techniques to full advantage further creating a floating sense of apparent luminosity by their practice of framing the view with depicted architecture which would then surround an opening to a lighter depiction of clouds and sky. Certainly the larger expanse of such paintings helped the effect as this would create an entire visual environment for the viewer – a factor later emphasized by Ruskin, Katz and Birren. Tiepolo was certainly a master of this sort of manipulation of color organization and contrast to create such a sense of luminosity in his ceilings.

By the 19th Century Casper David Friedrich perfected color orders to create what is commonly called atmospheric perspective – used since at least Leonardo – together with an overall sense of ambient light suffusing the picture which simultaneously created a sense of luminosity and transparency on the surface as one looked at his depiction of space. And by the later 19th century the American Luminists, having learned well from Turner, achieved perhaps the ultimate presentation of apparent luminous film color in representational painting. In a work by Sanford Robinson Gifford for example, the colors and forms are organized so as to show sharper contours and darker surrounds near the frame depicting the foreground, and progressively using less saturated and more equal valued colors in each area as it steps to ever lighter and less saturated ranges which depict the far distance and sunlight. Though these are still depictions of light, they nevertheless create a sense of apparent luminosity coming from the painting to the viewer. Gifford's work was so effective in creating what was referred to as a "luminous haze" it confounded his contemporaries.

This is of course a very brief and selective history of the attempts to create a sense of apparent luminosity in representational painting, but the principles established were to distract a viewers' awareness of surface by emphasizing the framing edge while using forms and color progressions which appear to go from in focus to out of focus and from a more contrasted surround to an ever less contrasted and lighter area.

Starting in the early 20th C, with the advent of concrete art, the experience of film color and apparent luminosity would have to be created more directly from the object of the painting itself without any depiction of nature. The gestalt explanation of organizing the visual field into figure and ground perception also explained that the figure tends to be seen in the surface mode and the ground in the film mode. Katz also documented that film color is experienced more in the periphery while surface color is seen more in the fovea. This further aligns the experience of the film mode with seeing colors somewhat out of focus as things in the periphery are generally out of focus. Katz's reduction screen experiment – the use of an aperture or frame placed in front of a color sample - to reduce all colors to the film mode essentially depends on putting colors out of focus as in this experiment the screen or matte used is seen in focus while the isolated colors within and behind are always out of focus (Katz 1911/1935).

Kazimir Malevich's seminal experiments in 1915 which elicit clear figure and ground separation in just black and white are first examples to create some film mode experience from a concrete painting. But in a slightly later painting by his contemporary Ivan Kliun, *Red Light,* we see an artist first accomplishing luminous film color without any representation and by the simplest of means. The painting is a rather small square with a dark unsaturated surround closest to the frame edge and progressing in color to a lighter and highly chromatic or saturated red circle presented out of focus – with no clear edge. Kliun also experimented with illusions of transparency and attempted simultaneously to build an impression of luminosity by layering ever lighter rectangles and circles of colors over darker ones. Wladyslaw Strzeminski used the repetition of horizontal lines to create by the assimilation of color groups an illusion of transparency and a a sense of film color in a concrete painting, much as Seurat, Signac and some other neo-impressionists had done earlier in representational works. Though this painiting had little sense of luminosity, it opened up further directions to achieve this within the non-representational language, as later seen in the paintings of the Swiss artists Richard Lohse and Max Bill.

The achievement of a strong sense of luminous film starts to be seen in a few divergent approaches by the American post war artists, Mark Rothko, Josef Albers, and Ad Reinhardt. In those works of Rothko which use a dark surround, and progressively lighter and more saturated or chromatic hues for the floating rectangular forms which are brushed on to create an out of focus impression, the viewer really feels a sense of luminous film color. This is clearly not true of all Rothko's work and so we can understand how luminous film is achieved by comparing various works of his.

Albers interestingly achieves such luminous film color using quite a different approach. His work more directly depends on the viewer's durational fixation to effect the desired experience. In his *Homage to the Square* series begun in 1949-50 he typically presents a format with three or four concentric square in a color gradation. These are painted on relatively small panels – ranging from 12" to 48" while Rothko's work was more frequently wall size - and the color sometimes limited to closely related hues and in other works ranging through grey from one complementary hue to another. Those that are more limited in color range and start with a dark and less saturated surround close to the frame and progress to a lighter and more saturated hue in the center are most effective in creating apparent luminosity. Moreover, as the viewer fixates on the center of the image, simultaneous contrast creates an experience of progressively changing color planes where physically only flat colors are painted. Thus with this durational experience the whole image seems to have soft edges out of focus – that which Rothko actually painted. This effect along with the apparent transparency of the colors is what creates a sense of film color.

Reinhardt, building on Albers approach, created 5' square paintings composed of three so closely related dark hues that the painting initially appears to be a monochromatic black square. With viewing duration, the perceptive viewer adapts to the level of contrast – approximated 60 seconds of fixation – and rather magically experiences a sense of extremely dark luminous film color. This is done without any light/dark value contrast within the painting, but from hue contrast.

The organization causes through the simultaneous hue contrast to make the center appear slightly luminous – a dark light - and film like.

Larry Poons's dot paintings of the early 1960s also used durational viewing and simultaneous contrast to create luminous film color experiences. By fixating on the painting the viewer stimulates afterimages of the painted dots which then float around in one's eye and are seen simultaneously with the painted ones. When the afterimage created is lighter and more saturated than the established field color, the floating dots appear strongly luminous in quality. Two students of Albers, Richard Anuszkiewicz and Julian Stanczak, investigated luminous film more directly by creating surfaces made of small elements in progressively changing colors frequently from dark to light and from less saturated to more saturated which by assimilating create strong experiences of luminous film color in painting.

Most of the foregoing analysis assumes a kind of vision that is peculiar to the experience of pictures: the viewer may fixate on a point, or fixate points in succession. Accepting these limitations of vision has been useful for the analysis of the experience of paintings. But as James Gibson pointed out (Gibson1986), there are two other types of visual experience to be considered: ambient vision which involves moving the head and ambulatory vision which is walking around vision. Ambulatory vision leads to discoveries about ambient light which creates our sense of environment. When we experience a traditional easel painting we essentially suspend our involvement in such environmental information. Perhaps only when entire interior rooms are decorated such as those by Tiepolo, do we become involved in ambient vision. Stimulated by such historical interiors and more specifically the late 18th and 19th century panoramas, the author has experimented with painting entire 360 degree environments. Unlike the earlier panoramas which limit the viewer to a central platform and thus attempt to restrict ambulatory vision, these new experiments allow the viewer to walk anywhere in the room surrounded by color. By walking and looking – at whatever pace the viewer chooses - the viewer is offered a constantly changing array. It is felt that such ambulatory visual experiences together with the already described fixation, and sequential modes of vision, in such an enlarged visual field which constantly includes peripheral vision – already recognized by Katz as an aid to luminosity - leads to an experience of a new kind of apparent luminous film color in painting. By structuring the color and forms in a total surround, the peripheral vision, naturally losing focus, establishes a sense of ambient luminosity which only strengthens the luminous film quality of what is focused upon in the center of vision.

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oral paper

Interaction of mosaic pieces

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Abstract

The subject of this paper is the interaction of color and light in the material *mosaic*. In addition, it discusses the viewer as a "participant" in the room adorned with mosaic. The paper deals with mosaic used as a building material and ornamentation. The theory and technique of its artistic scenes and geometrical patterns are traced in ancient and contemporary architecture. When looking at a mosaic wall, the appearence in the room varies: the walls are transformed from matte to shiny and back again depending on light and the position of the viewer.

Byzantine mosaic

The traditional mosaics consist of marbles and stones in the scale of black and white (sometimes together with red), using material which was available in nature. From the beginning in the Antique, mosaic was used only as pavement, stones on the ground, a floor material. During the first centuries of Christianity, the church took over the mosaic. The Byzantine technique with walls done with mosaics was new in the 5th and 6th centuries. In Ravenna, in the basilicas, the Byzantine mosaic masters worked with entire walls of mosaic made up of small pieces of colored glass and gold, affixed to mortar. Thus, the mosaic masters possessed knowledge of the eye's ability to apprehend color mixing. They also acquired understanding of the changes colors underwent with distance, and also of the interaction of light and material.

The new materials that the Byzantine mosaic masters introduced were colored *glass* – and also *gold*. These materials offer a wider and more intense color scale than the marble mosaics. As mentioned, the walls consist of compositions composed of small pieces of colored glass, *tesserae*, which are affixed to mortar. *Tesserae,* the term derives from a Greek word meaning "four-sided", is the standard for mosaic pieces. Before being divided up, the tessera is a piece of blown flat glass in the form of a so-called "pizza-plate" (in today's terminology). *Smalti* are the technichal term for the brilliant, opaque colored crystalline material fused with glass. The tesserae-mosaic is a kind of color material that is mixed optically. The material interacts in a special way with vision and light. The surface is shiny, hard, and reflective. Glass pieces are shiny and slightly irregular in pure colors and gold. The gold picks up light and reflects gold light back into the room. The entire composition involved the setting of mosaic pieces at different angles so as to reflect light as effectively as possible (Fig. 1).

There is a great contrast between the exterior and the interior of the Ravenna basilicas. The facades consist of flat unadorned brick; the interiors glitter and shimmer with light, color, and brilliant mosaics. Here follows a presentation of two Basilicas: *San Vitale* and *San Apollinare in Classe.*

Basilica di San Vitale

The *Basilica di San Vitale* (526–547) is an octagonal church with a dome. Through a new system for repairing large arches, windows could be placed in all sections of the wall. The glass used in these windows was made of thin, opaque slabs of marble. The stone lets through some light, but they are not transparent. Basilica di San Vitale is dark. The windows provide a slightly yellowish light because of the marble discs. The mosaics are placed high on walls and arches. Yet both the images and the colors of the mosaics stand out clearly from various distances and angles in the room. The mosaic images oscillate between being anchored to the wall and glistening a bit in front of the wall in an immaterial gleam. The irregular surfaces of the glass mosaic resemble small reflectors which create a shimmer in the room.

The relationship of San Vitale to the Byzantine court, is represented by two portraits of the founders done in mosaic, on each side of the altar. The motifs show a service with the emperor Justinian and his empress Theodora accompanied by courtiers and the clergy (Fig. 2). The people depicted have been given the same uniform length – they have slender bodies, closed mouths, and large, observing eyes. Their clothes are magnificent and patterned. The subjects of the mosaic are perceived as static. The sense of movement is non-existent.

The image motifs in the basilica, are thus created with an awareness that the images would appear at a time when daylight was the only light source. The colors of the mosaics are pure. Despite the size of the mosaic walls, the colors are not so strong that they are intrusive to the eye. The images are often constructed from contrasting colors. Red stands against a green in costumes and clothing designs. A pair of red shoes meets green grass. When two contrasting colors meet, there is an increase in both colors.

Another approach used by the mosaic masters to avoid changes in color is applying a contour line between two colors. This contour line prevents the colors from spilling over into each other. Instead, the colors are depicted without visible distortion.

Basilica di San Apollinare in Classe

Basilica di *San Apollinare in Classe* (533–549), just outside Ravenna, is orientated along the longitudinal axis. The church is grand and airy with large windows of white-gray marble slabs. In the sanctuary, the mosaic image of St. Apollinaris is positioned at the front of the dome, surrounded by sheep and nature in a green landscape (Fig. 3).

Even at a distance of *ten* meters, the mosaic pieces condense into entire surfaces. The mosaic material and technique are not as prominent. The distance between the dome and the floor is about *twenty* meters. At that distance, the mosaic pieces can be seen clearly in the gold sections of the mosaic, but not in the green-colored parts of the landscape. This green is seen instead as entire matte surfaces, that appear to have the properties of textiles – the eye does not perceive with any certainty that the material is a mosaic. There is a kind of connection between mosaic and textile perceived at a distance. Standing at the back of the church, the viewer's eye still perceives the gold in the sanctuary as glittering pieces that reflect in different directions. The space signifies an "overlap", as Merleau-Ponty puts it, between the material of the mosaic and the person looking at it and between that which is noticeable and that which is visible (Merleau-Ponty 2004: 257). This "overlap" means that we perceive the material in a tactile way despite our not actually feeling it. Perhaps we interpret the mosaic as a real material, a material with expression, functionality, and credibility. In this way we can imagine the material in a tactile way without feeling it with our hand.

A study of the full-length portrait of the *Archangel Michael* positioned against the shorter wall, shows that the mosaic image appears matte when seen from the side, and glittering with gold when seen from the front. Via the angle the mosaic pieces were laid in the wall, the mosaic masters were able to determine how light will be reflected, and thus how the images appear in the room. As one walks sideways along the sanctuary, the following takes place: At a distance from the long wall the gold has no shimmer. Gold has been applied to the angel's wings, in patterns and details, on Michael's footplate as well as in the background. While walking sideways, slowly moving closer to the image, the angel's wingtips and a contour line surrounding the subject, begin to shine in a gold color. Shortly after, the contour line around the halo begins to glow silver, and finally, in the middle of the picture, also the background glows silver. So in this last moment, everything that is gold glows, glittering and strong.

Summary of the mosaic in Ravenna

Thus, when viewing a mosaic wall, the changes of the material from matte to shiny can be discerned: how the mosaic is reflected depends on its angle against to wall – placing two colors of the same basic hue but with different tilt angles such that each ends up with its own hue. The effect results from light projecting and reflecting different information to the eye. Reflection is also dependent on how the light strikes the mosaic pieces, on whether the tesserae are glass (blank) or marble (often matte), on the viewing angle, and on how the viewer moves in the room.

The appearance of the rooms varies in the basilicas, but no movement of the subjects on the walls is perceived. The hues are perceived as stable and unchangeable, and unaffected by nearby colors. But with the movement of the viewer in the room, and the changes in the eye's view, the mosaic walls are transformed from matte to shiny and back again. Through the mosaic, the viewer participates in the process of change. The Austrian art historian and mosaic specialist Otto Demus expresses this involvement as: "an intimate relationship between the world of the beholder and the world of the image":

> *This relationship was certainly closer in Byzantine than it was in Western mediaeval art. In Byzantium the beholder was not kept at a distance from the image; he entered within its aura of sanctity, and the image, in turn, partook of the space in which he moved. He was not so much a "beholder" as a "participant". (Demus 1948: 3f)*

It is perhaps precisely this way that the mosaic invites the viewer to "participate" in the room – as opposed to simply remaining in a "consideration" of the mosaic walls – that reveals the grasp of the nature of perception possessed by the mosaic masters. The viewer is transformed via the mosaic into someone who is an active participant in the experience.

Mosaic of today

Finally, what can we say about our own time? How can we interpret the interaction of contemporary mosaic? Let us glance briefly at a few Swedish examples of modern mosaic pictures and patterns. One is the Stockholm City Hall, designed in 1923 by the architect Ragnar Östberg, with its Golden Hall created in mosaic by the artist Einar Forseth (Fig. 4). The walls of the Golden Hall are covered with more than 18 million glass and gold mosaic pieces. Using a Byzantine inspired style the mosaics depict portraits of historical figures and interprets certain events in the Swedish history. We can also find the byzantine technique in an underground station situated in Rinkeby, a suburb of Stockholm, created by the Swedish artist Nisse Zetterberg in 1975 (Fig. 5). Zetterberg used mosaic in gold, in the tesseare technique and with different angels from the background. The mosaics depict patterns, symbols and runes inspired by the Viking Age and found in the Rinkeby excavations.

A different way to work with mosaic is seen in a dwelling-house near Vasaparken in central Stockholm. The house owner ordered a mosaic exterior wall, made fast to a low cost. Computerized technique nowadays makes it possible to fabricate, in China, the tesserae/mosaic pieces as standardized components. The image or pattern is produced in the same country and the whole package is shipped back to the purchaser.

The process raises a number of questions: Is this art? Or craftmanship? Is this a way to maintain the mosaic tradition? Is it still possible for the viewer to participate in the adorned room – and to interact with the artwork?





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oral paper

The enigma of the offing: The representation of light and colour in sea and sky

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Abstract

For artists involved with landscape, a fundamental investigative and aesthetic concern is the relationship between the forms, spaces and colours seen above and below the horizon. For image makers in particular, this horizontal division is often used as a powerful compositional construct, emphasising the separation of land and sky, or sea and sky. This paper explains a concentrated study of the visual phenomena seen by looking across sea water, and particularly the division between this water and the sky immediately above it; a place described poetically as the area of the offing, or factually as the sea level horizon. The fundamental objective of this study is to understand something of the nature of the colours seen in these phenomena and how in turn these colours can be used pictorially to evoke such encounters. Colour in this aspect of the natural environment is clearly seen to be determined by the level of sunlight intensity, but how this light is revealed is complex and the variations of its manifestations astonishing.

1. Introduction

An ongoing theme of investigation for visual artists, especially those interested in landscape imagery, is the fundamental relationship between earth and sky. This can be understood and explained as an archetypal landscape experience and pictorial imagery derived from a response to this experience often has qualities of an essential or primary visual structure. In the Western tradition of landscape imagery the recognition of this archetypal form, and a confidence to find pictorial equivalents to express it, probably begins most clearly in the Romantic era with painters such as Caspar David Friedrich (1774–1840) and Joseph Mallord William Turner (1775–1851). Almost contempo-raneously the new process of photography was significantly advanced both technically and aesthetically by the boldly simplified monochromatic images of sea and sky by the French photographer Gustave Le Grey (1820 – 1882). The later paintings of Claude Monet (1840–1926) especially his *Haystacks*, *Poplars* and *Waterlilies* series extended an understanding of how the phenomena of colour in landscape could be represented through repeated primary pictorial forms. Twentieth century Modernism and especially the development of forms of Minimalism continue to have a significant stimulating effect on this type of imagery. The characteristic paintings of Mark Rothko (1903–1970) with their reduction of pictorial form to divisions of coloured horizontal bands, while not overtly descriptive of landscape are at times difficult not to associate with this subject. Other and subsequent artists have used this same pictorial structure with landscape references clearly intended. L.S. Lowry (1887–1976) made hauntingly evocative paintings of just sea and sky in his characteristic muted palette at various times throughout his career. Brice Marden (1938 -) has explored the connection between paintings constructed of primary visual structures and place association in their titles (*Adriatic* 1972–73, *Sea Painting* 1973–74). As well, the Japanese, American, English and Australian photographers; Hiroshi Sugimoto (1948–), Richard Misrach (1949–) Gary Fabian Miller (1957–) and Murray Fredericks (1970–) have all explored ways of framing and presenting minimal landscape imagery that stresses this archetypal relationship between the horizontal division of sky and land, or sky and sea. Such images represent the clearest and most simple expression of landscape as prospect (Appleton, 1996).

2. The Project

This paper explains my investigation, through the medium of painting, to find ways of representing the experience of looking at primary landscape structures and specifically that of the powerful compositional division of the horizon when looking across sea and through sky and the realization that this is critically a question of how colour is perceived and represented.

For a number of years I have made paintings in response to the experience of looking at the horizon from across water. These images have been created by a variety of painting processes and techniques and until recently were made in a studio context using source drawings, studies, notes and memory. Over the last few years this study of light and colour has been focussed on images made completely on-site and so in direct and continuous connection with their source subject. These images are painted in the full light of day on the edge of an area of sea outside Melbourne, Australia. They are made in a variety of atmospheric conditions and at varying times of the day without reference to photographic images but with the complete sensory experience of being in association with the phenomena of space, air, water, light and colour.

These painted images are made over longer periods of time than most photographs, typically over a number of hours and so locate time differently. They are not instances of time but rather extended durations of it, they distil time rather than record it. With this subject, time and colour are inextricably linked, for colour over sea and in sky is the result of varying sunlight intensities at different times of the day and changing atmospheric conditions created by physical forces through time. The procedures involved in making these images on-site, develop and extend principles and practices discovered in a previous investigative project (Smith, 2007). This enquiry attempted to analyst and describe the empirical experience of looking at the colours of clear blue skies. The range of effective pigments discovered during this earlier project has been used as the starting point for this enlarged study. As in the previous study an attempt has been made to be as objective as possible to the actual colours perceived in the observed phenomena. This has been done while being mindful of the procedural paradoxes of, on occasions, being in an intensely lit and coloured environment for extended periods of time and the perceptual shifts in colour recognition that these experiences can induce. However not all of the images have been painted in conditions of full sunlight on a summer's day. Many were made under cloudy or overcast skies where levels of light intensity can be considerably lower. Colour in these sea/sky spaces then becomes much more subtle and is often made up of variations of warm (yellow, orange, pink and violet) and cool (green, turquoise and blue) greys.

Of special importance in this study is the interface between sea and sky, the area of the offing, that is the most distant part of the sea at the horizon's edge. This is an area of powerful poetic association in landscape imagery and it is where colour relationships between the divisions of these two primary forms define the character of the visual experience; the level of light intensity, the time of day, the disposition of the atmosphere. Sea water has a faint blue colour that increases with volume but its colour is also determined by the way that light from the sky reacts with it. Light is reflected from sea water's surface; scattered by particles within it; reflected from the underlying bottom surface, or by a combination of all these factors (Lynch & Livingston, 1995). Towards the horizon most of the sea's colour is from reflected sky light, including the colour of the clouds above it, for reflectivity increases as the eye's sight line across water becomes closer to the horizon. Here the division is between two different substances, air and water, gas and liquid. One is very light in weight and density, the other the opposite, one elastic and compressible, the other hardly at all, yet both are fluid and capable of mobility and of being pushed and shaped by the other. Height above sea level determines the perceived distance to the horizon, with the air above it, which is part of the encircling atmosphere extending much further back into deeper space. To see the boundary between these two substances over distance requires that there is sufficient contrast in colour or brightness between them. Generally this contrast increases as the surface texture of the water in the form of waves increases; conversely as water becomes smoother in still conditions the separation between air and water becomes less distinct. Waves on the horizon reflect more light from the higher and often darker parts of the sky and so the water at the horizon's edge is often darker than the sky immediately above it. As well, atmospheric conditions and varying levels of water vapour in air reduce visibility and soften the transition between water and sky.

3. The Process

How does the human eye perceive all this? In landscape painting when attempting to evaluate the objective nature of colour it is of considerable assistance if these colours are lit from the sun positioned behind the observer's back. This enables samples of mixed paint colour to be held up against a perceived colour in the landscape, with both actual and sample colour then in the full illumination of the sun's light and the sample evaluated and adjusted in relation to this light. If when doing this the light level on the mixed colour sample changes, through for instance, cloud shadow then the colour relationship between this and the perceived colour in the landscape changes so dramatically that it becomes very difficult to believe that one colour is an objective representation of the other. A similar difficulty arises in a landscape context when looking into the light, that is with the sun no longer behind the observer's back, for in this context any mixed colour sample held up against areas in the landscape will be in silhouette and therefore appear darker than the perceived colour. All this clearly indicates that the most important determinant of sea/sky colour is the level of sunlight intensity. On days when variable cloud cover in the sky is constantly masking or revealing the sun and therefore changing its local light intensity, sea colour similarly changes in response, becoming, alternately less or more saturated in hue and lighter or darker in tonal contrast. On such days when there is some cloud cover; sky colour appears lighter, than on days when there is no cloud at all. However logic would indicate that this colour shift is more subjective than actual for above the cloud layer sunlight intensity would be at the same or very similar level of intensity than on completely cloudless days. There is an apparent change in colour on days of high sunlight intensity and specifically the shifting of the perceptual recognition of colour further into the small wavelength area of the visible spectrum with the essentially blue colours of the sea/sky interface appearing to be darker in tone and more violet in hue. This hue change is in line with the description Bezold-Brücke effect. Studies of this effect all indicate that as light intensity increases, the perceived shift in the perception of hues in the blue region of the visible spectrum is further into the short wavelength zone, so blues do appear more violet (Hurvich, 1982; Pridmore, 2004).

Colour and light in sea and sky are therefore inextricably linked in a complex and interactive process; light creates colour in sky and this colour is in continuous dialogue with the sea, which itself has colour that is created and revealed through the agency of the same light. Both of the substances in these spaces; air and water, are by their nature reflective, transparent and mutable, the only constant in this interface is the variability across it. Recognition of this phenomenon of endless atmospheric and colour variation experienced in such maritime environments has stimulated a manner of image production and presentation that acknowledges dissimilarity. This investigation has consciously avoided the extreme variations of colour experienced at the beginning and end of the day, but rather has sort to explore the subtleties of colour variation observed in a restricted span of time throughout the day, specifically between 900 and 1200 hours, when the position of the sun in the sky offers the greatest possibility of full illumination of the colour mixing and evaluation process that is at the basis of all on-site or *en plein-air* painting. All the paintings created through this process were made at a height of only a few metres above sea level; the distance to the area of the offing at this height is therefore approximately five kilometers.

4. Summary

The increasing awareness within this area of investigation of the complexity of the observed colour variations and the procedural difficulties in recording them accurately has lead to the paintings made on-site being presented as a series of multiple images that attempt to record colour and disclose its continual change. The observed colour changes even within the narrow parameters of this test environment are many for the constantly changing combinations of all the variables in sea and sky produce endlessly modified permutations of their colours below and above the horizon line, and these chromatic connections are never quite the same on different or even proceeding days. Therefore a presentation made up of many images, made on many days, seems to be a more honest description of the essentially fugitive and transient character of the observed phenomena. These multi-part images are intended as a positive affirmation of the complexity of colour in the natural world, its continual fascination for artists, and as a way of making all this more evident, especially when revealed through imagery that is reduced back to its most essential.

Acknowledgments

The author wishes to acknowledge the support given to this project by the Faculty of Art and Design, Monash University.

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Interactive chromatic tools for architectural colour design

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Abstract

Architecture is the interplay of volumes constructed with material surfaces and details. Light and shadow reveal their colour, texture and form in space and time. While colour has the ability to manipulate form, reconstruct space, and influence our movement and our appreciation of space, colour is most often neglected in modern architectural projects.[1] Colour is added as an afterthought or as a last minute decision. Lighting designs and material palettes often suffer with budget cuts at the end of a building's programme. Architectural education and practise lacks fluent expression of architectural ideas through colour and light. Form, surface, colour, texture and light are not integrally considered. These mediums are not valued as a technical or aesthetic means of producing architecture.

However, colour specialists from different parts of the world have created tools to support designers develop their individual ways of seeing and their vocabularly and language to construct ideas through colour, material, light, texture and volume. Tools which engage observation and engender fluency of expression in establishing relationships between planes and volumes in artificial and natural light. Today, the design world is bombarded with mass produced colour charts in printing inks. The market dominance of international colour matching systems such as Pantone and RAL have led to a banal standardisation of colour choices for all types of architectural materials. It is therefore important to reflect on the way that we see colour and use it. This paper will address a number of colour tools which are each in there own way interactive, encouraging the interplay of light and colour in three dimensional space and endeavouring to give voice to intelligent constructions of colour material surfaces in light.

Colour keyboards

The work of Le Corbusier on the use of colour in architecture is a landmark in the history of colour and ornament. Both in theory and practise, Le Corbusier was adamant that the use of colour in architecture was vital in the construction and appreciation of space. He defined a very clear idea of the hues he desired to use, largely influenced by his painting at the time. He lamented painter's inability to mix the colours he wanted. In despair, he developed a collection of mat wallpaper colours for the Salubra Wallpaper Co. in 1931 and a complementary palette in 1959. For this collection, he devised a tool which he called 'Color Keyboards'. There is an illusion to a piano keyboard and the harmonic relationship between colour and music. Various forms of cardboard cut-outs may be used to play the keyboard, inviting the user to search for colour harmonies. Le Corbusier believed that colour should be instinctive. Each individual sees colour differently so will naturally be drawn to different colour chords. Two identical keyboards are layed parallel on the page and framed by three bands of colour each in a different shades. Each page is dedicated to different themes such as space, sky and sand. Le Corbusier intended that large blocks of colour be used to construct wall planes, while the colours in the keyboards be used to identify details, objects and furniture. The keyboard layout shows that proportion of colour, the construction of colour harmonies, and the identification of a theme or mood in which you develop your colour palette, aid the designer to construct space in colour and light. Spaces are the interplay of colour planes advancing and receding according to the play of light and shade.[2]

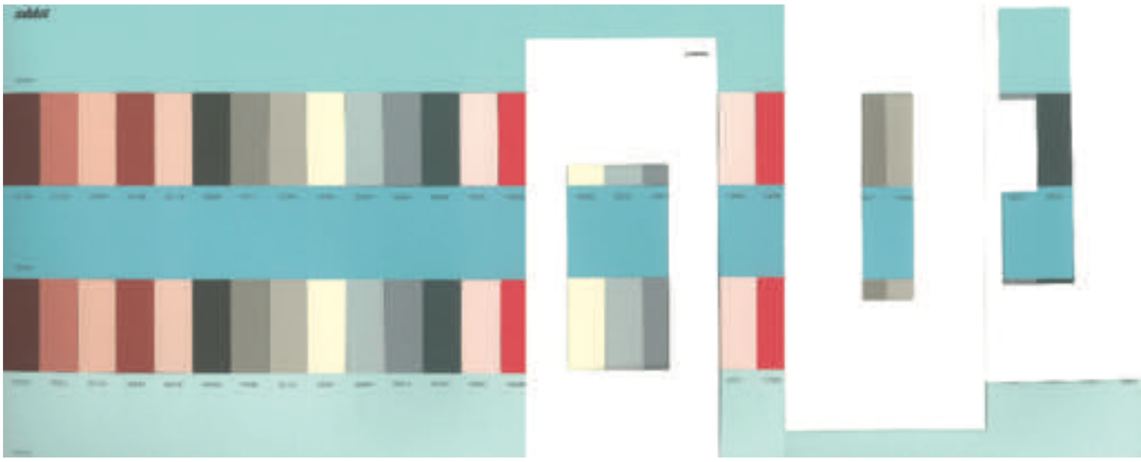

Fig 1. Le Corbusier, Salubra 1 & 11 Wall Paper Collection, Color Keyboards, 1931, in Rüegg (Hg), Birkhauser, 1997.

Chromatic pyramid

'Chromatic Pyramid – Light Facades' was designed by France & Michel Cler in 1992 to present two hundred and ninety hues for the paint company Gauthier. This interactive tool is described as a volume, a map and a cube, while also suggesting the form of a lotus flower. The key idea behind this tool is that it is a game of mobility, spatiality and constant change made by light and reflections through mirrored surfaces. The tool shows us that light and colour are not static but instead mediums constantly changing and evolving in dynamic interplay. Observation and visual association allow the designer to reflect on the notion of the fugacity of colour and light in architecture. Our modern built environment is laced with glass windows and wall planes acting as reflectors. Colour and light apear and disappear.

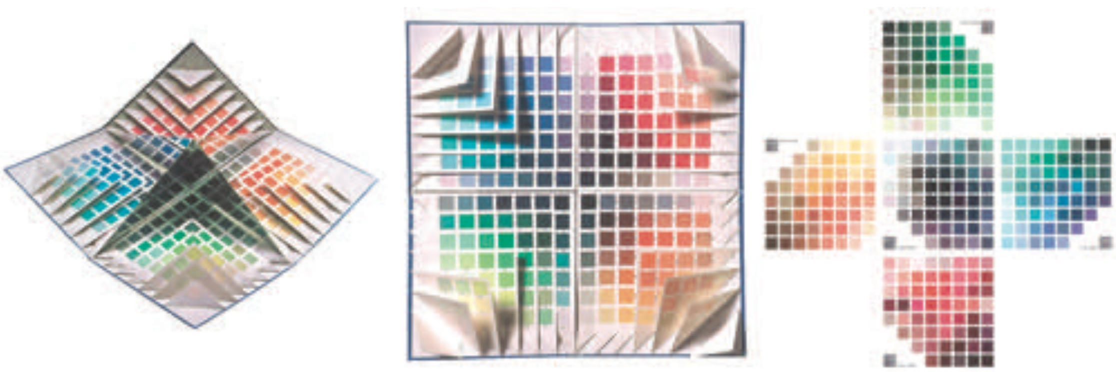

Fig 2. France and Michel Cler, Atelier Cler, Peintures Gauthier, « Pyramid Chromatique, Luminère Façades and Luminère Pontuelle », 1992 in Spillmann (Hg), 2009. Copyright Atelier France and Michel Cler.

The ‘Chromatic Pyramid’ is just one element in a complex kit of tools which is called the ‘colour case,’ presented in a triptych form. In the centre there are two‘cube cards’that unfold from one square to become five squares in the shape of a cross. And to each side there are six fandecks. As France and Michel Cler wrote, « Light, vibrating energy, awakens material. Colours, discovered in light and shadow, are revived. Fluid and fleeting, they are the revelation of depth and the resonance of touch. Harmonising the relationship between light-colour and material participates in the act to build and plan spaces.»[3]

Aalto colour books

For many years *Aalto Colour* refused to make a colour chart, believing that colours should be created with architects, designers and private clients for specific projects. Each colour made in function of the project’s concept, the orientation of the space and the amount of natural and artificial light falling on the planes of building surfaces. Hand-painted ‘brush-out cards’ were the primary tool to understand the interaction of colour and light in-situ. *Aalto Colour* approaches the making of colour from a fine arts perspective. Individual colours are made by building the colour on a palette, pigment by pigment, in the same way as the traditional artist. Colour is not the property of objects, spaces or surfaces; it is the sensation caused by certain qualities of light that the eye recognises and the brain interprets. Surfaces absorb and reflect different wavelengths. It is the reflected wavelengths which determine what colour we see. When separated, any single wavelength will produce a specific colour impression to the human eye. The more pigmented the paint, the more wavelengths are created and therefore the greater the perception of depth. *Aalto* colours are all individually built to allow this full interplay of light and pigment and resultingly constantly transform in light and shade.[4]

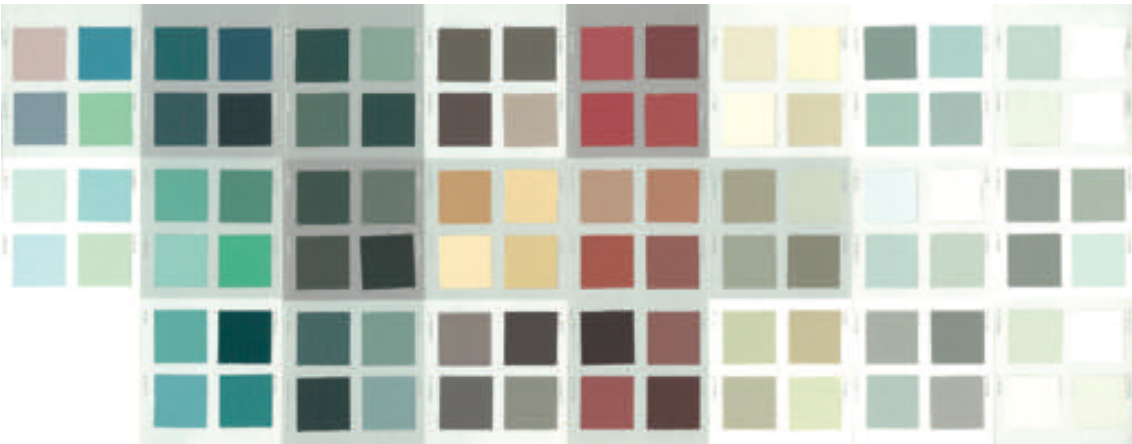

Fig 3. Melanie Yonge, Aalto Colour, Aalto Foundation, 1998, copyright Aalto Colour www.aaltocolour.com

In 1998 Aalto Colour edited four Colour Books. The first book was dedicated to white, aiming to clearly present the complex nature of white in an architectural building environment. Books II, III and IV where dedicated to light, mid-range and saturated hues respectively. The books were designed like the children’s book known as ‘heads, bodies and legs’. Three individual adjacent pages separated the families of warm, neutral and cool shades while at the same time allowing the user to create harmonies of three. Subsequently, Aalto Colour recognised the demand for a small palette of colours in which each colour, due to its pigment recipe, would be compatible with the rest. The *Aalto Foundation* was created as a response to the clarity, strength and constant change of light in the landscapes of the southernhemisphere. The layout is designed like the children's boardgame of 'snakes and ladders'. The eye moves, climbs or slides up and down the palette making and seeing colour combinations. A cardboard to isolator card singles out a colour or a group of four. One side of the isolator is white to identify the true character of the colour while the other side is grey in invite the user to make the mental leap of imagining the colour in space where the colour intensifies. Cool colours are placed next to warm ones, in a close proximity, just as we see colours in the natural environment. Colours in the landscape are never seen in an isolated manner. Instead they coexist in harmony, creating colour conversations between themselves and with the light. [5]

Argile's box of colours

In 2005 Pierre Bonnefille designed for Argile a tool in the form of a box which alludes to the French book format, the Pleiade. It is a box with a drawer, in which there are one hundred and twenty eight post cards dipped in real paint. The cards are like a playing pack inviting the user to create harmonies for space. The drawer allows the user to easily flip through the colours for selection, while the individual cards allow the user to associate the colours in proportion. Easily transportable in a slip-case, the colour cards are designed to help the user to continue the hunt for the perfect stone or tile. The true appearance of colour is vitally important. The way it appears in the shady corner of the room or in direct sunlight filtered through the trees. The cards are designed to be pinned to the wall to study the interaction between colour and light. It is interesting to isolate the colour but it is always important to fit the colour into a conversation of materials which exist in a space. The complete colour palette for Argile is laid out in the form of a landscape showing the viewer that our natural environment is constructed of many colours side by side. The colours are inspired by the colours of the earth, sand and rocks. Pierre associated the colours with journeys. Each post card or colour card bears a name of a place or a material encouraging the viewer to use his imagination to project himself into a journey or remember a place: Roman black, chalk from Marrakesh, yellow from Iceland, red from Malaga and green from Egypt.[6]

Fig 5. 'Argile couleurs de terre' www.argile-peinture.com copyright Argile couleurs de terre.

Conclusion

The complex boundaries caused by fluctuations of light, shade and hue in architectural spaces are often the moments of poetry and emotion that we remember. The passage way of red filtered light under the tori arches at Fushimi Inari. The mastery of subtle colour and texture which is greatly respected in both modern and traditional Japanese architecture. While colour tools aim to improve the syntax and grammar in our design world, I would like to finish by quoting Marina Warner, « Colour is experience that escapes representations in any other form but itself: though a paint chart strives towards a sensuous vocabularly of precise discriminations or encodes a variety of shades in a string of numbers, colour itself has to be seen for itself. It can be packed with symbolism, but cannot itself be symbolised, it can only be the thing itself. »[7]

Fig 6. Traditional and modern architecture in Japan. Photos Melanie Yonge

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Spatial visibility: Camouflaging functions of recommended colour design solutions for improved accessibility

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Abstract

Current Swedish recommendations about contrast marking of architectural details in public spaces, intended to improve accessibility for people with reduced sight, may function as camouflage in relation to the room as a whole. Contrast marking of potentially dangerous objects or elements, functional zones, room edges and guide paths may be efficient in making hindrances and paths to predetermined goals visible. However, while offering visual handrails contrast marking may, by camouflaging the real shape, simultaneously enhance the visually impaired user's handicap and make him/her more dependent on these recommended solutions. *Colour-Shape-Interaction Analysis* is here used to identify how recommended solutions in three types of cases affect spatial visibility. Colour design effects are analysed and experimentally manipulated in picture representations to allow visual comparing between recommended, "neutral" and co-shading colour designs. The main conclusion is that the studied recommended solutions function as camouflage that dominate visually over finer patterns of shadows revealing the real shape, while co-shading could enhance visibility. This paper also demonstrates how the *Colour-Shape-Interaction Analysis* can contribute to more relevant descriptions, analysis and understanding of how colour design affects the visibility of a room.

1. Introduction

The object of this paper is to describe how recommended colour design solutions, intended to improve accessibility in public buildings to people with reduced sight, affects the visibility of shape. The aim is also to point out an urgent area of research and suggest a fruitful approach. Three concepts, developed from camouflage theory for an architectural context (Häggström 2009, 2010) and previously not applied within research on accessibility, are used to develop relevant descriptions, analysis and understanding of how colour design, interacting with shape-defining variations given by the light situation, affects the visibility of shape. The results show that awareness of camouflaging or shape-enhancing effects ought to contribute to a better ground for colour design recommendations that more efficiently improve accessibility for visually impaired.

2. Background

2.2 Swedish recommendations and regulations

Currently valid Swedish recommendations about contrast marking (here "contrast" aim only at difference in lightness) of architectural details in public spaces, intended to improve accessibility to people with reduced sight, are based primarily on research in two dimensions and figure/ground relations. Spatial visibility has not been considered. Despite explicit concern about the users possibility to have a correct spatial perception and free access to public buildings, contrast marking is primarily intended to produce a warning signal telling that something is going on, and "then it is up to each person to find out what is happening" (Newman 2009:23).

Studied sources / pages where \ **Recommended soloution**	In floor marked guide paths	In floor marked functional zones	Marking of objects / elements	Marking of room-edges	Floor-wall-ceiling contrasts	Lighter window-wall	One wall strongly contrasting	Marking of beginning & end of stairs	Marking of nose on each step / stairs	Marking of door swing in floor
Gustavsson, M. 1982	18	19	18	18	33		48	48	48	31
Svensson, E. 1995	48	48	49	100	99	99	48	52		
Månsson, K. 1999	69		70	73				71		
Tillgänglighets program 2000	33		21		20	21	21		19	
Lidmar, K. 2002								86		
Tillgänglighet inom fritid-idrott-kultur 2003	52	52	51		52			50	53	
Removal of Easily Eliminated Obstacles. BFS 2003	6		6					6		
Boverkets Författningssamling 2004:15	3							5		
Enklare utan hinder 2005	69			67				81	47	68
Regelsamling för Byggande 2008	78		77					178		
Newman, E. 2010			59-64	59-64	59-64	59-64	62-64	59-64		

Table 1. Recommended solutions and page/pages where they appear in referred sources

3. Method

The recommended and required solutions have been identified as currently valid in Sweden through a literature survey covering Swedish building regulations, material from Visually Impaired National Association (Synskadades Riksförbund) and authority supported texts/books on accessibility in general and colour design for improved accessibility in particular.

From the theoretical assumption about our visual separation between colour and shape (Häggström 2009), spatial visibility is analyzed as an interaction between colour design and shape-defining variations given by the light situation. Three concepts developed from camouflage theory for the purpose of analyzing colour design effects on shape (Häggström 2009, 2010) are used in a Colour-Shape Interaction Analysis.

The selected solutions analysed in the picture study are based on pictures that have been published as "good examples", mainly by Swedish National Board of Housing, Building and Planning in EuH 2005 (*Enklare utan Hinder*, 2005). The solutions are here studied in series of manipulated grey-scale paintings illustrating different interpretations of the suggested solutions.

4. Colour-Shape Interaction Analysis

The recommended contrast marking of potentially dangerous objects or elements, functional zones, room edges and guide paths seems to visually dominate over the more subtle shape-defining variations given by the particular light situations. The recommended solutions may be efficient in making hindrances and paths to predetermined goals visible, but it is doubtful if they help the visually impaired person to perceive, and autonomously orientate in, the room. In relation to the shape-defining finer variations essential for spatial visibility, contrast marking may function as *countershading, disruptive or constructive camouflage*. While offering visual handrails they may actually enhance the visually impaired user's handicap, making him/her more dependent on the recommended contrast markings.

4.1 Contrast marking of ramp

The picture illustrating contrast marking of beginning and end of a ramp (EuH 2005:47) shows a ramp on which the inclined plane is slightly shadowed by a directed light coming from upper left side (Fig. 1a). If floor and ramp had been uniformly coloured, the light situation ought to have produced a visibly darker shade on the ramp than on the floor (see Fig. 1b). Now the strong contrasting fields in beginning and end of the ramp dominate over the finer nuances revealing that the plane is inclined. The dark fields function as *disruption* in relation to the shape-defining pattern. It also re-shapes, as a *constructive shading*: their darkness appear as shadows caused by larger inclination, while the plane in between appear to have the same light as the surrounding floor (Fig, 1c). Applying instead *co-shading,* enhancing the shadow that shows how the ramp plane deviates from the floor (Fig. 1d), ought to produce a more accurate vision of the spatial situation.

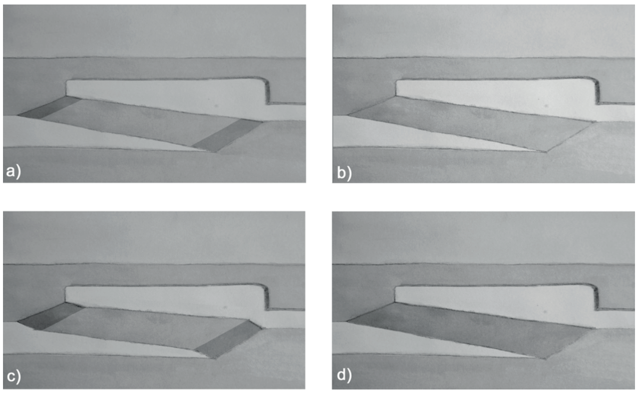

Fig. 1. a) Recommended marking of beginning and end, b) uniformly coloured floor and ramp, c) illustration of re-shaping effect of constructive shading, and d) alternatively suggested shape-enhancing co-shading.

4.2 Contrast marking of staircase

One recommended way of marking staircases is by adding a contrasting colour to both sides of the nose (Fig. 2a): This marking is supposed to "help people with visual impairment to perceive the shape of the staircase" (EuH 2005:83). The strong contrast of the nose, compared to the colour of tread and riser, visually dominate over the finer shades given by the light situation. This way the shape of the nose is more or less obliterated: it appears almost rounded and the exact meeting of the horizontal and vertical plane is difficult to perceive.

An architecturally maybe more logical solution suggested by Lidmar (2002), illustrated below, is to give the whole staircase a contrasting colour. This visually separates the staircase as a body of its own, and indeed makes the staircase as an object more visible (Fig. 2b). The staircase stands out as an isolated unity in relation to the room as a whole, and the shape-defining colour variation pattern of the steps is not broken. Because of this continuity the solution presents neither disruption nor constructive shading, even though it does not really makes the shape of the staircase steps more visible.

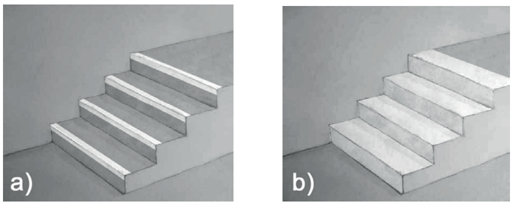

Fig. 2. a) Recommended marking of staircase nose, and b) marking of staircase as a separate body

The most frequently suggested solution is contrast marking of beginning and end of a staircase, in EuH (2005:81) represented by a line drawing showing dark bands marking the front edge of the first and last step (Fig 3a).

When this strongly contrasting field is dark it *countershades* in relation to a light coming from above. The riser below the marking appears almost as light as the tread or floor plane above, on the other side of the dark band, and so this step is visually flattened.

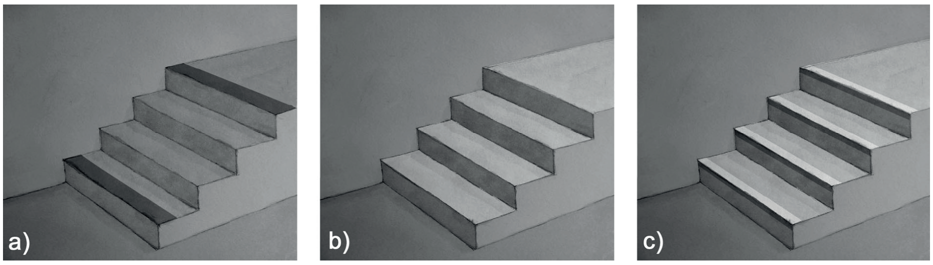

Fig. 3. a) Recommended marking of beginning and end of staircase, b)suggested co-shading to enhance shape visibility, c) enhanced by light marking of upper staircase nose.

The strong contrasting bands could also dominate visually over the finer pattern of light and shadow on treads and risers. It disturbs our clear vision of shape and function as a *disruptive* pattern. Co-shading, assuming light from above, with lighter horizontal planes (treads) and darker vertical planes (risers), ought make the shape more visible in most normal light situations (Fig. 3b). Marking of staircase nose (another often suggested solution) could be used to enhance shape, if only the upper side of the nose is marked with light colour and only the vertical/lower nose side with dark colour (Fig. 3c).

4.3 Contrast marking of room edges

The example for marking of room edges (EuH 2005:67) shows a rehab centre corridor, where the room shape is intended to be defined by very dark wide edgings around the lighter floor, both in a frieze and in a lower wall-edging continuing into door-framing (fig. 4a). Instead of making the room shape conspicuous, the exact meeting between wall and floor is efficiently hidden in the double-sided edging where vertical and horizontal edges have the same, towards wall and floor strongly contrasting, colour.

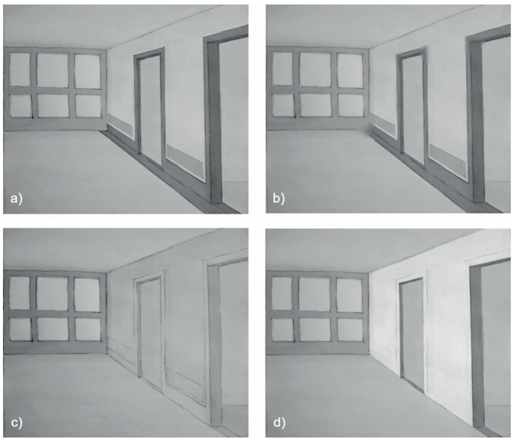

Fig. 4. a) Recommended contrast marking of room edges, b) illustrated effect of blurred perspective information, c) neutral / uniformly coloured version, d) contrast marking of room defining planes.

If we add blurry spots (or anything else) hiding parts bringing essential perspective-related information, it gets really hard to see exactly where wall and floor meets (Fig. 4b).

Also when such strongly contrasting wide edging band follow only one of the planes, wall or floor, as in previous examples, a contrasting edging band visually breaks the continuity of the shape defining pattern, and thus functions as a disruptive pattern. Contrast marking of pathways and functional zones is considered to function in the same way as wide marking of room edges in the floor, that is, as disruptive or constructive shading. By instead applying contrast marking to the room defining planes, creating or simulating co-shading, the shape of the room is visually enhanced (Fig. 4d). However, such marking should be done with awareness of the shape-defining patterns produced by each room's various lighting situations. The recommendation to make window walls lighter to avoid glare (see Table 1) imply the opposite in relation to daylight: it creates counter-shading.

Results and conclusion

The analysis shows that:

a) The recommended contrast marking of staircase nose produces an ambivalent edge, which is partly co-shaded and partly counter-shaded. A lighter marking on the upper side of the nose and a darker on the vertical would instead improve visibility of shape.

b) The recommended contrast marking of beginning and end of ramps as well as staircases function as disruptive or constructive shading and camouflages the fine variations defining the real shape. Co-shading making horizontal planes lighter and vertical planes darker on a staircase, or a ramp surface as a whole lighter or darker depending on the main direction of light, would instead enhance visibility of real shape.

c) Recommended contrast marking of room edges may work as disruptive camouflage, or produce indefinite edges, depending on the inherent colour of the markings and walls. In general, to enhance room shape the perceived contrast between horizontal and vertical planes ought to be stronger than contrast on the same plane. The width of room edge markings ought to be minimized, with respect to impaired vision and efficient viewing distance, so as to be perceived as enhanced edges and not as deviating planes (that is, avoiding camouflaging effects).

Any contrast marking that can be seen as part of the shape-defining pattern, may visually suggest differences in level or plane direction and thus function as constructive shading. The camouflaging effect of marking of room edges (when wide), functional zones or guide paths may thus create a visual ambivalence that ought to be more difficult for visually impaired people, and (as previously observed) for people with dementia. Co-shading can however not be used to mark pathways or functional zones, since this implies markings on one and the same plane. Possibly better and also recommended solutions are to instead use different materials or surface structures, or surface colour patterns that clearly display the real shape.

The *Colour-Shape-Interaction Analysis* help us to understand how colour design affect visibility of shape, and allow us to both explain and predict what difference this or that design will make. Even though further research is clearly needed to reach well-grounded knowledge about efficient solutions for visual accessibility, the awareness of possibly camouflaging effects of any colour design may directly guide the architect or designer in practice, and help him/her to achieve better visual enhancement of shape.

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Montpellier the white city, Toulouse the pink city, two territories in color and light, two identities in question

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Montpellier and Toulouse, two cities in the South of France, two millennium cities: the first one, Mediterranean and sunny; the second one, authentic and landbased. Renowned cities molded by stories and history, their reputations precede them. Revered, dreamed, idealized, it is today complex to distinguish what recovers from the History and what recovers from the fantasy, the image. Having traditions and the strong practices of color and light, they now have **tools to guide their color and light development for their architectural, urban and landscaped heritage (Master plan Development Light, Light Squeme and Chromatic Charters).** Their conceptions have been done by experts of the city, engineers, designers…

These cities having a regional as well as national aura, give themselves to look at, to discover not only through their particular stories, but also through the **creative and identotary signatures.** Thus, what is in question is the **identities** of the city.

In Toulouse, a chromatic chart ordered by the city was acheived for the historic center and has transformed its appearance. In Montpellier, a wellknown lighting designer brings his gaze to serve the city by staging it.

Each of those two cities has worked its image, on the one hand serving the heritage, on the other hand serving the renewal. Montpellier, Color heritage and Light symbol, Toulouse, Color symbol and Light heritage.

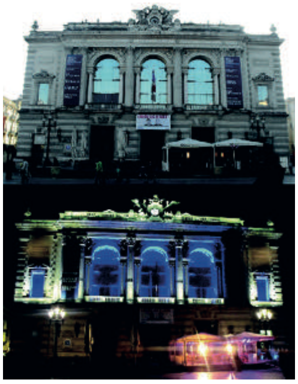
1- The image of the city, serving the heritage

Nowadays, how can a city come to terms with its history, revisit its fundamental and exploit its rich architectural richness? Montpellier and Toulouse have been positioning themselves, each in their own way, in this transmission of knowledge and image of cities offering history and heritage richness to share.

The professionals who have been working on these cities, have proposed tools (color charts, lighthing plan and other requirements) holding authenticity. **In Montpellier, the chromatic chart of the city,** which aims at defining the colors and materials to be used on the facades in Montpellier downtown has been implemented by Luc Néples, architect specialized in traditional material.

His approach, very close to the technique, with a view to perpetuating the practices of color in architecture, is a process beyond fashion and trends. He is looking for the color in the charges, not in the pigments, and combined it with the history of architecture in Montpellier. His posture was to perpetuate know-how, and not just be "in the spirit of » the era. We go out of the style, the pattern, to move towards know-how. On top of that, the old techniques that are prescribed, are compatible with upcoming buildings being more environmentally friendly. Thus, a so-called "old" posture can create opportunities and is an advantage for the city that wants to turn towards the future.

Beyond the diktat of the industry, the valorisation of specific ways of intervening on the facade are in the margin, and thus they position and engage themsleves. Therefore, in



Opéra Comedie, Lighting Designer Y. Kersalé

Basilique Saint Sernin, Lighting Designer R. Narboni

Pont Neuf, Toulouse, Lighting Designer J. Lavergne

Montpellier, in a landscape that until now bore the image of the past (a clear stone tone for all the old center), the work of Luc Néples allows to move from idea to material. Thus, Montpellier was indeed primarily a white city, which due to abuse of the color has erased the traces of the diversity of ages fo its architecture, a city that at a moment wanted to wear the colors of a single era, that of the *Place de la Comédie,* the colors of the sun and the colors that welcome the light better. Nevertheless, today Montpelllier is a city that questions its practices, and develops a willingness to respect the know-how, stone colors, coated with a broom and colored washes that are back in the city center.

In Toulouse, In Toulouse, the « pink city », it is a reflection of a lighting designer who is at the service of authenticity. While the chromatic chart renews today in a very contemporanean way its inventory of colors by introducing colors for doors, ironworks and details never used in the past on the architecture, the lighting plan prepared by Roger Narboni aims at using the white light in tones of hot white in order to enhance polychromy presence in the city. Here, this work has been though in a search of historicity and truth, in a posture enhancement of the existing. *"The colors of the City"* have bearing the lighting plan, as Toulouse has a real chromatic rcihness, and this richness, of which Roger Narboni offers a night face, suggest by its natural diversity of perspectives many possible views.The Basilique of Saint Sernin is a good example. Its lighting, composed of white hot to cold is a tribute for th brick. After the intervention of R. Narboni, the lighting plan was adopted and then readapted. Indeed, prescription tools are made to evolve as the city is in a perpetual movement. Services of the City Hall have resumed their autonomy regarding the management of the lighting of some sites, and some installations have been established by Joel Lavergne, Manager of Lighting Technical Services of the city, not from a restoration of natural polychromy point of view, but step by step, by evocating the chromatic diversity of the city by the use of colored light. On the Pont Neuf, a sequence of 5 minutes reveals all the tones of brick from the lighter red to the most flamboyant red.This willingness to play with the codes of the material in place, through a soft echo or through an over interpretation of color codes, presents a real interest in the intimate relationship established with the architecture.

2- An image of the city at the service of the renewal

Toulouse, the pink, **Montpellier**, the white, portray two distinct as well as unitary representations of the city. Figurations coded by a color-sign which calls for the materiality of historic architecture and a building tradition on the one hand but also a more phenomenological aspect consecutive to a local context defined by hydrographic, topographic and light caracteristics that determine the very appearance of the city.

The wellknown expression *Toulouse pink city* seems ageless, it has probably designated Toulouse since Roman times. Today it continues to glorify the city as an exotic figure and characterizing of the southern city, resulting both from a certain consummated experience of the city and the stereotypical image of the city that precedes this experience. Its reputation precedes it. This monochromatic definition includes the ideological modernist hygienist axiom tinted with a sort of romanticism, the one of the warm and welcoming cities in the south of France, the incarnation of the good life, idealization of a remote and unattainable territory, the south. Unattainable... because this unitary and monochrome expression belongs to the gaze of the one who look at something far from it, without taking into acount the nuances. But this chromatic and rigid determinism that identifies the city in a sensitive way nevertheless, but from a unique point of view, is it not a kind of desincarnation of the materiality of the city?

Against the galvaudage of a **« local color »** that becomes insignificant due to its decontextualization and desincarnation, the city of Toulouse has called know-how and expertise of a colorist in architecture, Isabelle Boisseaud, to reintroduce the polychromic dimension in the Toulouse architectural landscape.

Mostly, the establishment of such a tool qualifies a process of preservation of built heritage. In the case of Toulouse, it was also to keep the unity of the chromatic city. We will describe the result of the application of the color palette on one of the main axis in the protected perimeter of Toulouse: the Avenue Alsace-Lorraine. This major axis is representative of the Haussmanian urbanism and inspired by the perspective theories. According to Richard Sennett, "modern architecture has tried to satisfy the desire of the « Lumières »: to live in a world physically unifiable" (1). the design of the modern city is based on this intellectual construction of space, the perspective. How, then, treating the colors of the facades of the avenue Alsace-Lorraine? The answer was to propose a color palette that does not hamper the formal unity of architecture, but instead supports its similarities. Thus the recurrence of colorful harmony on the facades using ranges of orange clear pink ochers and blue, blue-green and green, underlines the homogeneity of the urban landscape of the avenue and erases the differences to reveal this unity. One can question this color choice: is it not an over-signification of the original urban project? Would this not be a compliance of the heritage aesthetics to the idea of modernity? This ambition of clear foresight, of the permanent readability would be the condition of the existence of the urban project. A fundamental treatment that could be a sort of absolute mastery of the image of the city, without blurring, empty space, without accident, and that would eliminate the heterogeneous form symptomatic of chaos. For Isabelle Boisseaud, the creation of color ranges for the city center was originally a purely aesthetic issue, she has been inspired by local materials, traditional techniques of whitewash and plaster, clay colors for general color for the facades and she was looking for the "harmony". But it is also the issue of renewing the image of the city that the colorist had to tackle with. And this renewal has taken place, since after ten years of renovation campaigns conducted by the department of aesthetics and urban heritage of the city of Toulouse in the protected perimeter, the face of downtown has been transformed and unified. Transformed because the colors that do not belong to the areas of light ochers and blue-green have disappeared ; unified since the urban landscape is now dominated by a color harmony based on a soft hot / cold contrast. The process of enhancement of the architecture of downtown is not without consideration for the historical aspect. The architect of French buildings works in this direction, the color palette for facades is a valuable tool that supports its mission. But the willingness of synthesis that emerges, seems to sum up the complex fabric of the old center of the town, entanglement of different ages of buildings from the fifteenth to the twentieth century, to a colorful impression a bit trivializing even if aesthic. Don't we revive the simplified image of Toulouse pink city? A photogenetic image immediately understandable. Is this the price to pay to enter the area of the twenty-first century, when the city's plan would sometimes be able to free itself from its history, its past identity to lay the groundwork for its future identity?

In Montpellier, the artist of light, Yann Kersalé, has created a lighting plan for downtown, it has been produced as part of the operation « Grand Coeur », a recovery operation of the historic area of town. **"The night of links"** signs his conceptual approach on the heart of town, the blue color is emblematic, metaphor of water in the urban areas. For the technical service responsible for the lighting of the city, the artist has "brought another aesthetic dimension " that they would not have imagined, "an artistic approach. " Dated from 2007, this light path begins with the lighting of the Arches, a succession of blue arches, spanning urban space at the Place de la Comedie. Link between the railway station and the center, friendly and festive living space, where the facade of the Municipal Theater was also enlighted. Large candelabra can be seen along the tram and along one side of the square. Their size seems to be the extent of this immense place. In doing so, they repeat vertical blue lines, a kind of plumb line of facades, and floating they en-chant the night scenery.

Taking advantage of the metamorphosis of the urban night, the blue light, sometimes imposing leitmotif, sometimes acting as an index, offers a different reading of the city center, linking, one by one, the remarkable and identitary sites of the city, revealing also the part remained in the shadows. This unifying blue creates, in the simultaneous of colorful appearances, a poetic theme that can be read only in moving, like an imaginary map. One can rediscover the urban space reinvented, freed from its materiality and its order. Blue, as a signature of the nightlife identity of the city, prints in its impermanence another image of the city, at the borders of tangible. It reveals not the city material but a symbolic representation. Effectiveness of the luminous sign that engages again the renewal of the image of the city. Here, this revival is based on a blue continuum, fictional referential of water, which moves away from a historicizing and heritage narration, and recreates sense from the percept. This poetic dimension allows the city at nighttime to capture a defined image, circumscribed but singular in the territory of the blue color.

The night of the links is the work of his creator, anyway, it belongs to who contemplates it as any sensitive work: the inhabitant, the walker, revives in this blue night, with his own experience of the city.

The difference between Montpellier and Toulouse in the way of answering the issues of preservation and enhancement of their heritage, both during day and night, shows that if the problem is similar, the search for authenticity becomes a cultual object capable of defining our own modernity. Through those sensitive daytime and nightime writings, Montpellier white city and Toulouse pink city may prepare their sustainable development.

Acknowledgments

Thanks to I. Boisseaud, J. Lavergne, R. Narboni, L. Neples, the technical lignhting service in Montpellier, the architecture service in Toulouse for their testimony.

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Chromatic interactions of surfaces and illuminants: Physico-environmental regularities as cues for the perception of colours

oral paper

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Abstract

The visual stimulus associated with an object surface varies with the illumination falling on the object. To accomplish the constancy of perceived surface colours under changing illumination, the visual system must in some sense internalize the regularities of the chromatic interaction between observed surfaces and the incident light as these jointly determine the visual stimulus.

1. A multiplicative change of the cone excitations under changes of illumination, where the excitations of each cone type are scaled for all surfaces by the same factor.
2. A chromaticity-dependent change in luminance: surfaces similar to the illuminant in chromaticity are rendered as lighter than surfaces dissimilar from the illuminant.
3. A resistance of narrow-band surfaces to chromaticity shifts.
4. A compression of the chromaticity gamut with narrow-band illuminants.

I will also summarize psychophysical experiments that address the question which of the above mentioned regularities are taken into account by the human visual system for perceiving surface and illumination colours. In order to obtain almost constant surface colour percepts under different illuminants, the visual system must estimate the chromatic properties of the current illumination. One class of cues to the illumination are the so called chromatic scene statistics: statistics of the chromatic distribution within the retinal image received from the scene. For instance, under a reddish illuminant the retinal image becomes on average reddish and thus a reddish mean chromaticity within the retinal image could indicate a reddish illuminant. However, taking the mean retinal chromaticity as a cue to the chromatic properties of the illuminant faces a difficulty: a non-neutral mean chromaticity cannot be attributed unambiguously to a chromatically biased illuminant because to some degree it also could be caused by a chromatically unbalanced composition of surfaces in the scene. To enhance the estimation of the illumination, it would be helpful to take additional scene statistics into account if they vary systematically with the illuminant. Candidates for such additional scene statistics as diagnostically useful cues to the chromatic properties of the illumination can be derived from the above mentioned analysis of regularities in the chromatic interaction between surfaces and illuminants. The psychophysical experiments presented in the third part of this talk investigate which of these candidate cues are indeed taken into account by the human visual system.

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oral paper

A study on color difference based on visual assessment of existing lighting and LED lighting

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Abstract

LED lamps show distinctive characteristics compared to existing light sources such as incandescent lamp or fluorescent lamps, as its design is quite different from the existing ones. If such difference caused by characteristic spectral energy distribution of LED lamps is large enough, it may cause repulsion to users of the light source owing to large difference of colors. Even more, such light source may not be applied in some operations.

Thus, visual assessment was made in this study to find out the color difference between LED light source and existing ones. The test was implemented as follows:

1) To perform the test, two light cabinets were built to compare a standard light source and LED lights concurrently. Inside walls were painted with N7.5 achromatic color of to eliminate influence of surrounding colors.

1. The subject of assessment had the diversified color arrangement patterns as facilitated in the color design field.
2. Emotional evaluation was implemented following the evaluative adjectives under the standard light source and LED lights.
3. The number of subjects who were selected among graduate students majoring in illumination and chromatics who might have good capacity in distinguishing colors.

The result of the visual assessment standard light source and LED lights was analyzed through the factual analysis, and the difference of the result was demonstrated through the fact float chart.

1. Introduction

Around the time of September, 2012, all of the incandescent lamps will disappear from the stores and the use of all other lamps with low energy efficiency will be banned by 2016, which will increase the demand of the high energy efficiency lamps in the future. As a solution to reduce the energy expenditures and the environment-friendly lighting technology, the LED lighting with the low electricity use with the ability to create various colors and designs is rapidly rising.

According to this social trend, an evaluation for the environment suitability for the indoors LED lamp use is needed. The LED lamps have a different luminous method from the existing lights, such as the incandescent or fluorescent lamps, which gives it different characteristics that were not seen in the existing lighting sources. One of the characteristics of the spectrum distribution of LED may create an awkward feeling if the difference in the visible colors is significant. Also, different visual tasks may lead to mistakes due to the different visible colors under the LED as well as the different emotions from seen in the real lights.

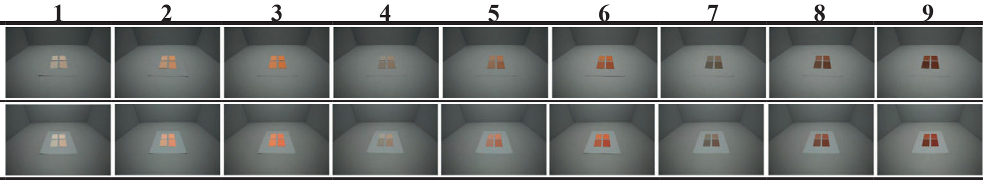
2. Purpose and Methods

Therefore, this study carried out a naked eye evaluation to investigate the visible color differences between the LED light sources as a new light source with its increasing application areas and the fluorescent lights as an example of the existing lights as following.

1) The lighting space that has light source installed were the 2 light cabinets with the size of 610×510×550mm so that the existing light (fluorescent light) and the LED light can be compared at the same time. The colors of the inner walls were fixed at an achromatic color of N7.5 to exclude the effects of the surrounding areas. 2) The existing light (fluorescent light) was installed in one light cabinet and the other one had the LED light installed. For the emotional evaluation to be carried out under the same color temperature and same intensity of illumination the color temperature was fixed at 6500k±4% and the intensity of illumination was fixed at 3000lx±5%. 3) As the subjects for the evaluation, the NCS color chips, a natural emotional system for colors in the Y40R series, that are often used in the inner and outer spaces of the architecture. The evaluation subjects were comprised of 9 types based on saturation and brightness. Each subject for the evaluation was comprised of 4 color chips with the size of 370mm*520mm each.

Table 1. Evaluation Subjects

Light	Evaluation Subject								
	1	2	3	4	5	6	7	8	9
LED									
Fluorescent									



4) The tester who sits in the middle of the 2 light cabinets compared the colors of the color chips that are seen underneath the lights on both sides and marked which light seems more yellowish, reddish or grayish on a prepared evaluation test. Also, the adjectives that describe emotions from related studies were collected and 13 adjectives that suit the purpose of this study were extracted as following.

Table 2. Evaluation adjectives

Clean	Light	Cheerful	Chic	Warm	Still	Bright
Simple	Colorful	Casual	Urbanely	Dignified	Soft	

The tester evaluated their emotions in the 7 step Semantic Differential Method regarding the color chip colors under each light according to the evaluation adjectives. 5) The selected testers were 15 graduate students who majored in lighting and colors who were deemed to have a superior color differentiation abilities and also are familiar with the lighting environment evaluation tests.

3. Results and Analysis

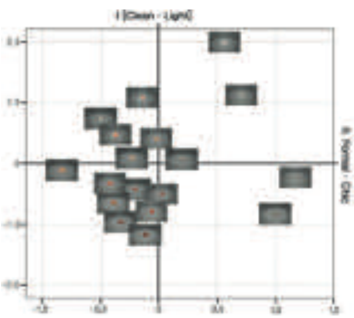
3.1 The resulting values of the testers that marked yellowish, reddish or grayish were analyzed to get the maximum value, the minimum value, the standard deviation and the means. As per the spectrum distribution, the LED lights tend to show a more yellowish color than the fluorescent lighting and the fluorescent lights showed a more reddish light. Also, the degree of the influence differed based on the brightness and the saturation. In the sensitivity evaluation, the results different more when the brightness was higher and the saturations were low.

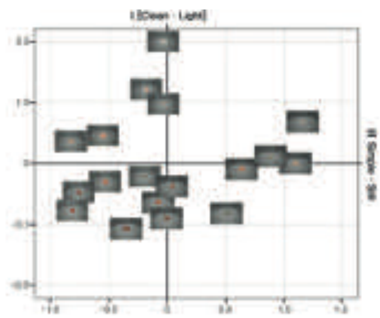
1. Evaluation result of which light shows more yellowish
   The evaluation subjects determined that under a high brightness-high saturation as well as a high saturation-low brightness, the degree of yellowish presentation was the greatest. This is understood as the yellowish tendency is most affected under high saturation-high brightness and high saturation-low brightness of LED light.
2. Evaluation result of which light shows more reddish
   The evaluation subjects determined that under a high saturation – high brightness, high saturation-medium brightness, high saturation – low brightness, medium saturation-low brightness of fluorescent lights, the reddish tendency is the greatest. This is analyzed as the reddish tendency is most influenced under a fluorescent light that has high saturation – high brightness, high saturation-medium brightness, high saturation – low brightness, medium saturation-low brightness.
3. Evaluation result of which light shows more grayish
   The evaluation results differed based on brightness, saturation level and lighting. When it was high brightness-medium saturation, the LED light showed more grayish tendencies but under a high brightness-low saturation or a low brightness-low saturation, the fluorescent lights showed more grayish tendencies. This is analyzed as the grayish tendencies are more affected under a low saturation fluorescent light.

Table 3. Results of factor analysis

Factor	Evaluation term	Factor 1	Factor 2	Factor 3	Factor analysis
I	Clean	.912	.221	.138	Clean · Light
	Light	.894	.093	.165	
	Simple	.857	.365	.145	
	Bright	.769	.215	.300	
	Cheerful	.701	-.262	-.464	
II	Casual	.102	-.866	-.033	Formal · Chic
	Chic	.179	.793	.076	
	Urbanely	.475	.734	.051	
	Warm	-.268	-.676	-.144	
III	Colorful	-.057	-.297	-.810	Simple · Still
	Still	.097	-.351	.809	
	Soft	.320	.249	.742	
Eigen value		3.903	2.952	2.263	
Contribution rate		32.526	24.598	18.857	
Cumulative rate		32.526	57.124	75.981	

3.2 The results of the testers who evaluated their sensitivity from the 7 step Semantic Differential method using the evaluation adjectives for the color chip colors under the lighting were analyzed for the factors. The data results from the sensitivity tests of the 8 subjects under each light were arranged from 1 to 18 and the PASW Statistics 17 statistical analysis package was used to analyze the factors. Initially, they were divided into 4 axes, but the adjective "dignified" did not show any specific trends by the evaluators in this study and was eliminated at the researchers' discretion.





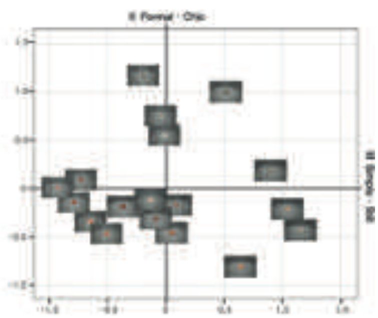


Figure1.Factor Plots(1-2axe)   Figure2.Factor Plots(1-3axe)   Figure3.Factor Plots(2-3axe)

This resulted in 3 separate axes with the confidentiality level of 75.98%. Each axis was named as the following and the factor plots were drawn up based on the 3 axes. The factor plots show how the sensitivity test results have changed for the same evaluation subject under the LED and the fluorescent lights.

1. [clean-light] axis and the [formal-chic] axis plots are shown in Figure 1. As a result, the high brightness-low saturation, high brightness-medium saturation had a large difference in the sensitivity analysis and the medium brightness-high saturation and low brightness-high saturation had a smaller difference in the sensitivity test results.
2. [clean-light] axis and [simple-still] axis plots are shown in Figure 2. As a result, the sensitivity test results were greater in high brightness and medium brightness with all of the saturation levels of the evaluation subjects and the medium brightness-high saturation and low brightness-high saturation had a smaller difference in the sensitivity test results.
3. [formal-chic] axis and [simple-sill] axis plots are shown in Figure 3. As a result, the high brightness with any level of saturation showed a greater sensitivity test differences and medium brightness-high saturation and low brightness at any level of saturation had a small difference in the sensitivity results.

Also, the color chips underneath the fluorescent light were evaluated to be closer to the [clean-light] axis and the color chips underneath the LED light were evaluated to be closer to the [simple-still] axis.

4. Conclusion

The naked eye test to determine the differences in the visible colors underneath the LED light source and the existing light source, namely the fluorescence light, showed a great difference in the visible colors depending on the brightness and the saturation of the same color. In addition, it also seems to affect the changes in sensitivity, which calls for a study on the improvement of the LED light color rendition limitations that will be used more in the future.

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Colour differences for a Farnsworth-Munsell 100-Hue test illuminated by a D65 source

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Abstract

From experimental measurements of the 85 samples in a completely new issue of the Farnsworth-Munsell 100-Hue test (D65 source, CIE 1931 colorimetric observer), the next main conclusions were achieved: 1) The 85 samples had almost constant lightness, but high chroma variations (coefficients of variation of L^*=3.2% and C_{ab}^*=23.7%). 2) On the average, contiguous samples showed CIEDE2000 lightness-, chroma- and hue-differences of 26.1%, 12.2% and 61.7%, respectively. 3) Colour differences between contiguous samples had high coefficients of variation of 33.9% and 33.5% for the CIEDE2000 and CAM02-SCD colour-difference formulas, respectively. 4) The next anomalous colour-difference pairs were detected: $\Delta E(27,29)<\Delta E(27,28)$; $\Delta E(35,33)<\Delta E(35,34)$; $\Delta E(47,49)<\Delta E(47,48)$; and $\Delta E(49,47)<\Delta E(49,48)$, where ΔE designates both the CIEDE2000 and CAM02-SCD colour-difference formulas. 5) Although the reference illuminant for this test was C, the use of illuminant D65 or an appropriate simulator can be also admitted, bearing in mind that average colour differences between contiguous samples change less than 0.1 CIELAB units. In summary, although current results must be tested from other issues of the FM-100 test, probably it will be convenient to revise the set of samples provided by the FM-100 test, looking for an improved uniformity in modern colour spaces.

1. Introduction

The Farnsworth-Munsell 100-Hue Test (hence FM 100 test) is a well-known exploratory technique for the laboratory examination of human colour vision (Farnsworth, 1943; Farnsworth, 1957). Its primary uses are, first, to separate persons with normal colour vision into classes of superior, average and low colour discrimination, and second, to measure the zones of colour confusion of colour defective persons. The test has 85 coloured samples (caps), distributed in 4 different cases, and assumes illuminant C. The main goal of this paper is to analyze the distribution of the 85 caps of this test in different color spaces, with a particular focus on the magnitude of the colour differences between caps. In addition to CIELAB, the last CIE-recommended colour-difference formula, CIEDE2000 (CIE, 2004a), and the recent CIECAM02-based colour-difference formula, CAM02-SCD (Luo, Cui, and Li, 2006), have been employed. It can be assumed that, under our experimental conditions, these formulas provide close measurements to visually-perceived colour differences. No visual experiments are reported here.

2. Methodology

Using a PhotoResearch PR-704 spectroradiometer, we performed 3 independent measurements for each one of the 85 caps of a completely new issue of the FM 100 test. Each cap was placed on the floor of a GretagMacbeth Spectralight III colour cabinet, with its corresponding D65 source, and the optical axis of the spectroradiometer was tilted 30º with respect to the normal to the cap. The CIE 1931 colorimetric observer was employed, because each cap subtended about 1.5º at a viewing distance of 50 cm. For each cap (*n*) we employed the average of its 3 spectroradiometric measurements, and computed its colour differences (Δ*E*) with respect to its nearest neighbors on the left (*n*-1) and right (*n*+1) hands; and also the next to the nearest neighbors on the left (*n*-2) and right (*n*+2) hands, if both samples in these colour pairs were placed in the same case. Case #1 has the caps numbered as 85, 1,…,21; case #2 from 22 to 42; case #3 from 43 to 63; and case #4 from 64 to 84. The illuminance at the floor of the cabinet was 1420 lx, and an average surround was assumed, in such a way that the next values of CIECAM02 (CIE, 2004b) parameters were employed: F=1.0, c=0.69, N_c=1.0, Y_b=20, L_A=90.3.

3. Results

Ideally, the 85 caps of the FM 100 test should have constant lightness and chroma values, but this is not exactly the case, as shown in Figure 1. We can see (Fig. 1, left) that lightness variations follow a very similar trend in CIELAB and CIECAM02, being considerably small: coefficients of variation of 3.2% in CIELAB, and 2.9% in CIECAM02. However chroma differences (Fig. 1, right) are considerably bigger: specifically, we obtained coefficients of variation of 23.7% in CIELAB, 13.5% for both CIECAM02 Colorfulness and Chroma, and 6.9% in CIECAM02 Saturation. It can be said that FM-100 caps are not placed in a circle in the chromaticity plane neither in CIELAB or CIECAM02.

Also ideally, the colour pairs in the FM-100 test should have only hue-differences, but, once again, this is not the case for many colour pairs, as shown for the CIEDE2000 formula in Figure 2. Specifically, on the average, for the 84 colour pairs, CIEDE2000 lightness-, chroma-, and hue-differences were 26.1%, 12.2% and 61.7%, respectively.

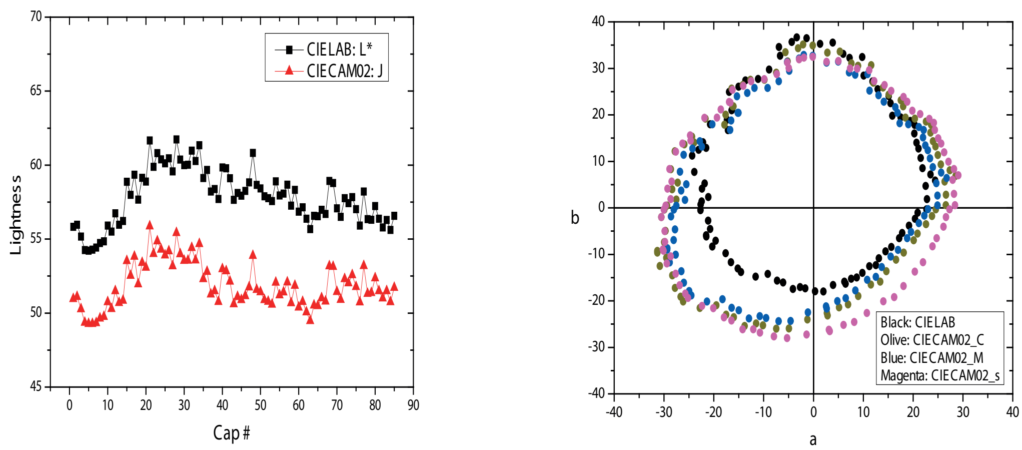

Figure 1. Lightness (left) and chroma (right) variations for the 85 caps of our FM 100 test in CIELAB and CIECAM02. CIECAM02 Colorfulness M, Chroma C, and Saturation s are distinguished in the right Figure.

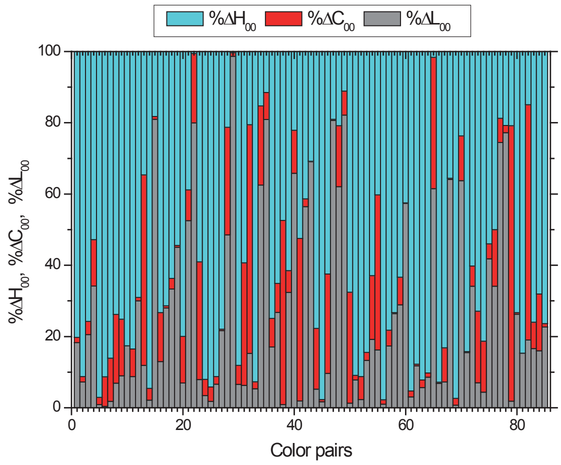

Figure 2. Percentage of CIEDE2000 lightness-, chroma-, and hue-differences for the 84 colour pairs (contiguous samples) in our FM 100 test.

For each cap (*n*) we computed its colour differences (Δ*E*) with respect to its nearest neighbors on the left (*n*-1) and right (*n*+1) hands; and the next to the nearest neighbors on the left (*n*-2) and right (*n*+2) hands, when both samples in these colour pairs were placed in the same case (Table 1). If the caps of the FM 100 test were regularly spaced in colour space, we'd obtain for all possible *n*, Δ*E(n,n-1) or* Δ*E(n,n+1)* (as well as Δ*E(n,n-2) or* Δ*E(n,n+2)*) equal to constants. However, on the average of all cases we found high coefficients of variation of 33.9% and 33.5% for nearest neighbors, and 24.3% and 24.2% for next to nearest neighbors, using the CIEDE2000 and CAM02-SCD colour-difference formulas, respectively. In addition, on the average, the ratios *[ΔE(n,n+2)/ΔE(n,n+1)]* or *[ΔE(n,n-2)/ΔE(n,n-1)]* were always lower than 2 for both formulas, which indicates a lack of linearity when the size of the step between the caps changed from 1 to 2. Similarly, Table 2 shows a lack of symmetry of the colour differences when we consider the left and right caps with respect to a given cap, both for nearest neighbors and next to nearest neighbors caps. For example, the average size of this asymmetry was 0.7 CIEDE2000 units with coefficient of variations (C.V. %) greater than 68% for nearest neighbors.

Table 1. Averages and coefficients of variations (C.V.%) for CIEDE2000 and CAM02-SCD colour differences between nearest neighbors and next to nearest neighbors caps in our FM 100 test.

	CIEDE2000				CAM02-SCD			
Pairs	ΔE(n,n+1) or ΔE(n,n-1)		ΔE(n,n+2) or ΔE(n,n-2)		ΔE(n,n+1) or ΔE(n,n-1)		ΔE(n,n+2) or ΔE(n,n-2)	
	Average	C.V. %	Average	C.V. %	Average	C.V. %	Average	C.V. %
Case #1	1.8	34.2	3.2	17.1	1.5	35.4	2.7	18.5
Case #2	1.8	36.5	2.9	29.3	1.8	35.5	3.0	26.7
Case #3	1.8	32.8	3.2	26.8	1.7	30.8	2.9	23.4
Case #4	1.6	32.2	2.8	19.4	1.7	32.8	3.2	25.0
All	1.8	33.9	3.0	24.3	1.7	33.5	2.9	24.2

Table 2. Symmetry of the CIEDE2000 and CAM02-SCD colour differences considering both nearest neighbors and next to nearest neighbors caps in our FM 100 test.

	CIEDE2000				CAM02-SCD			
Pairs	|ΔE(n,n+1)-ΔE(n,n-1)|		|ΔE(n,n+2)-ΔE(n,n-2)|		|ΔE(n,n+1)-ΔE(n,n-1)|		|ΔE(n,n+2)-ΔE(n,n-2)|	
	Average	C.V. %	Average	C.V. %	Average	C.V. %	Average	C.V. %
Case #1	0.7	82.7	0.4	79.1	0.6	71.0	0.3	103.8
Case #2	0.8	53.3	1.0	60.1	0.8	55.9	1.1	62.8
Case #3	0.6	88.7	0.9	77.7	0.5	85.0	0.8	81.5
Case #4	0.6	51.4	0.6	85.3	0.6	64.3	0.7	77.2
All	0.7	68.9	0.7	80.5	0.6	68.3	0.7	85.5

Because the right order of the caps is the key question in the FM 100 test, it should be unacceptable to obtain for a given *n* that $\Delta E(n,n+2)<\Delta E(n,n+1)$ or $\Delta E(n,n-2)<\Delta E(n,n-1)$. However, we were surprised by the next anomalous results: $\Delta E(27,29)<\Delta E(27,28)$; $\Delta E(35,33)<\Delta E(35,34)$; $\Delta E(47,49)<\Delta E(47,48)$; $\Delta E(49,47)<\Delta E(49,48)$, where ΔE designates both the CIEDE2000 and CAM02-SCD colour-difference formulas, and $\Delta E_{00}(76,78)<\Delta E_{00}(76,77)$.

Finally, we have checked that colour differences between contiguous caps in our FM 100 test are very similar under illuminants C (the reference for this test) and D65. In fact the maximum change between these two illuminants was 0.3 CIELAB units, with an average value of only 0.05 CIELAB units. Also, comparing illuminant D65 with the D65 source provided by the GretagMacbeth Spectralight III colour cabinet, we found that the average change of colour differences between contiguous caps was 0.06 CIELAB units, although this value was doubled using other D65 sources, like the one provided by the VeriVide 132 colour cabinet.

Conclusion

From current results it could be concluded that the measured samples (caps) of our FM 1000 test are not regularly distributed in colour space (García-Romera et al., 2011). Current results are being tested using two other issues of the FM 100 test, as well as another spectroradiometer and colour cabinet. Probably it will be convenient to revise the colours of the caps provided by the FM-100 test, looking for an improved uniformity in modern colour spaces

Acknowledgments

Research Project FIS2010-19839, Ministerio de Educación y Ciencia (Spain), with European Regional Development Fund (ERDF) support.

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The impact of luminance level on the assessments of colour appearance and difference

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Abstract

Luminance is one important viewing parameter affecting colour appearance of objects. The objectives of this project were to model the visual effect of luminance, to evaluate the measured and perceived colour difference and to investigate the performance of various colour difference formulae and colour appearance models under different luminance levels. Twenty observers participated in a unique experimental setup including two viewing cabinets and a combined psychophysical method using short-term memory matching and grey scale methods for the investigation. Five luminance levels were examined; forty textile pairs having mainly hue differences were measured and various statistical methods were employed for data analysis. The performance of CIELAB and CIEDE2000 colour difference formulae along with CIECAM02 and CAM02-UCS colour appearance models were investigated under the different luminance levels studied.

1. Introduction

Most colour difference formulae except colour appearance models, can only be applied according to the reference viewing condition defined by the CIE (CIE, 2004a), i.e. high luminance level, D65 illuminant, grey background, no separation between two samples, etc. However, in real life varying luminance levels are applied in different circumstances. For instance, when a piece of art is exhibited, luminance can be varied to achieve a desired effect. In industrial applications luminance level is strictly controlled since it influences colour appearance of an object and/or colour difference of a pair of specimens. Colour appearance models include parametric factors and various aspects so as to predict different colour phenomena (CIE, 2004b). For the development of a complete and accurate colour appearance model, luminance effect needs to be accurately modelled. Previous research in this area has investigated three luminance levels with different psychophysical experiments (Guan, 1999).

2. Experimental setup

A unique experimental setup and a combined psychophysical method were applied for the investigation. Two almost identical viewing cabinets with the same D65 simulator lamps were used. These viewing cabinets were placed side by side, separated by a thick black cardboard to prevent observers to view both cabinets simultaneously. One cabinet was used as the *testing field* where the five luminance levels were adjusted to 1257.5, 444.8, 33.4, 3.3 and 0.8 cd/m^2. This covers a range from mesopic to photopic vision. The other one was the *reference field* with fixed luminance of 146.6 cd/m^2. Optical density filters were used to achieve stable luminance. The values were defined by plotting the logarithmic value of luminance against each level as illustrated in Figure 1.

In the testing field, the 40 coloured textile pairs were presented one by one in a random

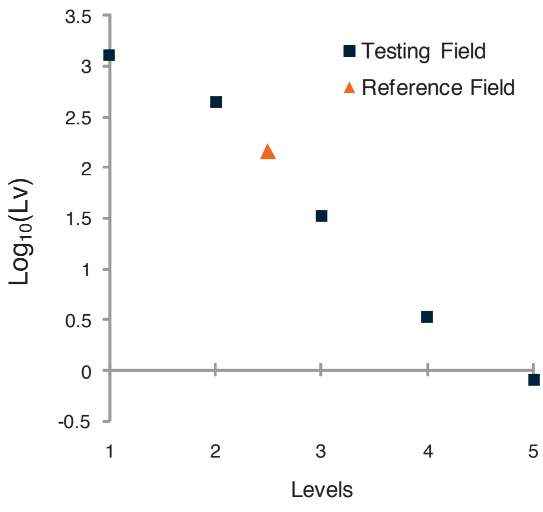

Figure 1. Logarithmic plot of luminance

order while in the reference field a textile grey scale was. Visual assessments with a grey scale have been employed in various studies in different ways (Cui, 2001). The coloured samples were chosen so as to have pairs of clear colour difference in the testing field. It was decided to select mainly pairs of hue difference, i.e. little difference in lightness and chroma. The selection of the coloured pairs was based on specific colorimetric criteria: colour difference $\Delta E_{ab}*$ between 5-10 units and absolute value of $\Delta H_{ab}*/\Delta E_{ab}*$ greater than 0.8 - i.e. 80%. Eventually, the mean $\Delta E_{ab}*$ was 7.8 units with samples ranging from 5 to 10 units. The grey scale samples had been prepared according to the specifications of ISO 105-A02:1993 standard method and were graded from 1 to 5 plus the reference sample.

Two instruments were used for the colour measurements: GretagMacbeth CE7000A spectrophotometer and Konica Minolta CS1000S tele-spectroradiometer. The former was used for the spectral reflectance of samples under SPIN, UV included and large aperture size. The latter was used for the luminance of samples in situ under all five luminance levels at 0°: 45° geometry. The instruments' results agreed reasonably with each other.

Prior to the psychophysical experiments, the 20 observers who participated were examined for having normal colour vision by conducting Ishihara test. Moreover, each observer received a training session for using the grey scale method with short-term memory matching. The average age of observers was 31 years old.

To begin with, the experiments were carried out in dark room, so observers had to adapt in the new viewing conditions. The viewing geometry was 0°: 45° and observers were instructed not to look at both viewing cabinets simultaneously. Each observer was asked to memorise the colour difference of the coloured pair presented in the testing field. Then, they had to move their chairs into the reference field and to rank the memorised colour difference by using the grey scale. They had to make a grey pair by using both the reference and one graded sample so as to represent that colour difference. Then, they reported the chosen grade. They were also advised that if a coloured pair's difference was between two adjacent grey samples, then they should report by estimation a decimal value between the two samples.

3. Data analysis

The data were processed with various statistical methods such as the relative colour difference (expressing the variation of $\Delta E_{ab}*$ between pairs) and the absolute colour difference with MCDM (expressing the precision of colour difference of each sample) (Nadal, 2010). The stability of the reflective properties of samples was tested by measuring them at different times during the entire experimental period and calculating their relative colour difference. Equally, the accuracy of lamps' luminance was assured by taking measurements of standard white tile over time periods and examining them with MCDM. The above gave small colour differences, which indicates stability and repeatability of used means. Moreover, the recently developed statistical method called STRESS was used in order to check agreement between different data sets in percentage estimation of error (Garcia, 2007). Mean inter-variation and mean intra-variation of observers were 28% and 30% respectively which indicates that the group of observers had good performance.

Firstly though, the raw grey scale responses were converted into visual difference values ΔV by using 2^{nd} order polynomial model for the ΔE_{ab}* of the gray-scale's 5 possible pairs. The resulted equation was $\Delta V = 0.8179*G^2 - 9.7556*G + 28.761$, where G is the raw gray scale responses. Moreover, from the spectral reflectance measurements, mean L^*, a^*, b^*, h_{ab} & C_{ab}^* values were calculated by employing weighting functions for CIE D65 and 10^o observer. Furthermore, the luminance measurements were transformed into tristimulus values XYZ by combining the chromaticity co-ordinates *xy* with instruments' data for standard white tile, and subsequently into mean L^*, a^*, b^*, h_{ab} & C_{ab}^* values.

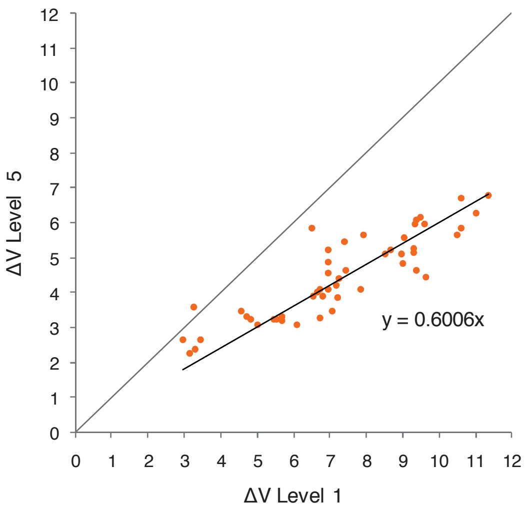

Figure 2. Visual effect of the brightest level 1 against the darkest level 5

The visual results were used to reveal the effect of luminance and to model it. This was achieved by plotting the brightest level's ΔV values against each other level's; as seen in Figure 2. These plots confirmed a reduction of perceived colour difference by 3%, 21%, 31% and 40% from the brightest level – i.e. 1257.5 cd/m^2 to the darker levels – i.e. 444.8, 33.4, 3.3 and 0.8 cd/m^2 respectively. The visual effect was modelled by using regression analysis for the aforementioned plots' coefficients SF against the logarithmic values of luminance $Log_{10}(Lv)$. This resulted in a linear relationship controlled by the equation $SF = 0.1274*Log_{10}(Lv) + 0.6239$.

This visual effect was also modelled in CIELAB and CIEDE2000 colour difference formulae. It was found that the ratio of magnitude was the same for both formulae even though their accuracy differed. These findings were processed by plotting the visual colour difference against the calculated colour difference of each formula as demonstrated in Figure 3.

The visual differences ΔV were also used to evaluate the performance of different colour difference equations including both CIELAB and CIEDE2000 colour difference formulae and CIECAM02 colour appearance model plus its extension colour space, CAM02-UCS (Luo, 2006). STRESS showed that CIEDE2000 performed the best, but the other formulae and spaces gave similar performances when individual scaling factor *F* (from STRESS equation) was applied to each space or formula. However, when applying only one scaling factor *F* to the visual results from all luminance levels, CAM02-UCS and CIECAM02 performed distinctly much better among all the colour difference formulae studied. The reason is that the other formulae and spaces required different scaling factors for each luminance level in order to give results that included the impact of luminance. The above imply that CIECAM02 and CAM02-UCS as colour appearance models can predict the luminance effect well.

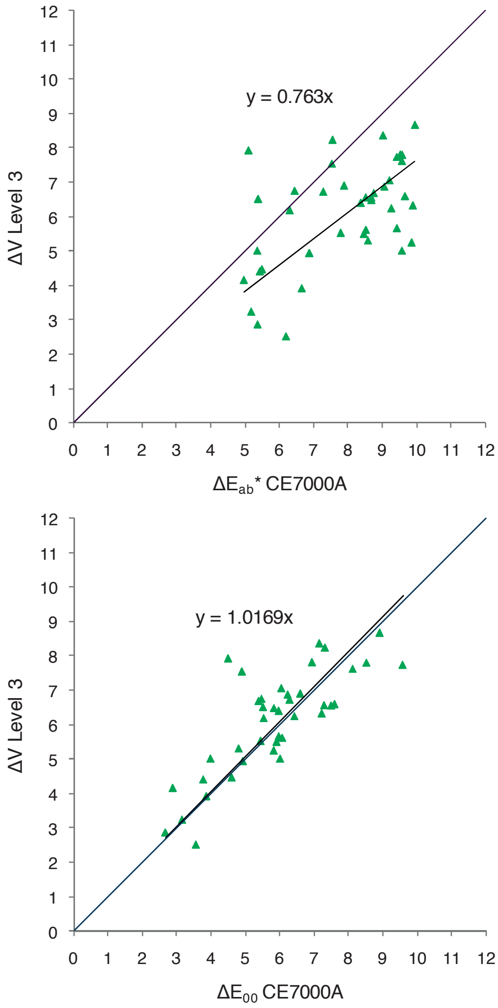

Figure 3. Visual V against measured ΔE differences for Level 3(33.4 cd/m2)

4. Conclusions

It was found that modelling luminance in CIELAB and CIEDE2000 gives a linear relationship which can be used to predict corrected colour difference under different luminance levels. This means that both formulae could be extended in order to embed luminance coefficients. On the contrary, CAM02-USC agreed well with human vision responses and performed better under different luminance levels.

Acknowledgments

Ms. Maria Georgoula would like to acknowledge the State Scholarships Foundation of Greece for the financial support and the academic staff of Colour Science Department at University of Leeds for their guidance and support.

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Classifying papers according to their light scatter properties

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Abstract

Light scatter in paper plays an important role for predicting the color of printed halftones. In this work we measured and evaluated *edge spread functions* for a set of 12 papers. We found, that the light scatter properties of the papers can be classified to only a small number of *light scatter classes*. The light scatter class could be useful information for fitting existing printer models to a printer setup or developing new printer models.

1. Introduction

Light scatter in paper plays an important role for color prediction of printed halftones. Scattered light within the paper bulk causes the so-called *optical dot gain* (ODG) or Yule-Nielsen-effect. It is consensus within the scientific community that modeling ODG is a key element of an accurate printer model and, therefore, a prerequisite for accurate color printing. The detailed knowledge of light scatter within paper can improve the accuracy of printer models and reduce the number of training colors to fit the model to the printer.

In a previous work, we proposed an apparatus and method for measuring local anisotropic light scatter within graphic art papers for predicting ODG, see Happel et al. (2010). The setup is an enhancement of existing approaches which allows for a more robust determination of the light's *point spread function* (PSF).

In this work we investigated *edge spread functions* (ESF) for a set of 12 papers that were detected with a slightly changed measurement setup; PSFs were not calculated. From the results we conclude that a general classification of papers into *light scatter classes* (LSC) is feasible. We believe that this can be useful information for fitting existing printer models to a printer setup or developing new printer models, see Arney et al. (1996).

2. Measurements

The measurement setup consists of a microscope where we placed a razor blade into the light path (see Figure 1a). This allows us to project an edge-shaped illumination onto the sample. A lens system can be utilized for focusing the projection of the razor blade on the sample surface. Furthermore, we enhanced the sample focus by introducing a sample holder, where the sample surface and a reference, in this case a first surface (FS) mirror, are aligned in one plane that is parallel to the microscope stage. This allows us to adjust the focus using the FS mirror and then slide the sample holder to the sample without leaving the focus. A second advantage is that we can use the edge projected onto the reference as the edge that is "best to achieve" considering the optical transfer function of the setup. All measurements are performed relative to this reference edge. The sample holder allows a rotation of the sample to analyze anisotropic scattering.

Images are captured with a camera for each sample and the reference. The edge of the razor blade is aligned to the pixel columns of the camera. This allows us to average over the pixel rows

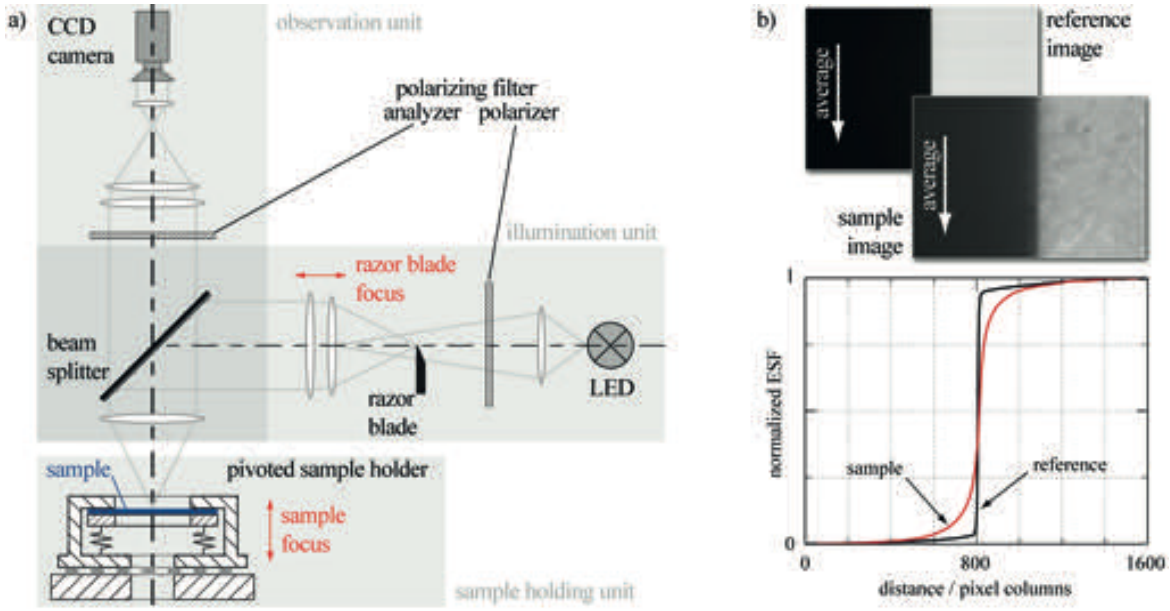

Figure 1. a) Measurement setup; b) Averaging the captured images of reference and sample to ESFs.

to reduce the noise of our measurements, receiving ESFs for all samples and the reference (see Figure 1b).

With a special computation algorithm presented by Happel et al. (2010), we can extract the PSF out of the captured ESFs assuming isotropic light scatter. We found that scatter in paper is almost isotropic. This is also valid for the papers examined here.

In contrast to previous measurements with a halogen lamp, we changed the illumination to a green narrow band LED. This reduces the adverse effect of chromatic aberration on focusing. We chose an LED with a maximum emission at 530 nm. That takes into account that the luminous efficiency function $V(\lambda)$ has its maximum at 555 nm. We changed the previous 8 bit RGB CMOS camera to monochrome CCD with 12 bit depth. In addition, two polarizing filters, located in illumination and observation path respectively, prevent capturing surface reflections. The changes to the previous setting in brief:

1. Green LED - narrow band illumination,
2. Monochrome CCD camera for detection, and
3. Polarizing filters for omitting surface reflections.

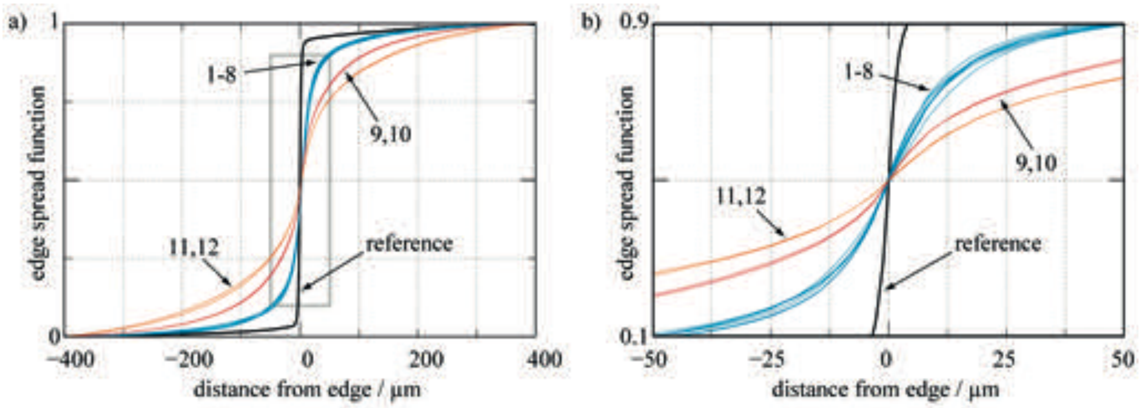

Figure 2. ESFs (a) and their magnification (b) of reference (black) and different samples: inkjet photo papers swellable (red) and microporous (orange), fine art papers (blue); Numbers indicating the paper sample according to Table 1.

For one sample, we capture the edge projection in six angles with 30° distance, covering a total angle of 180°. At each angle, we take five captures. One paper sample is always represented by three specimens. All images are averaged to one single measurement. This reduces disturbing effects of noise caused by illumination changes or thermal effects and of inhomogeneities of the paper, either angular or lateral.

We performed a series of measurements on 12 papers (see Table 1) including four inkjet photo papers (swellable and microporous, matte and glossy coated) and eight fine art papers of two paper series (matte and glossy coated, different paper weights).

3. Results

The different ESFs, obtained by the measurements, can be found in Figure 2a. The ESFs are normalized to an interval of 0-1. Also, for better comparability, the location, where the ESF takes the value 0.5 is set to x=0, indicating the distance from edge.

From the measurement results, we can clearly distinguish three different paper classes. The differently coated fine art papers (blue) are the closest to the reference edge (black). Within this class, there is only little divergence of the ESFs. A noticeably bigger deviation from the reference ESF can be found for the *inkjet papers*. Obviously, the coating of these papers has much larger scatter properties than typical paper ingredients. In addition, the swellable and microporous papers can be distinguished easily. The dependence of the surface gloss on the ESF is negligible.

In Figure 2b, a magnification of the *fine art samples* shows, that the differences in this group are small. There are no significant dependencies between paper weight and scatter properties among the samples of the two fine art paper series. The differences among the measured ESFs might also result from measurement noise or paper inhomogeneities.

Table 1. Papers of the research.

No.	Producer	Series	Coating	Paper weight (g/m²)	LSC
1	Scheufelen	Consort Royal	glossy	115	1
2	Scheufelen	Consort Royal	glossy	250	1
3	Scheufelen	Consort Royal	matte	115	1
4	Scheufelen	Consort Royal	matte	250	1
5	Scheufelen	BVS	glossy	100	1
6	Scheufelen	BVS	glossy	250	1
7	Scheufelen	BVS	matte	100	1
8	Scheufelen	BVS	matte	250	1
9	Felix Schöller	PE-Photopaper (swellable)	glossy	230	2
10	Felix Schöller	PE-Photopaper (swellable)	matte	230	2
11	Felix Schöller	PE-Photopaper (microporous)	glossy	240	3
12	Felix Schöller	PE-Photopaper (microporous)	matte	240	3

3.1 Light Scatter Classes

The papers investigated can be categorized into three *light scatter classes* (LSC): 1. Little Scatter (fine art papers), 2. Medium Scatter (inkjet swellable), and 3. Large Scatter (inkjet microporous). It seems to be reasonable that a general classification of papers due to their scatter properties is possible. Such an LSC could be included into the papers' data sheets. The ODG property of a paper could directly be deduced from its LSC. This could simplify modeling printing systems or fitting printer models to a given printer setup. LSCs can be incorporated especially into first principle models as presented in Wyble and Berns (2000).

For instance, Arney et al. (1996) proposed to replace the Yule-Nielsen n-factor by two variables, one of them (*w*) is referring to light scatter in paper. He found an analytical representation of this variable *w*:

$$w = 1 - \exp(-A\, k_p f)$$

where A characterizes the halftone geometry, f is the halftone dot frequency, and k_p is a constant that is proportional to the mean distance of light scatter. This parameter k_p could directly be deduced from the LSC.

4. Outlook

In future research, additional papers will be measured, including other inkjet and fine art papers, but also uncoated papers and special papers. A database of papers and their scatter properties shall be created. With these results the definition of scatter classes could be enhanced. Additionally, we study how to enhance existing printer models with the results from our measurements, e.g. how to relate the Yule-Nielsen n-factor to the light scatter properties or the LCS of the paper.

Acknowledgments

The authors thank Manfred Jakobi and Karsten Rettig for their electrical and mechanical constructions on the measurement setup.

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Interference colors on titanium: From science to art

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Abstract

The study of interference colors that may appear at the surface of a metallic material goes back to the early XIX century. From that time on other studies followed, focusing in particular on titanium. Among them the work of Pietro Pedeferri gave rise to the development of a robust technique that permits to obtain beautiful colors on the surface of titanium, while maintaining an engineering control of this technique.

The method proposed and patented by Pietro Pedeferri is a powerful technique that permits the obtaining of a wide range of beautiful colours. Furthermore Pietro Pedeferri used this electrochemical method as a painting technique exploiting a peculiarity of the oxides growth.

The "memory of titanium", permits the obtaining on the surfaces of pattern and images called "appearences" in honor of Nobili, the inventor of metallocromic art. These appearances show invisible aspects of phenomena that took place, or that are taking place, on the surface of titanium. Pietro Pedeferri called the former field appearances and the latter movement appearances.

Field and movement appearances are different, and therefore transmit different sensations. There is one thing they do equally as well, that is, to show the invisible side of nature.

1. Introduction

In memory of Pietro Pedeferri (1938-2008)

The study of interference colors that may appear at the surface of a metallic material goes back to the early XIX century. At that time Leopoldo Nobili, an Italian scientist, first studied and obtained with an electrochemical technique colors on the surface of a lead plate in the presence of an acid solution.

From that time on other studies followed, focusing on other metals and in particular on titanium. Among them the work of Pietro Pedeferri gave rise to the development of a robust technique that permits to obtain beautiful colors on the surface of titanium, while maintaining an engineering control of this powerful painting technique.

The formation of a transparent oxide film on titanium, with thickness ranging from a few nanometres to a few hundreds nanometres, generates the appearance of chromatic effects arising from the interference of light radiation illuminating the oxide: when irradiated with white light, only a part of the incident photons are reflected by the oxide surface, while the remaining part enters the oxide and is reflected by the metal surface (Fig.1). Interference phenomena taking place between the two exiting light waves result in the appearance of colours on the surface, whose hues are determined by the light components that happen to exit the oxide in phase (constructive interference).

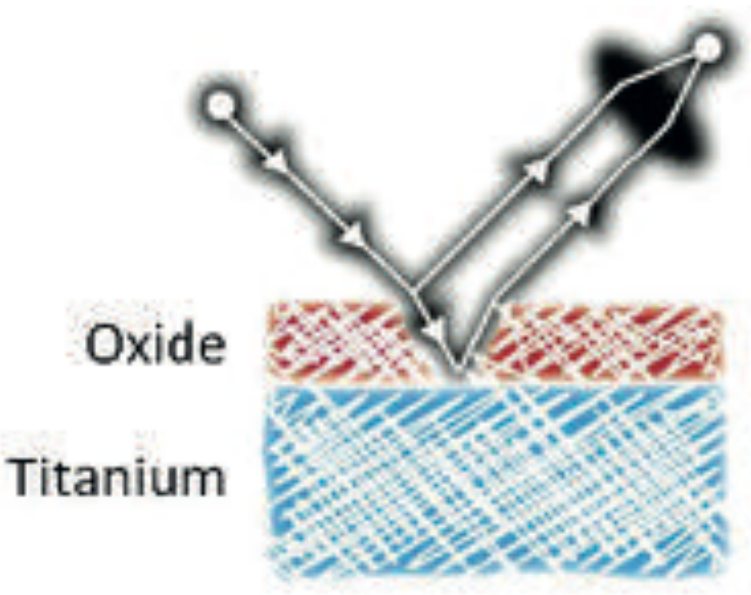

Figure 1 – Interference phenomenon that give rise to color at the titanium surface

The in-phase wavelengths depend, in turn, on the optic path, that is, on the oxide thickness: therefore oxides with different thicknesses generate different colours (Fig.2). This course of action can be exploited to obtain a desired colour on the anodised surfaces by accurately controlling the oxide thickness.

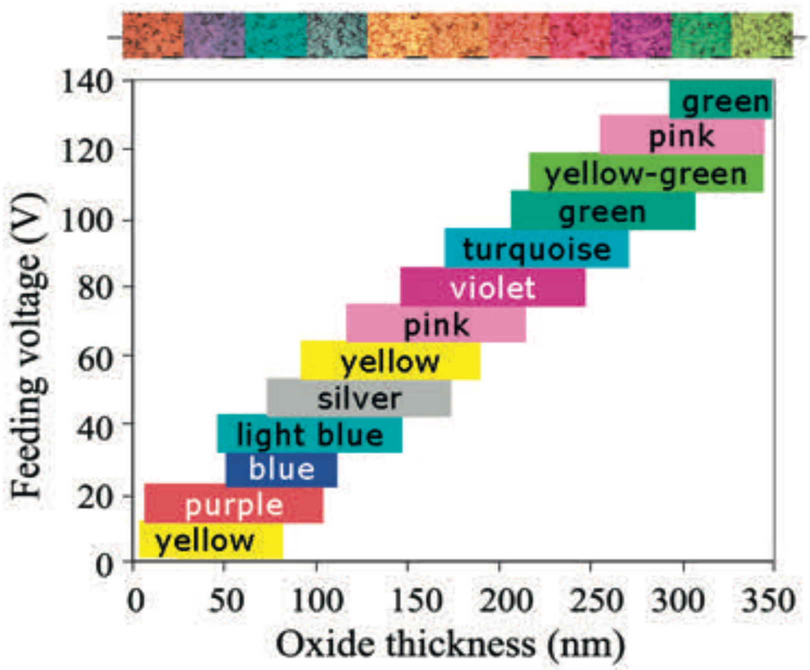

Figure 2 – Chromatic scale of interference colors obtainable by increasing feeding voltage during titanium anodizing

The oxide thickening can be achieved by means of anodising as reported by Diamanti, Del Curto and Pedeferri (2007). Both hue and saturation strictly depend on anodising steps and parameters, and in particular on cell potential. Hence, a deep understanding of anodic oxidation is essential to assure an optimal control of morphology, structure and homogeneity of the nanostructured layer, which determine its properties, from the aesthetic qualities to the resistance to either atmospheric or indoor exposure.

2. The memory of titanium

Changing the surface appearance of titanium is not an issue, but a robust and precise control of the anodic or thermal oxidation is mandatory when brilliant and saturated colours are requested. The method proposed and patented by Pietro Pedeferri in 2000 is a powerful technique that permits the obtaining of a wide range of beautiful colours, Pedeferri.

Furthermore Pietro Pedeferri used this electrochemical method as a painting technique exploiting a peculiarity of the oxides growth. In fact, although the final colour depends on the cell potential imposed in the initial stage, colours that appear at the metallic surface are also strongly influenced by the very first conditions of the electrochemical process (i.e. the first milliseconds). After the first moment it is possible to change hue but only within a peculiar set of colours.

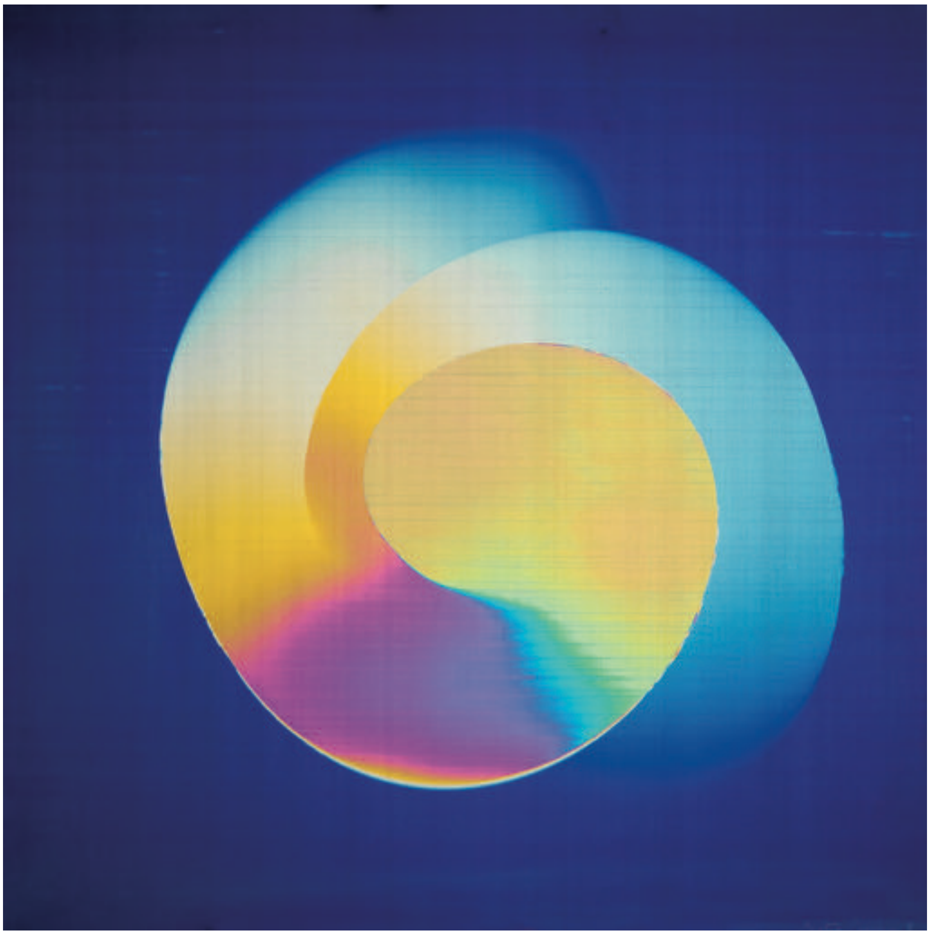

Figure 3 Field appearance on titanium (Pietro Pedeferri)

This behaviour, called "memory of titanium", permits the obtaining on the surfaces of pattern and images called "appearences" in honour of Leopoldo Nobili, the inventor of metallocromic art. These appearances show invisible aspects of phenomena that took place, or that are taking place, on the surface of titanium. Pietro Pedeferri called the former field appearances and the latter movement appearances (Pedeferri 1982 and 1984).

The appearances of the first type are obtained when titanium is oxidized in the presence of a non uniform current distribution. They provide a map of the thickness of the oxide and of charge exchanged. In some circumstances and with some approximation they give information on the current distribution on the surface of titanium and the electric field in its immediate surroundings: in such cases, colours generated by the electrical field represent the “colour solution” of Laplace’s equation (Fig.3). These appearances reveal then the “landscape” of nanostructured oxides and the different colors, like contours, give “the terrain”. It is possible to vary forms and hues by changing the distribution of current, operating conditions or boundary conditions, but this always leads to a “landscape” that describes the infinitely small and complex world where nanotechnologies operate, transmitting astral visions and “feelings of lightness, suspension, calm spell” as Italo Calvino would say.

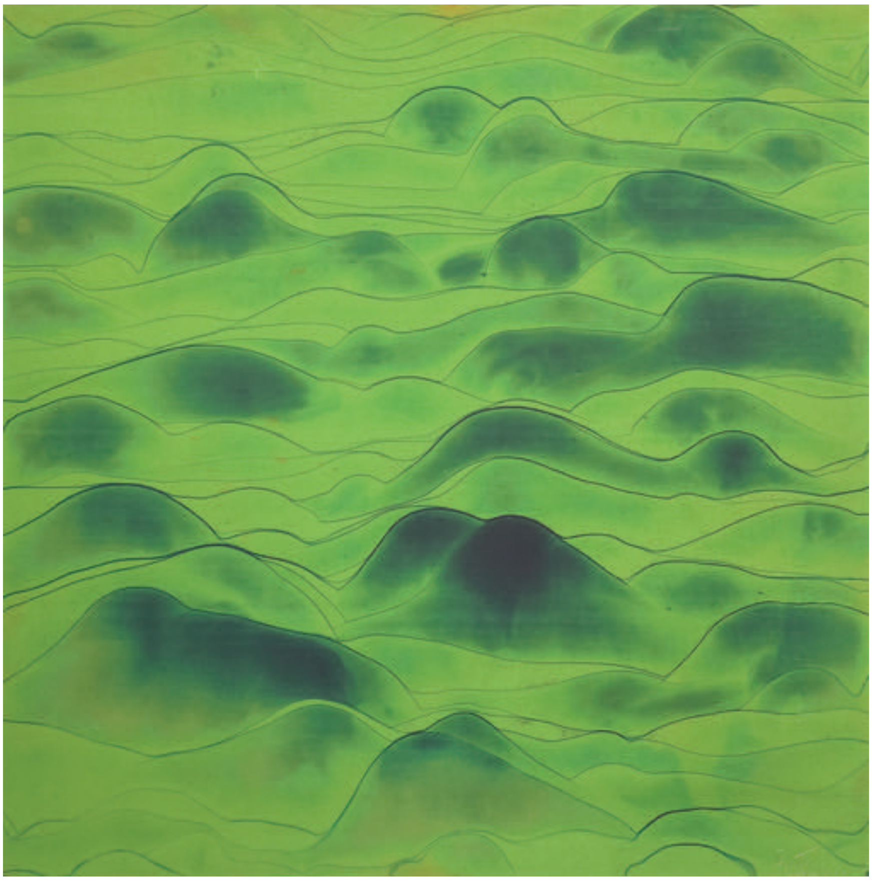

Figure 4 Movement appearance on titanium (Pietro Pedeferri)

The movement appearances (Fig.4) are obtained by changing the electrochemical potential across a critical value of a titanium sheet in contact with a solution. Whenever the potential varies on the surface of titanium the position of the liquid is etched. These appearances are then chronophotographs: the phenomenon revealed is the movement of the liquid and the frequency of shots is that of the oscillations of the potential. Similar appearances can describe chemical physical processes. For example, by soaking in a liquid a titanium plate previously wetted with a non-conductive fluid it is possible determine the subsequent positions of the front of the solution moving on the surface and mixing or reacting with the liquid that covers it.

The movement appearances depend on how processes are produced on the surfaces, hence there are many ways to vary them. For example, it is possible to bend, or drill the titanium plates,

oral paper

give them specific forms, place obstacles in their area; furthermore it is possible to change the nature and composition of the solution or even create waves, or vortices.

Field and movement appearances are different, and therefore transmit different sensations. There is one thing they do equally as well, that is, to show the invisible side of nature.

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Measuring dynamic lighting atmospheres

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Abstract

Solid state light sources have revolutionized lighting. Apart from optimizing traditional uses of lighting, completely new applications are emerging, among which the creation of fully dynamic atmospheres. To be able to provide optimal atmospheres, the connection between lighting parameters and the perceived atmosphere is needed. Even though there have been a number of studies focusing on the influence of static lighting parameters, no such studies explore dynamic light. The aim of the study presented in this work is to understand the influence of dynamic light on atmosphere perception. To explore this influence, a user study was conducted investigating the influence of *speed*, *direction of change*, *amplitude of change*, *type of change* and *spatial distribution* on the perceived atmosphere, perceived naturalness and general attractiveness. Results show that nearly all the factors have a significant effect on the perceived atmosphere and the overall attractiveness of the room. These results can be used to create personalized dynamic atmospheres and design intuitive and effective lighting controls.

1. Introduction

Solid state lights have in recent years revolutionized lighting. Their projected efficacy and cost, as well as the use of more environmentally friendly raw materials compared to traditional light sources and the main competitors, promote LEDs into a leading candidate for the light source of the future.

The revolution, however, is brought by the unique capabilities of LEDs that not only optimize traditional use of lighting, but enable completely new applications (Evans 1997). While traditional lighting systems can only change the intensity of the produced illumination (for most of them only at two levels – on and off), solid state lighting systems can enable full control over both the intensity and the chromaticity. Furthermore, the time interval at which these changes can be controlled is very short and the small form factor results in effects with much larger spatial frequency. This enables the creation of fully dynamic atmospheres, leveraging lighting to a status of a new communication and artistic medium.

Most natural light is dynamic. From the very slow change of intensity and color temperature over a day due to the movement of the sun, to the fast flickery changes of fire or lightning. Furthermore, these changes happen without human interaction. Contrary to this, changes in traditional lighting systems are interaction driven. A Dutch study (Tijdschrift van marketing 2007) showed that people that were familiar with the Philips Living Colors, an LED based decorative lamp, liked the dynamic demo mode of the device and considered the addition of controlled dynamic light effects a valuable feature.

The introduction of new capabilities also introduces new challenges. The freedom gained using solid state lighting systems increases the number of control dimensions that determine the produced effect. For a large number of light sources, the task of controlling the system becomes dauntingly complex even for professionals.

The perception of the atmosphere created by the lighting, however, is not uniquely determined by the individual lights and their settings. A large number of light effects in a certain space can result in the same perception of the space. A model that can predict that perception of a space can be instrumental both in the measurement of the perceived influence the illumination has on the environment and the creation of a desired effect.

Vogels, de Vries and van Erp (2008) have recently introduced a model that promises to fit the requirements given above. This, so called "atmosphere perception model", captures the essence of the perceptual evaluation of a space using four dimensions: *coziness*; *liveliness*; *tenseness*; and *detachment*. Furthermore, Vogels et al. (2008, 2009) map basic physical properties of the lighting scene (brightness, uniformity, color temperature, hues) to their influence on the atmosphere dimensions. An important distinction in the model is that it measures the affective evaluation of the space and not the affective state of the person doing the evaluation. This, however, does not rule out the potential subsequent influence of the environment on the mood of the person.

Previous atmosphere perception studies have been carried out using static atmospheres (Seuntiens and Vogels 2008, 2009). The aim of the study presented in this work is to understand the influence of dynamic light on atmosphere perception. To explore this influence, a user study was designed and carried out. As a first step, the influence of five factors (*speed*, *direction of change*, *amplitude of change*, *type of change* and *spatial distribution*) on the perceived atmosphere was studied.

2. Experiment

The experiment was carried out in a mock-up of a living room. The lighting in the room consisted of a functional part (ceiling recessed halogen lights) and a decorative lighting part (4 LED wallwashers and 3 LED spot lights). The dynamic scene was generated using only using the decorative lighting, while the functional lighting was set to a standard Dutch living room level for the duration of the experiment. Figure 1 gives an impression of the experimental room and the spatial arrangement of the decorative lights.

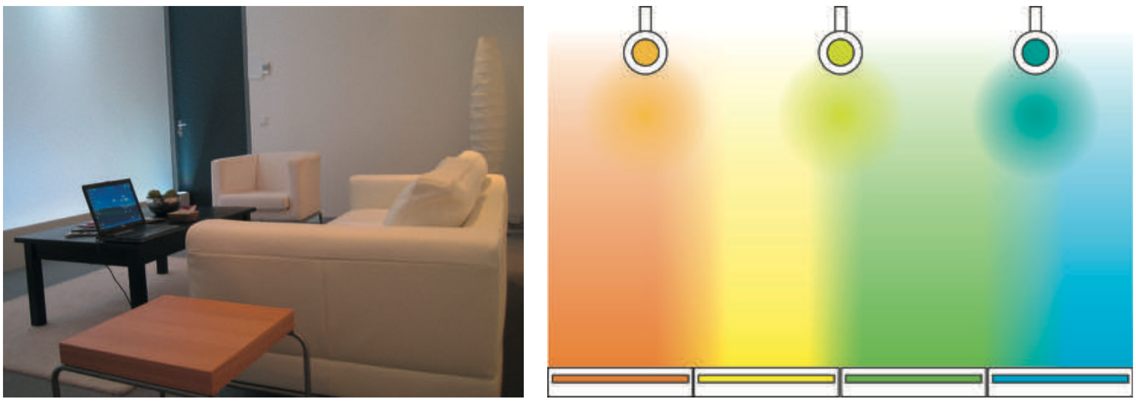

Figure 1. An impression of the experiment room and the spatial arrangement of the light sources used in the experiment.

2.1. Stimuli

Stimuli in the experiment were dynamic light variations on a single wall. The variation was sinusoidal to produce a smooth effect. To control for hue and spatial distribution preference, a static setting was also included. This resulted in two levels for the factor *type of change*, *static*, and *sinusoidal*.

The second factor was the base *hue* of the variation. Three setting were used for this factor: *orange*, *blue*, and *green*. The third factor was the direction of variation around the base point. There were three possible dominant variation directions: *brightness*, *colorfulness*, and *hue.* The variations were shown with two different *speeds of change*: *slow* (20 second cycle) and *fast* (5 second cycle), and two *amplitudes of change*: *small* and *large*. Figure 2 gives an overview of the stimuli.

The final factor was the *spatial distribution* of the effect. Three settings were selected: *single light*, where only the middle LED spot was on; *wall*, where all the light sources varied synchronously; and *wall cycling*, where a phase shift between the effects on the light sources was introduced based on their spatial position.

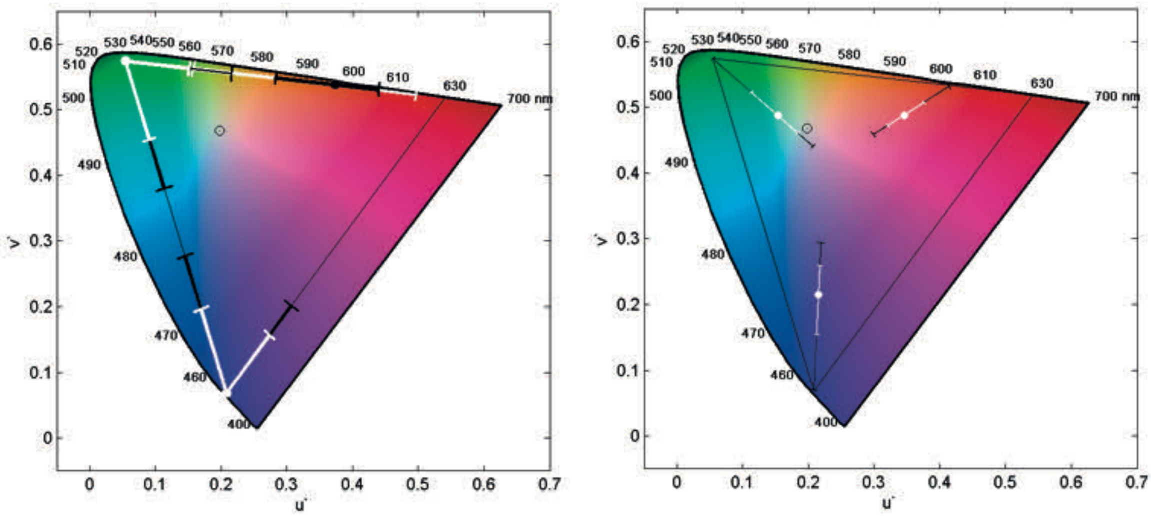

Figure 2 Overview of the stimuli. The images depict large (black) and small (white) variation in both the hue direction (left image) and colorfulness direction (right image).

2.2 Participants and Procedure

In total 39 participants, aged 23 to 54 with an average of 33 participated in the user study (20 female, 19 male). Most of the participants were native Dutch speakers and all of the participants had no previous experience with dynamic lighting. Seven of the participants owned a Living Colors lamp.

The test was divided into two sessions. In the first session participants scored 133 stimuli on 6 questions (4 atmosphere dimensions, perceived naturalness and overall attractiveness) using an interval scale (-3 to 3). In the second session additional 43 stimuli were rated using the same procedure and afterwards an interview was conducted. Due to the large number of stimuli and time limitation, not all participants could rate all stimuli and a balanced block design was used. All the stimuli were shown with their order randomized per participants. A neutral white stimulus (D65) of 10 seconds was shown before every stimulus. The scoring was carried out using a computerized questionnaire.

3. Results

The measured scores on the six dimensions were analysed separately using Analysis of Variance (ANOVA). The model fitted had all the five experimental factors as fixed factors and participant as a random factor. Only main effects and two way interactions were tested.

Table 1 gives an overview of the main effects in the experiment. For each factor, the significant differences between levels are noted. For example G<B<O denotes that all the levels were significantly different, with O scoring highest and G scoring lowest on the measured axis. The equal sign denotes a lack of significant difference between levels. Additionally, the overall effect significance level is given in parentheses. Additional to the main effects, most interaction effects were significant. The most interesting interaction effects are the ones with participant being one of the factors. The significant interactions with the factors *speed* and *hue* show the need for personalization on these factors.

Table 1. An overview of the main effects of the dynamic settings.

	Coziness	**Liveliness**	**Tenseness**	**Detachement**	**Naturalness**	**Attractiveness**
Hue (orange, blue, green)	G<B<O (p<0.001)	B<G<O (p<0.001)	O<B (p<0.001)	O<G<B (p<0.001)	B<G<O (p<0.001)	B=G<O (p<0.001)
Direction (brightness, colorfulness, hue)	B=C=H	C<B=H (p<0.001)	C<B=H (p<0.001)	H<B<C (p<0.001)	H<B<C (p<0.001)	B<H<C (p<0.001)
Spatial distribution (single light, wall, wall cycling)	S<W=C (p=0.021)	S<W=C (p<0.001)	S=W=C	S<W=C (p=0.016)	S<W=C (p=0.016)	S<W<C (p=0.016)
Speed (slow, fast)	F<S (p<0.001)	F=S	S<F (p<0.001)	F<S (p<0.001)	F<S (p<0.001)	F<S (p<0.001)
Amplitude (small, large)	L<S (p<0.001)	L=S	S<L (p<0.001)	L<S (p<0.001)	L<S (p<0.001)	L<S (p<0.001)

In the interview 72% of the participants indicated that they want dynamic lighting in their living room. However, the quantitative findings show that smaller amplitudes of change as well as slower light effect were seen as more attractive, showing preference for subtle dynamics.

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From (slow) motion to emotion: The color-light event and the experience of the interval

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Abstract

This paper deals with the temporal dimension of the interaction of color and light in contemporary art, and more specifically with the intervallary nature of the color-light event. Based on the author's light installations, it examines the question of monochromatic color and of the interaction of colors in painting as compared with the contemporary use of sequences of colored light. It shows how the author's installations avoid both unchanging and rapidly changing light in order to focus on interval-enhancing slowness as a factor of the emergence of color. The paper first describes the 1950s and 1960s breakthroughs of color-light as both distinct from and similar to the painters' use of pigment. Then it focuses on the questions raised by light works that include temporal evolutions and it insists on the spatial and temporal dimensions of color juxtaposition. Based on this notion of juxtaposition, it then develops the author's theory and practice of the interval. It describes how her recent installations focused on duration and slowness so as to expand the experience of the interval, thus provoking sensorial and emotional experiences associated with the intervallary color-light event.

Introduction

The site-specific light installations I have created since 2007 are based on a score organized in a series of colored "tableaux" of light that slowly, silently and almost organically fade into one another to create a developing series of atmospheres. This contrasts with other light installations, such as Ann Veronica Janssens' *Donut* (2003), which is based on the quick pulsation of large colored concentric circles projected on a wall with the rhythmic support of loud music. Based as it is on the interaction of successive after-image effects, *Donut* aims to unsettle our perception of color and space. Such is not the object of my installations which focus on slowness as a decisive element in the advent of color.

But the use of colored light as a medium raises a few questions : how does one work with it ? how can it be contained ? how can it be used without the support of surfaces ? in which ways does it differ from pigments ?

From Pigment to Light

Color, form and surface are most generally considered inseparable. Bridget Riley considers they cannot be dissociated (Gage 2009: 103). Michel Verjux uses light in a way that doesn't differ much from white paint on a surface. In his case, color apart, the use of light as a medium is not truly light-specific. Things are different with some of James Turrell's earlier works that circumscribed colored light in a form. He first used white light—as in *Casto (White)*, 1967—and then chose to use colored light—*Casto (Pink)*, 1968. From the right viewpoint, the flat surface painted on the wall is perceived as three-dimensional, like a hologram. This work is more light-specific in the sense that it produces a three-dimensional colored sensation related to no existing material object. It avoids the medium-alienation of transitive lighting, and it explores light's ability to inhabit space and to create a self-contained volume. Such questions partly stem from the interrogations of 20th-century painters and critics.

For instance, Clement Greenberg's notion of the *allover*—often used about Pollock's drippings—suggests that the canvas is cut out of a broader field whose virtual presence beyond the picture's physical limits is part of the beholder's experience. Such preoccupations can be linked with Robert Irwin's and James Turrell's interest for light. From 1967 to 1971, they both worked on sensory deprivation with psychologist Edward Wortz, in the *Art & Technology Project*. Wortz worked on the *Ganzfeld*, a perfectly homogeneous color-field with no perceptible object or shape, or any visual accident. In this experimental context, one may say that Turrell's priority in the 1960s was not color, but sensory deprivation and the beholder's spatial disorientation.

From « non-color » to colorism

If color is secondary in the *Ganzfelds*, one may question its importance in most of Turrell's work. *Cherry* (1998), for instance, is part of his Space Divisions series in which color plays no part. The first works in the series—*Rayna* (1979), *Jida* (1983)—involved no artificial light but the occasional lighting of the exhibition room. For thirty years, well into the 1990s, Turrell was not a colorist. Color, for him, is an inessential supplement—or ornament—in the more fundamental questioning of our perception of space. In this respect, neither color, nor space, nor light are his media. As he very clearly said, "perception is the medium".

While his works' power of attraction does seem to reside in these large monochromatic panes or volumes of light, the choice of color most often is irrelevant. His choice of low intensity, high saturation color for the monochromatic works of his most important series is not determined by what Rothko would have called the color's "poignancy" (Arasse 2006: 92). It is determined by the color's ability to intensify our spatial disorientation—what we might call its "power to unsettle". In other words, it is only indirectly that Turrell's earlier work may be associated with the "poignancy" of color.

However, it seems Turrell's work for Pascal Dusapin's opera, *To Be Sung*, in 1993-1994, was a turning point. There, Turrell may be described as a colorist—in Roger de Piles's sense—arranging and tuning colors. For color cannot be experienced in monochromes—neither of paint nor of light. It is the result of an arrangement or juxtaposition of colors, either in space or in time, which plays on saturation and intensity, and creates effects of contrast and gradation.

From fixed color to colored light variation

When an artist arranges colors, in paintings or installations, there is an illusion of movement involved. With the same double-entendre as the *movere* of ancient rhetoric, the art of the colorist *moves* us. The question is how the physical, optical or mental motion triggers emotion. Roger de Piles had understood that such was the power of the colorist.

In the case of painting, the arrangement of colors determines the conditions of our gaze's mobility. Although they evolve in time, my installations are based on similar aspects of the interaction of colors in visual perception. The difference however is that my installations change in time. Like a piece of music, the modulations of colored light explore the dimensions of time and change. As they evolve form one luminous and colored state to another, the exploration of *space* and *duration* focuses on the phenomenon of *spacing*. The very fact that they are *moving* installations is related to questions of duration, transition, and intervals. In other words, they constantly rasie the question of how successive states (of color) are joined.

Indeed, temporality is at the heart of my practice *and* technique. It is also related to color. It is the stretching of duration—or slowness—that led me to my interest in the advent of color. And indeed, to work on the advent of color means to work on duration, for the artistic manipulation of color must take into account the subjective dimension of the color sensation, the fact that color always fools us, as Albers suggested (Albers 1963: 11). Color is phenomenological. It exists as color only because of our eye's capacities of mobility and adaptation.

However, Lois Swirnoff's experience—somewhat like Turrell's Dark Spaces series—shows that the experience of color is not exclusively optical. Thus, extreme slowness allows to explore the eye-brain relationship, the relations between visual perception, cognition and emotion. My artistic research focuses neither on stability nor on quick changes like *Donut*, it does not put the eye under intense and instant pressure. I wish to stretch every state, in order to explore the plasticity of duration (and of color).

The experience of the interval as the advent of color

To conclude, I will insist on the notion of interval. Mark Rothko regretted that the public was more attracted to his lighter pictures because the darker ones called for more concentration and visual effort. In my untitled installations 1 and 2 (2008), the extreme slowness of change, on the verge of imperceptibility, called for a similar type of concentration on color and time—much as when one listens to a solo cello piece. But it is with this focused attention, heightened by expectation and want, that color best appeared.

As we have seen, Turrell's monochromatic works do not focus the beholder's attention on the advent of color but on its attractiveness. On the contrary, in *Etude* and *Untitled* 1 & 2, the only light-events that make a difference are perceived only as color-events without the distraction of accidental and spectacular speed. In *Untitled* 1, change was slower than our natural physical motion and compelled the beholder to reduce the speed of his everyday perceptual agitation. By creating want, this could challenge his patience. But the everyday pace could also subside and allow the emergence of a durable experience of emerging color sensations.

Under such conditions, color does not occur in such or such predetermined luminous state or stage in the score, but in the movement from one of these stages to another—and this includes the beholder's own movements. It occurs in the intervals between the states, each state in its turn becoming a new interval in the continuous flux—and perceptible as the advent of such color only because it becomes an interval. The same state, when presented as such, is not an interval : it cannot be a color-event.

By questioning the modes of spacing with slow color and light variations, I try to act on the *spacing of the gaze*. What I try to effect with these installations' slowness amounts to doing in time what painters have perceived in space or on the picture plane. Thus, Matisse very precisely evoked what I have here described as the advent of color as interval, when he said about the Vence Chapel:

> *"One may not add any red in this chapel… And yet this red exists, it exists in the contrast of the colors that are there. It exists through the reaction in the beholder's mind" (Mèredieu 1997: 65).*

As Florence de Mèredieu has so aptly added, this is quite like music. “The interval, the void, the relation and the harmony” (Mèredieu 1997: 65) are all. This is exactly the reason why I believe that a research on color—artistic or not—necessarily is a research on composition. It consists in working on juxtapositons. Whether one works with successive layers of color, as in a glacis, or with a temporal succession of states, juxtaposition exists in movement. As far as I am concerned—but is it different with painters ?—it consists in creating intervals in a light score.

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The shadow of colors in Karagöz: Interaction of color and light in Turkish shadow theatre

oral paper

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Abstract

Karagöz protagonist of the Turkish Shadow Theatre, represents the most popular type of Traditional Turkish Theatre. This timeless spectacle play, gained its current form by the 17th century. Manipulated figures/*tasvirs* are projected behind an illuminated white screen. *Karagöz* is situated at the limits of shadow play due to its characteristic color scale. The figures consist of flat silhouettes of brightly painted transparent camel hide projecting color into their shadow. In this study, the relationship between form and meaning will be investigated through light and color. *Karagöz* with *Hacivat* reflect the multicultural panorama of Ottoman society. The making of *Karagöz* figures is the most important Folk Art of Ottoman Pictorial Art. The colors are inspired from Miniature Painting. As festival colors, they are stained glass colors which are not designed to be seen with the naked eye. White and translucent the *Karagöz* curtain absorbs the inherent colors and therefore it reduces gradation of shades. Consequently, perceived colors are situated in an elusive structure.

1. A spectacle of light and color within the confines of Shadow Theatre

Karagöz is a shadow play. Similar to the other shadow plays, manipulated figures/*tasvirs* are projected behind an illuminated white screen. But, it manifests a fundamental paradox in itself compared to precedents. The reason why *Karagöz* is situated at the limits of shadow play is because of the color which also gives it advantage. Thus, *Karagöz* figures consist of two-dimensional flat silhouettes usually made of transparent camel hide brightly painted, projecting color in their shadow. Therefore, they could be expressed by an oxymoron such as *the shadow of colors.* Certainly, the existence of shadow and the manifestation of colors depend on *light*. Before electricity, oil lamps/*şem'a* or candle lights/*meşale* reflected the shadow of colors. The aesthetic contribution and the magic brought by the flickering flame created a unique spatial atmosphere. Baltacıoğlu (1942) During that period of history, *Karagöz* was, first of all, an art of oil lamps. This light meaning *ruh* -''the spirit''in Turkish- refers to the mystical and was considered as an enlightenment beyond itself. Even the curtain, the dream curtain -*hayal perdesi*-, where the shadow play is performed, the candle light animates the puppets, and the puppeteer called *hayali* gives them life by operating them. All these aspects relate to the concept of *dream* which represent the concrete. *Hayal* (dream) also means the puppet while *hayali,* the *Karagöz* player who manually operates all the characters and impersonalizes their voices, acts as a one-man-act performer.

1.1 Distinctive features of a Traditional Pictorial Art

The spectacle play *Karagöz* which is the most popular entertainment of Traditional Turkish Theatre has a realistic form. It is an open system based on laughter, similar to the structure of farce, yet creating its own original and creative synthesis. The secret of 400 years of success derived from its independent and critical attitude against the politics of oppression and sexuality with humor in spite of the oppression and the pictorial ban of political Islam.

- The puppet *Karagöz* whose name is given to the play is the protagonist that represents the people. The other character is antagonist *Hacivat* who is presented as an Ottoman wanna be intellectual. The two characters are dialectically inseparable**.**
- They reflect the characteristics of social life, the multicultural panorama of Ottoman society and the immortal heroes from the fantastic universe of the historical patrimony of common cultures such as oral literary traditions, i.e. *Leyla vü Mecnun* and as a result they succeed to create a joyful and colorful world.
- A shadow puppeteer with a complete set should have 400 figures. Şapolyo (1947)

Finally, all these attribute to a hybrid system composed of music, dance, puppetry and clowning. But above all, *Karagöz* is an image, an icon and this system of images are performed on scene. In fact, *Karagöz* takes its source in pictorial art, and does not exist without its appearance of forms and colors. In other words, there are not tales of *Karagöz*, there are plays of it. Aksel (2010) No doubt, these plays are expressed in forms and motion.

1.2 Protagonists and Color Symbolization

Karagöz represents the public but he is not a normal type according neither in appearance nor in physiognomy. An odd and intriguing, yet stylized representation shows us an exaggerated view. This timeless flat profile, gained its current look during the 17th century. M. And (1977) Pieces of transparent leather that compose the whole, are united with the joints that able mechanical movements. This articulation is based on clowning, the origin of the motion comics. The active and cheerful character appears more communicative by the dominance of red. *Hacivat* who is antagonist of *Karagöz* conveys his conservative and passive personality with less capacity of movement and by the opposition of green. Black contours all around the characters' shapes outline the brilliant colors. Those colors have common points with the Turkish Miniature Painting which is a Court Art.

2. Light as a minimal sign

Light and color as minimal sign could be used to explain the relationship between form and meaning of *Karagöz*. In this respect light works as a metonymy for the shadow phantoms on dream curtain because the narrative is not operated by the whole figure but by a part of it. This is a syntagmatic organization of the abstract. ''Light is fixed behind and just below the screen. The light distance is determined by the need for sharp focus. The screen diffuses the light, and the light shines through the multi-coloured transparent material, making the figures look like stained glass''(M. And 2005: 42) But at the same time the translucent cloth, tones down the color intensity and various effects are created reducing or increasing the lightness. Ambiance and the sensation of space are obtained by gradation of tones. No doubt, all must comply with all comedy. The most important element which is light is a minimal sign that equilibrates the traditional and eclectic language of form. The time and the timeless come together therefore the union of different colors provide a wholeness ensured by its contribution. One of the valuable qualifications brought by the light is perforations. In general as part of the decorative aims, cut holes are also for the obtainment of the light for non-transparent shadow play figures. They are used here in *Karagöz,* to outline the interior drawing as well as its decorative function. Thus, explanatory light function unifies with the decorative one. Finally it is possible to eradicate the shadows of the horizontal manipulation rods which was visible formerly with appropriate lighting. Oral (2009)

3. Color in Turkish Miniature and Turkish Folk Art Painting

Shadow Play as a Folk Art follows the hues of the Eastern and Western Ancient Miniature Painting. But its colors are not jewel colors like them. As a practice of the commercial artists/ *çarşı ressamları* it has less color variety and a more restrained palette. From the Middle Ages to 16th and 17th centuries, another principle was changed. The clear cut drawing was not rendered any more as a pure color for each pigment. From now on, color mixture is preferred ''for more suptile coloristic effect''. Purinton et al. (1991) The same for *tasvirs (*figures*)*; layer is applied upon layer from both sides of the hide until the desired intensity.

The use of organic material from vegetable to insects is covered by the concept of fields of *kökboya* (madder). Aside from madder, the lack of covering power and tendency to fade, is accepted as a part of his own kind aesthetic. The burnt patina belonging to some of earliest *tasvirs* dating from the time of *meşale*/oil lamps were also admired. Gerçek (1942) Şapolyo (1947) But there are many examples of bright colors that are maintained until today. In addition to stable reds, kermes or cochineal, mineral ones like cinnabar/*zincifre* and vermilion/*sülüğen* were employed. Purples are *lâ'lî,* extracted from shellfish murex, Sönmez (1997) or, a mixture of lampblack with *hürmüzî*, hematite from the Island of Hormoz. *Üstübeç* is white lead while the black obtained from linseedoil is named *dûde-i siyah*. Also mentioned rhamnus/*alacehri*, curcuma/ *zerdeçal* and carthamus/*aspir* from the Ali Emiri list, as well as cheaper yellows such as saffron/ *zağfiran* and peori. M. And (2004) Indigo/*çivid* is used for blue, and the artificial verdigris mixing orpiment/ *zırnık* with indigo, is for green. Red ink made of kermes, *sürh* Sönmez (1997) and yellow ink made of *zırnık* Özen (1985) are also cited by M. And (2004). As seen from all over the world, the return to synthetic dyes after the abandonment of natural dyes, will determine all this corpus which is expressed by color names. ''Tender blue, deep purple, leaf green, olive green, red crimson, terra cotta, brown, yellow''. (M. And 2005: 43) Despite all these uncertainties each performance had an improvised structure, thus creating its own language of color.

3.1 Colors as a meaning organization in Karagöz

In this study, it is important to research about the colors of the palette, as well as to discuss how they come together and their role in organization of meaning. A huge repertory of 30 plays with 400 figures, the creation of new forms in addition to traditional ones as a result of being an open system, and, the *tasvir* artists' specific styles, form a new eclectic structure taken place with synchrony and diachrony. Identities of the subjects determined according to the level of speech, are reflected to the form level within the garment system. The connection with reality is not an obligatory condition primarly because this is art. Yet the personification of characters as stereotypes and representation in the same manner could bring a systematization relied on a particular logic of color.

The main types *Karagöz* and *Hacivat*, and *göstermelik* (show pieces) exist in almost every scene. The protagonists relied on red and green, referring to the concepts of gipsy Yakop (1938) or Bektashi order for *Karagöz* and pilgrim and Nakshi sect Şapolyo (1945) for *Hacivat,* are not always equivalent in contrast at the syntagmatic level. But we can affirm the symbolism of red is always present for *Karagöz.* A part of its unstability, green is less evident in *Hacivat*. As for stock characteres, they represent the multicultural society by variegation. Colors could be reduced for the expressive form style. Due to the fact that is a night performance, yellow and orange-red seem to be in a quantitative superiority. Reds appear dominant as a whole. The attribute of characters and the auxiliary objects occur metonymically following the relationship between the piece and whole. As for the smaller components, the application of decorative perforations is proportional to color reduction and it is inversely proportional to the increase of shapes. The increase of shapes assures the preference of more colors. In the area of signification, types such as Arab and Devil are included in the symbolization of red. While violet represents Rabbi, some negative creatures such as the Snake and the Dragon are symbolized by green.

Polychromatism dominates within illisory images/*göstermelik* such as show pieces and set displays as well as in the repertories of the famous puppeteers from 19th century to present, like Hayali Küçük Ali. For the last puppet master, a multicolored choice has been the highest priority. Such as his predecessors, he follows an eclectic color understanding using less colorful examples, and various textural expressions, even the burnt patina effect of the older figures. For the older figures, there is little color.

In common palettes, influences could be on the basis of the puppets. However during the performance of the player, original but evasive color lights occur by the contribution of the motion. In this context, the aesthetics of perceived colors is compared to a special property of Turkish natural dyes for carpet. It is called *abraş,* in old carpets. Color loss owing to this uneven dyeing of the threads, gives a specific kind of beauty. The magic of colors reduced by the set up of light, is outstanding in the darkness.

Karagöz, as a very much esteemed performance is presented especially at the old festivals and imperial weddings. It is a universe of color and light worthy to those happy days. Its authentic palette mentioned metaphorically as festival colors are stained glass colors which is not designed to be seen with the naked eye. Baltacıoğlu (1969) The translucent the *Karagöz* curtain which is white absorbs the inherent colors while it reduces gradation of shades. Consequently, perceived colors are in an elusive structure.

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Facilitating surface, colour and lighting choice

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Abstract

Light that falls on a surface is generally modified as it is reflected. What the human eye senses is an inseparable product that contains information about both the surface and the type of illumination used. How the surroundings appear to us visually is an important factor in determining the expectations we have of an environment. All of the professionals involved in designing a space seek to control these expectations through, for example, spatial layout, selection of materials, choice of colours and the type of lighting. Appearance science provides us with a whole catalogue of terms to describe optical properties like colour, texture, translucency and gloss. As separate entities, these are only of limited interest to architects and designers in their search for guides to assist them in envisioning the overall appearance of a space. We explored alternative ways to facilitate the process of material selection and choice of light by describing the design impact and also by providing visual impressions that illustrate the joint effects of material samples that have been lit differently.

1. Introduction

Light is a fundamental part of our daily lives. Although we are often not conscious of many aspects of its presence, light influences behaviour in several ways. By falling on objects and the surrounding environment, light affects how a scene appears to us visually. The image derived from what we see very much shapes the expectations we have about a space and hence influences any action we take. The world around us consists of objects that relate to each other in specific ways. To a large degree the way the built environment unfolds in front of our eyes is down to architects, designers and engineers. They seek to control expectations through manipulation of, for example, building shape, spatial layout, room size, material choice and colour. Appearance science clearly points out that lighting is, among other things, a factor that affects our interpretation of a perceived object or scene. The frameworks of total appearance by CIE (2006), image scales by Kobayashi (1998) and suggested measures of design impact by Hutchings and Luo (2010) are concepts that are utilized to link physical parameters to psychophysical descriptions and ultimately to the feelings or expectations that are derived from the observed object or scene. The image scale of Kobayashi with its two major axes “warm” to “cool” and “hard” to “soft”, which was initially developed for colour application, was extended by him to other aspects of the built environment. Hutchings and Luo suggested, among other things, incorporating materials and lighting. This paper provides a detailed view on the joint impact of material and lighting on appearance. It also presents conclusions derived from a demonstration setup created to support architects and designers by facilitating the process of defining desired combinations of material and light.

2. Lighting impacts appearance of materials

Human perception of the characteristics and appearance of a material varies under different lighting conditions. One advantage of a two-dimensional image map with the axes warm/cool and hard/soft, as suggested by Kobayashi, is that it can be applied to several elements of an interior (for example, furniture, lighting). The starting point for depicting illumination that varies along the warm/cool axis is the established measure of correlated colour temperature (CCT). Given in Kelvin, for achromatic light the CCT is a measure of the reddish and bluish light components. Daylight has a higher CCT than light from an incandescent bulb; we perceive it as being more bluish. Figure 1 shows one sample each of textile, wood and metal under five different light sources.

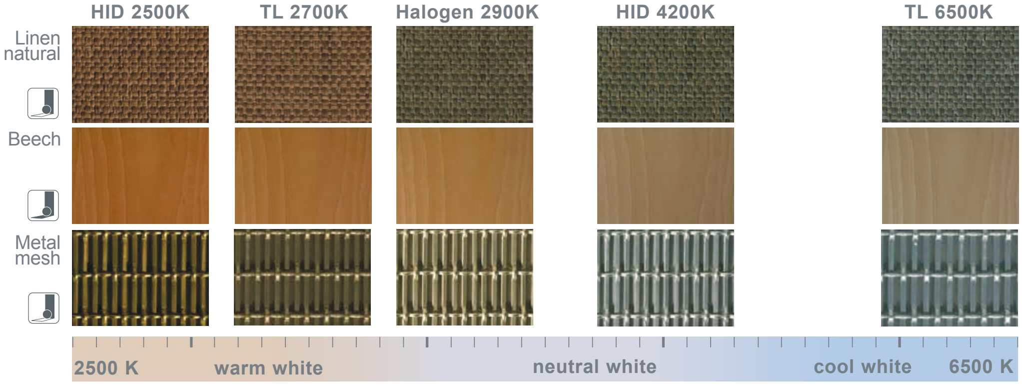

Figure 1. Material samples lit by a halogen lamp, two types of fluorescent tubes and two types of high-intensity discharge lamps.

In comparison with the halogen and discharge lamps, fluorescent tubes provide a more diffuse light. It is generally referred to as "soft" light. The lamp choice can therefore cause the illumination condition to be plotted in a different position on the warm/cool and hard/soft axes (see Figure 2).

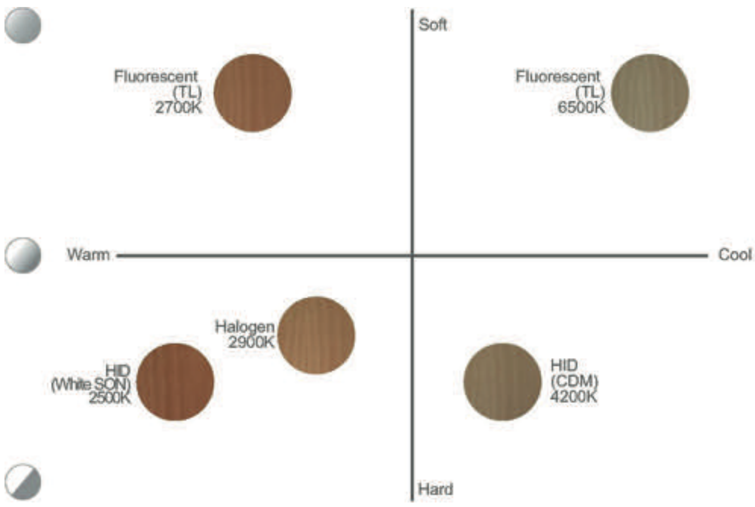

Figure 2. Differently illuminated wood samples in terms of warm/cool and hard/soft axes.

The "scale of shadows" by Frandsen (1987) is a quantitative measure for diffuseness of light. It uses the distinctness of the zone between the directly lit part and the shaded part of a sphere as a criterion. The size of the middle zone determines the intervals on the scale (see Figure 3). In completely parallel light there is no such middle zone, in totally diffuse light the graduation spans over the entire surface of the sphere.

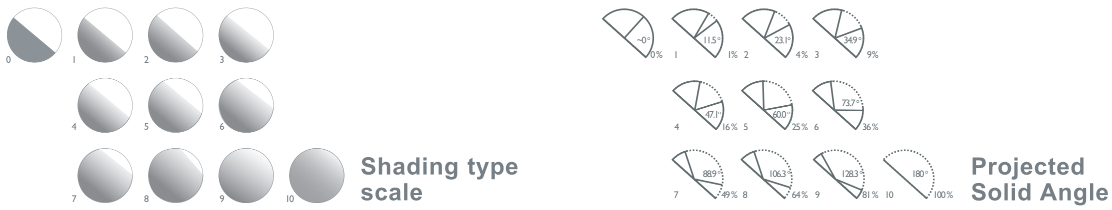

Figure 3. The scale of shadows according to Frandsen.

Visually perceived hardness is not solely dependent on the directional strength, but is also influenced by a number of parameters, with diffuseness being a major one of these. A more distinct shadow generally provides stronger contrasts which, in turn, provide a harder impression of the scene.

3. A demonstrator illustrating appearance of materials

Appearance research assesses the visually perceived properties of materials in different categories, such as surface texture, colours, gloss and translucency. Designers generally choose the materials they use on the basis of their overall ability to embody the predefined concept. To serve the needs of architects and designers, a selection of materials was placed on a wall and illuminated under different lighting conditions. In total, the demonstrator created shows 37 materials that are typically used in interiors.

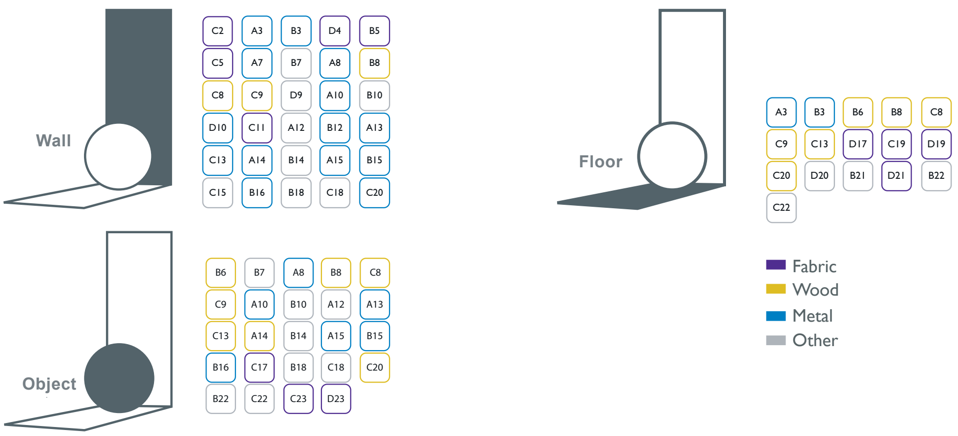

Figure 4. Selected materials named according to their position on the wall (row,column) and grouped according to the context categories wall, floor and object.

All samples can be viewed in six distinctly different lighting conditions, three achromatic scenes (see Figure 5) and three chromatic scenes. The parameters that were varied between the lighting conditions were the spectral power distribution of the light, the direction of the light and its diffuseness. This setup enabled a comparison between the appearance of materials under the same illumination as well as a comparison of the visual appearance of each material under specific lighting conditions.

Figure 5. Material wall illuminated with fluorescent down-lights, halogen up-lights and a combination of fluorescent down-lights and halogen spots.

In the following we compare the appearance of three samples – a stainless steel plate, a wooden tile with inlays and a plush textile – under light from fluorescent tubes and halogen lamps. Measured luminance profiles are given to enable interactions between light and surface to be traced. For the first two materials illumination with small halogen sources creates a harder impression, whilst in the case of the plush textile the situation is somewhat ambiguous. The halogen up-lights create a stronger contrast and therefore emphasize the irregular and intrinsically soft appearance. Under diffuse fluorescent light the material looks flatter and more uniform, which could be interpreted as being harder (see Figure 6).

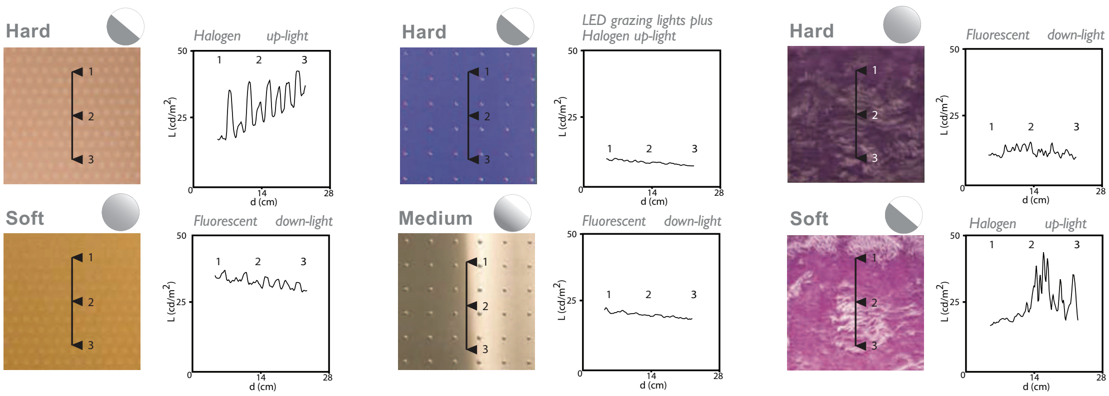

Figure 6. Photographs and measured luminance profiles for three samples lit by fluorescent and halogen sources.

In order to better illustrate more possible types of interaction between light and material, three additional case studies are presented. These case studies demonstrate specific interpretations that can be caused by the way light reflects off the material. The three topics studied include perceived depth of materials, manufactured versus natural material, and thread direction of material. Again, luminance graphs are used to illustrate the light interaction on the material. Corrugated aluminium is perceived differently under three different lighting conditions (see Figure 7). These conditions are fluorescent down-lights, halogen up-lights, and a combination of blue LEDs grazing right, red LEDs grazing left and halogen up-lights.

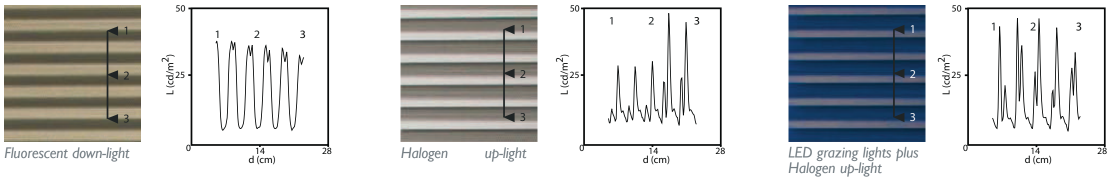

Figure 7. Photographs and measured luminance profiles for the corrugated aluminium sample under three different light conditions.

The interaction of the fluorescent light on the material is soft. Light shadowing can be depicted on the underside of the waves. As shown in the graph, the variance in luminance is smooth and the material is therefore perceived as being rather shallow. The interaction of the halogen light from below on the corrugated aluminium is relatively harsh. Shadowing can be depicted on the upside of the waves. The graph shows that the variance in luminance is sharp, and the material is therefore perceived as having depth.

The second case study concerns the difference between manufactured and naturally grown materials. It is observed that the interaction of light upon material varies according to the materials natural or manufactured qualities. Under a fluorescent down-light the three material examples are aluminium, paint and beech timber (see Figure 8). This manufactured aluminium has a predominately smooth surface. Due to the manufactured nature of the aluminium, the luminance is practically unchanged across the centre of the panel because the surface is uniform. This painted sample has a smooth surface. Due to the painted nature of the panel the luminance is also relatively unchanged across the centre of the panel because the surface is uniform. This material could be said to have a semi-specular gloss, as very slight variances do occur in its luminance.

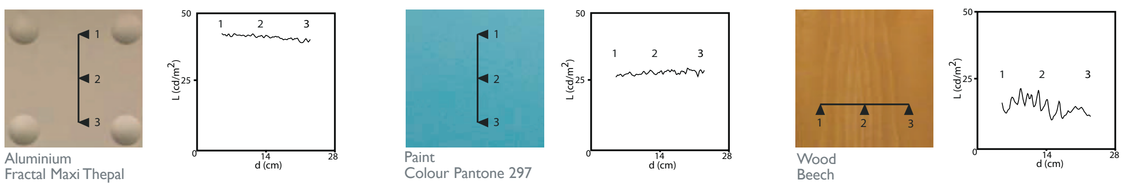

Figure 8. Photographs and measured luminance profiles for three samples lit by fluorescent lights.

This beech material has a smooth surface but there are natural highlights. Due to the organic nature of the beech, the luminance is variable across the centre. The graph depicts these organic features of the material that are accentuated by the light source. This material could be described as being diffuse and variances do occur in its luminance.

A strong visual effect was observed in the third case study. Depending on the light direction and the direction of material thread, the appearance of a material can become ambiguous. Under a light scenario of halogen up-lights, alternate rotation of a Vescom Ontario material was analysed (see Figure 9). As can be seen from this graph, the interaction of light on the identical surfaces varies considerably according to the direction of the material thread. The horizontal panel presents a more extreme luminance range due to the light being projected perpendicular to the thread, whereas the vertical panel's thread is parallel with this light and the interaction is therefore milder. As a result, for most observers the materials appeared to be different because the visual patterns perceived from a distance differed greatly.

Figure 9. Photographs and measured luminance profiles for the differently oriented material samples.

4. Quantification of appearance to facilitate design choices

In man-made environments there are clear reasons for the choice of materials and type of illumination. It is known that the fundamental properties of light can have a significant effect on how we perceive our surroundings. Furthermore, the spatial and spectral attributes of light can change the visual characteristics of material surfaces. Appearance science provides sufficient descriptors to enable us to describe the visual properties of a surface under varying light conditions. However, it makes sense to adopt a systematic approach to quantifying designs along axes that can be applied to several elements of a scene. Kobayashi's cold/warm and hard/soft bipolar axes have proven to be very applicable and suitable for predicting general tendencies.

Somewhat complementary to the abstract image description is the direct inspection of samples under simulated light conditions. What must be seen as a serious challenge − how to describe accurately a material's appearance by its physical characteristics − has been shown to be visually easily comprehensible to the human eye. At a glance, the essential characteristics of a material sample were evident, enabling the choices to be made that embody the envisioned concept best. A visual demonstrator is an effective way to make multiple facets of the material/light interaction immediately tangible.

Both ways of quantifying appearance can facilitate material selection and lighting choice in the design process. The most suitable strategy for a designer to use to materialize their vision will become clear when they consider the intrinsic limitations of each method.

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A model to link different modes and different aspects of appearance

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oral paper

Abstract
The model presented here is a conceptual framework for a better appreciation of appearances. It links different modes of appearance – illuminant, surface and volume – and different aspects of appearance – colour, texture, gloss, lustre and transparency.

1. Common visual experience

The complexity of appearances, as multi-dimensional visual phenomena, has been a deterrent to progress in theoretical development of the subject. David Katz (1935/1911) was the first to provide a systematic account of different 'modes of appearance'. His focus was colour but his approach can be extended to include other aspects of appearance: texture, gloss, lustre and transparency, topics I have touched on before (Green-Armytage 1991, 1993). The model presented here links different modes and different aspects of appearance. However, no model can encompass the full experience of seeing the world in space and time. This was acknowledged by the members of the Committee on Colorimetry of the Optical Society of America (1953: 145) when they referred to "the infinite variety of textures and settings with which colors are perceived in common visual experience." While much has been learned in 'laboratory conditions', with standardized lighting, uniform surfaces and isolated samples, this has been study of what is essentially an artificial world. In common visual experience colour cannot be separated from other aspects of appearance, nor can it be insulated from context. The critical role of context for perception is stressed by Steven Shevell and Frederick Kingdom (2008). And part of any context is the light by which things are seen, its coherence, colour and intensity, and the way it varies from place to place and over time.

2. Contrast and context

Between 1985 and 2001 I had many discussions with Western Australian artist Howard Taylor. Taylor objected to my work with colour chips. In one of his letters to me, quoted by Gary Dufour (2003: 19), Taylor wrote: "An isolated colour or other element is a specimen only – an I.D. card". In that letter he stressed the importance of contrast as it applies to all pictorial elements. Contrast is an essential feature of common visual experience just as it is for the pictorial elements in a work of art. Contrast with neighbouring colours influences the appearance of colours and without contrast there can be no appearance of texture, gloss, lustre or transparency.

The complexity of common visual experience is the concern of Juliet Albany (2009). In a session at AIC 2009 she presented a series of observations that were the fruits of her efforts to grasp the totality of what she sees around her, especially the influence of the changing natural light on local appearances in and around the place where she lives, her namesake city of Albany on the south coast of Western Australia. One year later, members of the Colour Society of Australia joined her in Albany for a series of workshops to explore her ideas. A major aim of the workshops was to find ways of describing visual phenomena that could help members of a community to become more sensitive to the particular visual qualities of their surroundings.

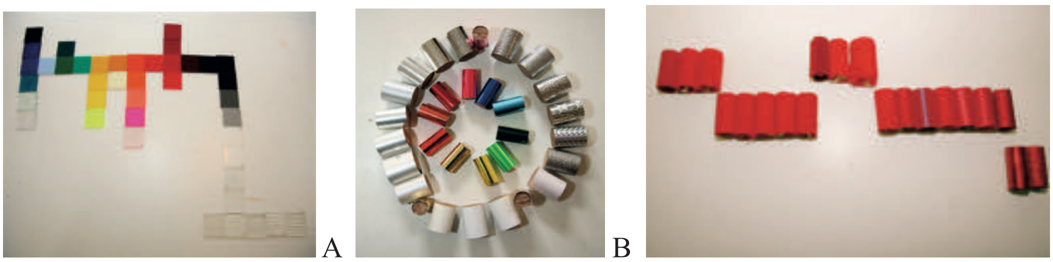
3. Describing objects and arranging objects 'in order'

In one study a collection of objects, that exemplified different modes of appearance and that exhibited a wide variety of appearance characteristics, was assembled as a 'still life' (Figure 1). The room was lit by light from the windows and this was supplemented by a spot-light that was focused on the display so that clear shadows were cast. There were two illuminants in the display: the tail light of a motor-car and a candle flame. The wine and the milk in glasses were examples of colour in the volume mode. In the surface mode, objects were smooth, textured, glossy, lustrous, transparent and opaque.

Figure 1. Still life display for studying different aspects of appearance

The task in the still life exercise was to write down words for describing each object. Many found the task difficult because there was so much variety and because they could not find words to describe some of the particular qualities they saw. One of the simplest objects to describe was a billiard ball. While some were content with 'red' and 'glossy' or 'shiny', one person wrote: "glossy, white highlights, bright red, deep red, curved shadows." Such close observation and detailed description were common.

In a follow-up exercise, participants worked with sets of similar objects and were asked to 'arrange them in order'. The results are shown in figure 2.



A B C

Figure 2. Sets of objects arranged 'in order'

This study revealed the importance of making a clear distinction between physical properties and visual phenomena. Objects can be seen clearly through transparent samples but not through translucent samples. Translucent samples allow light to pass through but opaque samples do not. However, it was not always possible to make these distinctions when the samples in set A were laid out on the table. Transparency and translucency, as visual phenomena, depend on contrast with adjacent colours. In fact it is possible to perceive as transparent something that is physically opaque, an 'illusion' illustrated by Augusto Garau (1993). The objects in sets B and C exhibited a rage of textures and degrees of gloss and lustre. Texture was revealed by the contrast between the small elements that constituted the texture. The cylindrical shape of the objects meant that, for each object, there was also the contrast between highlights and shadows that is characteristic of gloss and lustre. Gloss and lustre are defined here in terms of the colour of the highlights: highlights on a glossy surface are the colour of the illuminant; on a lustrous surface highlights are of the same hue as that which is perceived as 'belonging' to the surface.

4. A model for appearances

In each of the three sets it was difficult to arrange the objects in a single linear sequence. Some objects were the starting point for more than one sequence: the matte white cylinder in set B could connect with cylinders of increasing gloss in one direction and increasing lustre in another. The observation that one kind of appearance could connect with different kinds of appearance suggested the possibility of a model for appearances: a three-dimensional network of appearance sequences, linked through ‘primary sensation nodes’ which are the reference points for the model presented here (Figure 3).

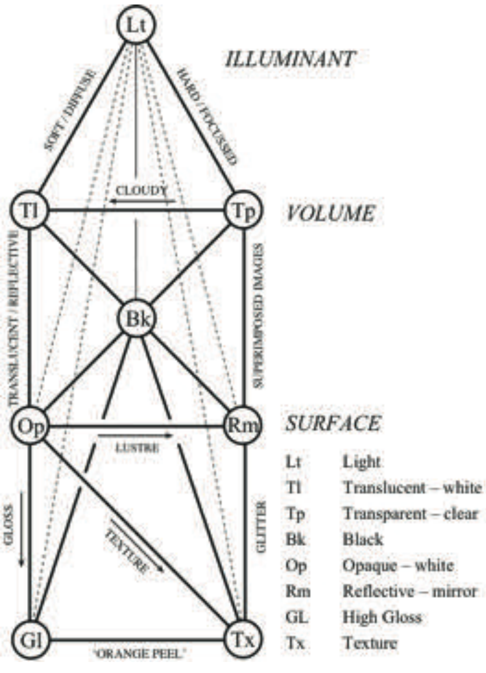


Figure 3. Diagram showing relationships between aspects of appearance and illumination

The model has, at its core, a model proposed by José Luis Caivano (1991, 1994) which deals with the way that materials transmit, reflect and absorb light. The primary sensations in Caivano’s model are translucent white (Tl), transparent clear (Tp), opaque white (Op), mirror/metallic reflection (Rm) and the black of total absorption (Bk). To these I have added full gloss white (Gl), rough textured white (Tx) and the glare of intense white light (Lt). Sequences of appearance phenomena, such as degrees of gloss, can be represented on lines which connect the primary sensation nodes. The lines that connect to black can also serve as the achromatic axes of order systems for colours that are translucent, transparent, opaque and mirror/metallic, thus connecting colours to other aspects of appearance. Colours that appear self-luminous can be related, in a similar way, to the lines that connect to white glare at Lt. Increasing apparent intensities of illumination can be represented on lines which converge at Lt. The coherence of a light source, which affects appearances, can also be represented on the diagram. ‘Hard’ light, as from direct sunlight and under which objects cast clearly defined shadows, is represented on the line Tp to Lt; ‘soft’ light, as from a heavily overcast sky and under which no shadows are cast, is represented on the line Tl to Lt. The billiard ball in the still life display (Figure 1), that appeared glossy under the hard light, could appear almost matte under soft light, an effect pointed out by Ralph Evans (1948: 53).

Evans (1974: 99–102) has also identified a threshold between coloured surfaces that appear to reflect light and those that appear self-luminous; in connection with this threshold he emphasises the role of contrast between a coloured area and its surround. Crossing this threshold would mean a change in mode of appearance from surface to illuminant. The dotted lines which converge at Lt on the diagram are to suggest scales of increasing apparent luminance beyond this threshold. Modes of appearance depend on the context but they are generally quite stable. However, a change in context can lead to a change in mode of appearance. Several examples of how a change in context can lead to a change in mode are described by The Committee on Colorimetry of the Optical Society of America (1953: 146–150). A three-dimensional model for texture, with dimensions of density, linearity and size, has been proposed by César Jannello (1963). Jannello’s model, like the models for colour, can also be linked to the diagram, with the line Op – Tx as Jannello’s scale for size, but there are some qualities of texture that are not captured in Jannello’s model.

5. Limitations and conclusion

The model described here does allow for a form of scaling but it is strictly a model for perceived appearances. Any measurement must depend on the judgements of observers. The model does take account of contrast and context, as they influence appearances, but it can only deal with parts of an object, or elements in a scene, one at a time; it cannot represent the object or scene as a whole. Also, there are textures and surface qualities for which additional descriptive words are needed. Words used by participants in the still life exercise included: rough, soft, furry, silky, waxy, grainy, dimpled, and speckled. Geologists in the field use a number of words, including 'silky' and 'waxy', to describe what they find as a first step towards identification (Whitten and Brooks 1972). A follow-up study is needed to develop a vocabulary of descriptive terms, with agreed meanings in relation to appearances, that could be used in conjunction with the model. While the model has limitations, and needs to be complemented with additional descriptive terms, it can represent different modes of appearance and the relationships between colour, texture, gloss, lustre and transparency. I hope it can lead to a fuller appreciation of the richness and complexity of common visual experience.

Acknowledgments

Howard Taylor and Juliet Albany inspired many of the ideas presented here. My thanks, also, to members of the Colour Society of Australia for their participation and feedback.

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Light and colour in the classroom – demonstrations from physics to the interaction of colours

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Abstract

Computer graphics is an excellent tool to create demonstrations, but exactly because of the ease of creating nearly any effect it may not be very convincing when we try to illustrate the separation, mixing or interaction of colours. While the material at the courses of the SENAI/CETIQT Colour Institute is presented in numerous Power Point slides, in our classroom demonstrations we illustrate the various concepts by showing real examples. In this paper we shall describe the demonstrations used in our colour courses for engineers and designers; showing the spectrum and illustrating selective absorption, diffuse and specular reflection, subtractive, additive and partitive colour mixing, the interaction of colours and the phenomenon of coloured shadows. The demonstrations generally don't need any special device beyond a conventional slide or overhead projector and some well selected dichroic or other colour filters. For partitive mixing a rotating disc is used.

1. Projection of a spectrum

A spectrum may be projected by using a slide projector, an overhead projector (Billmeyer and Alman, 1976) or a video projector casting the image of a slit onto an optical grating (preferred to a prism in this experiment). Using coloured filters in front of the light source we can project blue, green red, cyan, magenta and yellow light onto the grating and show the composition of the additive and the subtractive primary colours. The grating and the filters may be obtained from Edmund Optics (www.edmundoptics.com).

2. Selective absorption

To show the interaction of light and matter we use an aquarium filled with water, and project into it the image of five coloured circles from the side: white, blue, green, yellow and red. Non-selective absorption is illustrated by adding black ink to the water, where the gradual extinction of the white and the coloured rays becomes well visible.

For the illustration of selective absorption we add a very small amount of talcum powder to the water (so that the rays may be seen from the side), project the five coloured beams from the side and insert different coloured filters into the path of the rays. It may be beautifully illustrated how the coloured filters transmit the light of their own colour and absorb all the rest: each filter only transmits the light of its own colour, while absorbs all other lights.

3. Specular and diffuse reflection

In a completely darkened room a mirror (for specular), a glossy white tile (for mixed) and a Spectralon tile (for diffuse) are placed in the bottom of an empty aquarium. The aquarium is filled with white smoke (we've been using dry ice) and the white surfaces illuminated with a strong red laser beam. From the side both the illuminating beam and the reflected beam or beams are visible in the smoke.

4. Subtractive mixing (primary colours, complementary colours)

This is a very common demonstration with an OH projector and filters. With careful selection of the filters we can point out some aspects of subtractive mixing which may lead to a good discussion. By using additive (RGB) and subtractive (CMY) dichroic filters we can show that complementary pairs (R+C; G+M and B+Y) produce black in subtractive mixing, but the reverse is not true, colours that are definitely not complementary may also produce black, such as the additive primaries R+G, G+B and R+B. We should also point out here that the subtractive mixture of a true blue with true yellow results in black and not green (as many would expect).

5. Additive mixing (primary colours, complementary colours)

Although there exist countless computer simulations to demonstrate additive mixing (RGB) they simply do not have the same impact as showing the three coloured lights superimposed. The best way is still to use three slide projectors with good filters; or a combination of a video projector (to project one of the colours) with a slide projector + an OH projector. Should only the video projector and one slide projector or the video projector and one OH projector be available, you can first project say a red circle from the video, mix it with the blue from the OH, then project the two overlapping circles from the video and mix to it green from the slide or OH projector.

Both Phywe (www.phywe-systeme.com) and Leybold (www.ld-didactic.de) sell special apparatus for the demonstration of additive mixing.

6. Partitive mixing (spectrum colours, complementary colours)

Not much used nowadays for practical purposes (Kuehni, 2010), this is an interesting demonstration with the Maxwell /Newton disk. The Newton disk (with seven well-selected and properly distributed colour segments) is good to demonstrate that this type of mixture is not really additive (contrary to what we may find in many textbooks), because the mixture of the seven "colours of the spectrum" (which, of course, are not true spectral colours) give grey in the mixture and not white. The demonstration is also excellent in showing that complementary colours – mixed in the proper ratio – result in grey, but the result is different from the subtractive mixture of the very same pigments. We may also demonstrate that in the Munsell system the colours opposite each other in the hue circle are nearly complementary, while in the NCS system some (e.g. G – R) are reasonably "complementary", others (e.g. G – R) clearly not. Both Phywe (www.phywe-systeme.com) and Leybold (www.ld-didactic.de) sell apparatus for the demonstration of partitive (disk) mixing of colours.

7. Adaptation

Different colours viewed under daylight and tungsten light are physically different, but due to adaptation (and the uncertainties of memory colour) these differences are not always obvious.

Simple adaptation demonstrations include illuminating a set of coloured samples (e.g. A4 sheets of red, green, blue, yellow, light grey etc.) by daylight and asking the students to remember them. Then, some 20-30 minutes later, show the same samples illuminated by tungsten light, and ask if they think they are very different (generally the students think they are not). Then show the same samples illuminating half of the sheet by tungsten and half by daylight and observe the great difference. When using a *slide* projector "daylight" may be simulated by placing a light bluish filter in the projector (whose the unfiltered light is similar to tungsten), and when using a *video* projector "tungsten light" may be simulated by using a light yellowish filter in the projector (whose unfiltered light is similar to daylight).

An even more pregnant demonstration involves the projection with an OH projector the image of a collection of well-known objects (a fruit basket is ideal) covered with a sheet of light magenta (pink) or blue filter. In spite of the obvious magenta or blue overcast of the image of the fruits still show their typical colour (e.g. the bananas are unmistakably yellow). Taking off the sheet and covering only the bananas with a mask of the same filter shows the bananas in their "true" strong magenta or greenish blue colour.

8. Interaction of colours

In his incredible book Albers (1963)[1] explains in details the demonstrations. In this case some very clever computer simulations (e.g. Foote, 2010) may also work very well. The White illusion (Bach, 2011) is another example for which, together with many others, good computer simulation can be found, but in the classroom we are doing exercises with paper cuts, which are even more effective.

The Koffka Ring Illusion (Adelson, 2010) is demonstrated the same way: we give the students a printed version of a grey ring over two different (a lighter and a darker grey) backgrounds, then they have to cut and separate the two halves and observe the effect.

9. Coloured shadows

This is one of the most dramatic classroom demonstrations, and maybe one of the most misunderstood, although the phenomenon was first mentioned already in 1672 by Otto von Guericke (Hoeppe, 2007) and described in detail by Benjamin Thomson (1794) and Goethe in 1810 (Aach, 1971). Project the light from two projectors side by side on the screen, one with a coloured filter, the other without filter. You should dim the light from the projector without the filter so that its intensity is about the same as that of the one with the filter. (In our case the projectors have two brightness settings, we use "full" for the one with the filter and "dimmed" for the one without). Show how the shadows are black in both cases.

1 Now available in a less expensive – but still complete – edition (Albers, 2009)

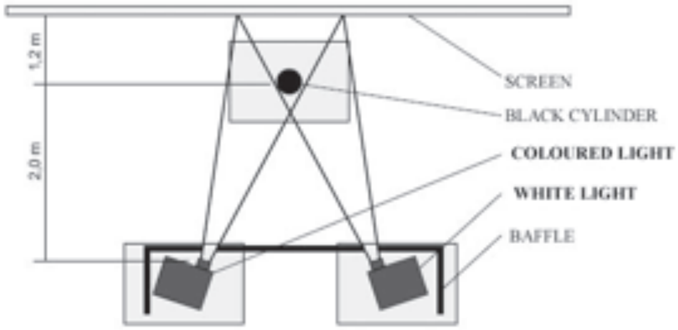

Figure 1. Casting two shadows for the coloured shadows experiment

Then precisely overlap the images (squares or circles) from the two projectors and project white light from the right projector and coloured light from the left as illustrated on Figure 1. There will appear two shadows: the one cast from the right projector will be the colour of the filter in the left, the other cast from the left projector will be its complementary colour.

This demonstration is described and explained in detail by Joy Turner Luke (1976). The demonstration may be done using two – or even three - coloured lights (instead of one coloured and white light), but, although even more spectacular, we find it somewhat confusing and thus less convincing than the simpler version.

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Management and development of proyectacolor.cl, a platform with theoretical and practical color resources in Spanish, useful for the observation, education, discussion and aplication of color in visual communication design

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Abstract

Proyectacolor is a platform with theoretical and practical colour resources intended for academics, professionals and students willing to learn about the powerful visual resource that color is. It was developed in 2008, with the aim to facilitate the colour education of Chilean graphic designers and students. It is based in a triadic composition: three different learning environments. Currently, Proyectacolor is a consolidated reference compendium of practical and theoretical colour resources in the Spanish language.

1. The project background

Proyectacolor is an academic project that was conceived in March 2008. Informal research, including interviews and surveys, was conducted among graphic designers in the subject of color. The results were surprising. The majority of Chilean graphic design students weren't learning the use and application of colour in visual communication. Not even the basics.

The surveys and interviews used were based on the following key questions: How are my colleagues Chilean graphic designers trained in colour related matters? What colour issues are taught in graphic design schools? Can anyone recognize the main references for colour learning and teaching? Are these sources available in your libraries? Are these sources available in any of your visited websites? Are these sources available in your language? Are these sources copyrighted or published under some license that allows you to reuse and share?

The research revealed that an important percentage of Chilean graphic designers don't know much about practical colour basics. In addition, the research showed that graphic designers received a poor theoretical colour training, as they were getting the Graphic Design Degree. Therefore graphic designers do not understand the importance of applying colour carefully and their use of colour is based on instinct. This situation showed a change was needed.

2. The project contents development

Based on the results of the informal research, the development of a platform for training in colour was started. During the first stage of development, the most reliable scientific, artistic and academic colour sources were consulted. Publications and books written by Sir Isaac Newton, Johann Wolfgang von Goethe, Wassily Kandinsky, Johannes Itten, John Gage, Josef Albers, Faber Birren, Harald Kueppers, Albert Henry Munsell, Rudolf Arnheim, Eva Heller, among many others, were evaluated.

The evaluation of the references showed the need for an organizational system. The contents and subjects were organized hierarchically; in order to find an appropiated format to present the information. This organization was helped by the definition of some keywords (see Table 1), that preceded the final structure.

Table 1. Example of keywords defined for the project organization.

From the project objectives, Proyectacolor must be:	Some of the contents that Proyectacolor must contemplate are:	The design of Proyectacolor must look and feel:
an starting point	colour (of course)	modern
a colour compendium	didactic exersises	clean
a useful tool	learning objects	interactive
relevant	actual colour information	easy to navigate
applicable to all cases	the new media formats	user-friendly
teaching resources	colorists references	concise

For the second stage of the project development a structure based on four basic units was generated. The units were named: *Colour Theory, Colour Perception, Colour Meanings* and *Colour Application.* Initially, the units were developed with the aim to provide practical colour basics for Chilean graphic design students. However, the content has been extended to Chilean graphic designers, visual artists as well as any other person interested in the subject of colour.

The next stage was to adapt the four basic units to the new media formats. Hundred years of colour circles, schemes and theories, that have explained the study of colour science, were converted to a digital system. The system included the didactic material provided by artists, scientists, chemists, and many others throughout history in an interactive and dynamic format.

Once the four basic content units were completed, including each unit and its corresponding didactic material on media format, a sharing platform was needed. By then, Proyectacolor acquired its final shape, which included three different learning environments: a triad.

2. The project triadic composition

The three different learning environments that Proyectacolor included are:

2.1 Website (www.proyectacolor.cl)

The Website pretends to be a compendium of resources about colour which allows immediate access to the four basic content units. It is also a rapid solution to colour doubts and needs. In addition, it facilitates the practical application of colour palettes for certain colour requirements in a design. The learning environment was developed based on some key concepts: the approach to content display, navigation, interactivity, use of interfaces for educational knowledge transfer and/or simply organizing content. These key concepts were aimed for the application of the four basic units in the learning and teaching of colour.

2.2 Colour Course

The Colour Course (in person) is an eighteen classes program, which can be fully implemented in Arts and Design schools. Also it can be implemented as workshops and modules about colour, providing access to a larger group of users and helping with the dissemination of the project.

2.3 Blended learning objects

The Blended Learning Objects are based on modular, adaptable and interchangeable resources. They provide a visual support and an attractive content implementation for the colour course and the workshops.

The learning triad is based on the theory, closely on the theory, found in the bibliography evaluated. Additionally, it seeks to help the users grasping the knowledge of colour, from the practical management of its interactive nature and techniques, such as experimentation and comparison. It starts from the exercising of human perception, to recognize some new colour knowledge and skills. Additionally, knowing its physical dimensions, harmonious and psychological means to acquire new professional competences for the visual area: important tools for tackling the projects and for applying colour in the own discipline.

Proyectacolor ensures the acquisition of basic colour skills and their application when the three learning environments are operated simultaneously. After the development and implementation of the platform, Proyectacolor has considered the ongoing evaluation of its operation in the three different environments. The assessment has involved comments and surveys from the project users. In addition, continuous testing of the environment and the practical implementation of the resources has led to modifications and improvements.

3. The future of Proyectacolor

Proyectacolor is intended for academics, professionals, and students who know that there isn't another visual resource as powerful as colour[1]. But beyond that, conscious that colour influences our environment and configures our perception, involves complex associations and symbolism, unleashes sympathy or antipathy, and transmits messages with same effectiveness as form, images and typographical or iconic signs. The philosophy behind this project is sharing knowledge in a disinterested way, motivating the users to take an active part in their own colour learning. It also helps to improve the teaching of colour and provides resources to support the related disciplines.

Today, Proyectacolor is consolidated as a reference compendium of practical and theoretical colour resources. It was mainly developed for the local Chilean community, however, we hoped to reach the Latin American community. This affirmation is supported by the spreading of the project through the Graphic Design and Visual Arts community, thanks to the different social networks. These networks had made possible that the users of the project could have shared their impressions, experiences and comments.

In addition, Proyectacolor has been presented in nine conferences, different universities, graphic design schools and institutes of Chile. It was also presented during the past 4th Chilean Biennial of Design. Proyectacolor has also been invited to participate in more than ten colour workshops, such as *Colour Practical Experimentation* and *Colour Language and Interpretation.* Each event with the participation of more than two hundred people. Another useful way to spread the project has been collaboration, supporting, organizating and sponsoring of several events related to visual communication.

There is no doubt that there's a long road ahead for Proyectacolor. There are many things that remain to do, specially when knowing that users have evaluated the project in a positive way. A further step contemplates the printing of some publications and/or a book: some kind of handy compendium about the four basic content units. The future also contemplates the development of

1 Heller, E. 2004. P*sicología del color*. Barcelona: Editorial Gustavo Gili.

printed materials about the Learning Objects, the combination of the existing didactic material with some new interactive media, and the implementation of the platform in some other languages. The road remaining is long, but certainly colourful.

Acknowledgments

The author would like to thank Eduardo Vilches for opening my eyes to colour; Juan Calderón Reyes for the guidance through the process; and finally, Felipe Cortez for his support and encouragement in the development of this project.

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A comparative study on colour & light visualization techniques: architectural models versus full-scale setups

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oral paper

Abstract

In colour design process, various colour visualization techniques are being used by designers. These techniques comprise a wide range of media/tools such as colour chips, coloured drawings, 3D models at different scales, computer aided simulations etc. Architectural space is a more complex context considering its 3-dimensional effects on appearance and perception of colours, under different lighting conditions. Hence, this study was conducted to explore spatial colour design evaluations of a full-scale experiment room representing a working environment, where 30 participants evaluated chromatic and achromatic colour schemes applied on surfaces under two different illumination levels (500 lux and 196 lux on the working surface), via semantic ratings. The colour schemes were also asked to be evaluated as colour chips and coloured perspective drawings. The significant differences were observed between evaluations of the colour chips and the full-scale setups for both illumination levels. Harmony and pleasure set apart under different illuminations of full-scale setups. However, the findings related with the colour attributes (hue, chroma, value) correspondent with; hue and chroma appear more determinative over the adjectives related with pleasantness and arousal, while value appears determinative over spaciousness. The findings of research also supported that, hue and chroma are more effective on evaluating spatial quality.

1. Introduction

Colour is used in interior design for different purposes since it is a flexible and powerful design element that serves as a tool of communication between people and the built environment (Holtzschue L, 2006). Colour plays an important role for the variables of environmental design such as theme, ambiance, image, function, built form, location, and direction. Therefore, the correct use of colour can reinforce users' ability to interact with their environment properly. In addition, colour as a design tool, is relevant for presenting the aesthetical, symbolic or cultural meanings of environments by the appropriate usage of the colour combinations (Smith D, 2003).

The primary aspect for designers to consider for interior colour design is to start with understanding the fundamentals, and from there, to find the ultimate colour solutions for specific design situations. Throughout the design process, designers should consider both the psychological properties of colour and the effects of colour on spatial dimensions. In colour design process, various colour visualization techniques are being used by designers. These techniques comprise a wide range of media/tools such as colour chips, coloured drawings, 3D models at different scales, computer aided simulations etc. The colour visualization techniques are also within the field of interest in colour research. The findings of the studies on comparing abstract media to applied colour(s) in the different fields of design (*e.g.* Osgood CE et al., 1957; Sivik L, 1974; Hogg J et al., 1979; Ural SE, 1995; Taft C, 1997; Ural SE, and Yilmazer S, 2010) show that there are differences in the evaluations of colour(s), besides the similarities.

The results of many studies can provide cues to enhance colour design of interiors, however, as is stated (Kwallek N et al., 1997), "simply viewing colour pictures or slides of interiors were not realistic, so people need to be exposed to real interior environments that can be more representative for subjective evaluations". In this sense, architectural space is a more complex context considering its 3-dimensional effects on appearance and perception of colours (Billger M, 1999) under different lighting conditions (Ural SE, et al., 2006, Yilmazer S, et al., 2009).

2. Experimental Study

In this study it was hypothesized that, colour/colour design evaluations of a space by "subjects" who are shown different abstract media/architectural models would be different than the "occupants" who experiencing full-scale setups. One chromatic and one achromatic scheme with coequal values were used in the experiment. The experiment was conducted as two phases. In the first phase, 30 subjects were asked to rate the colour schemes which were presented as colour chips and coloured perspective drawings of the experimental room. The second phase was carried out in the experimental room that was designed as a simple private office space (Figure 1). The 30 subjects made their evaluations for the two colour schemes under two different illumination levels (500 lux and 196 lux on the working surface), against seven bipolar, five-step semantic differential scales. The scales consisted of harmonious-discord, pleasant-unpleasant, comfortable-uncomfortable, spacious-confined, static-dynamic, exciting-calming and extroverted-introverted.

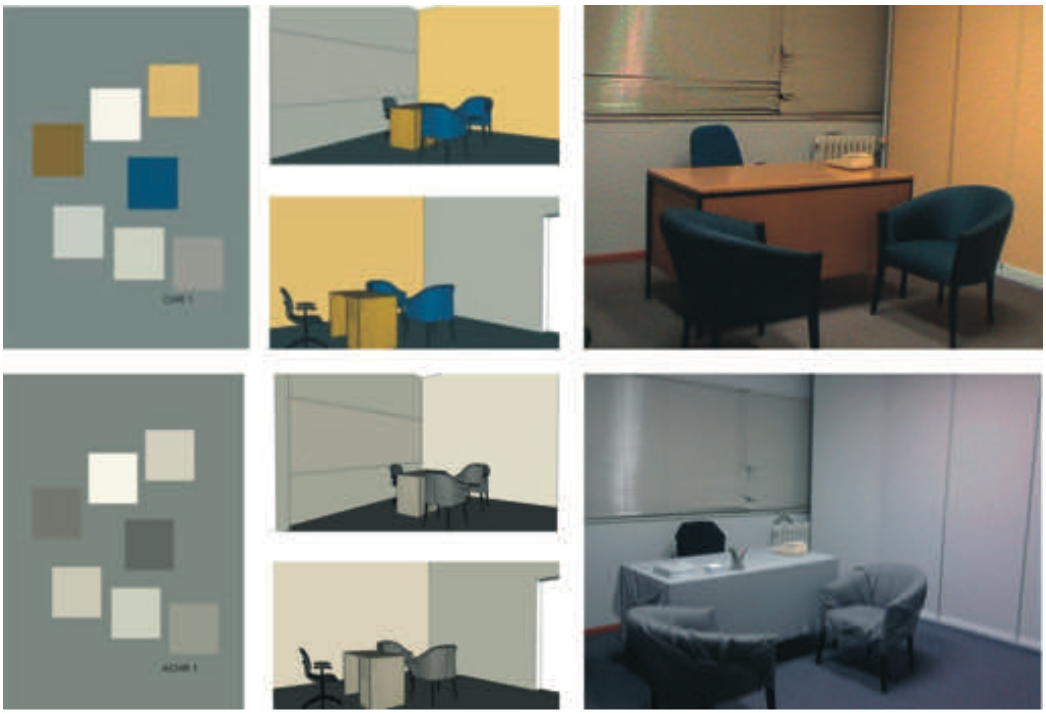

Figure 1: Colour chips, perspective drawings and exprimental room.

Wilcoxon Rank test performed in order to see whether there are any differences:

a) between appraisals of the abstract and contextual media;
b) between appraisals of the visualized and full-scale space and;
c) between appraisals of high and low levels of illumination.

The results showed that the only significant difference between the appraisals of colour chips and perspective drawings was for spaciousness for both chromatic and achromatic colour schemes, although this construct have also meanings independent from “space” in Turkish.

According to the results there are significant differences between the visualized and full-scale space in terms of dynamism, comfort, harmony, spaciousness and introversion for chromatic scheme. The negative and positive ranks explain that the full-scale setup was found more dynamic, comfortable, harmonious, spacious and extroverted. However, for achromatic scheme no significant difference was observed for the appraisals of the perspective drawings and full-scale setup.

The results also showed that, illumination level is very effective over the appraisal of the space. For chromatic scheme, significant differences were observed for all constructs apart from harmony. The chromatic space illuminated with higher quantity of light (500 lux on the working surface), was found more pleasant, dynamic, comfortable, exciting, spacious and extroverted. However, for achromatic scheme significant differences were observed only for pleasantness, comfort and introversion. The achromatic space illuminated with higher quantity of light (500 lux on the working surface), was found more pleasant, comfortable, and extroverted.

The significant differences were observed for all constructs between the evaluations of the colour chips and the full-scale setups under both illumination levels.

3. Discussion

From the results of the study it can be concluded that abstract media can be used as a tool for initial colour-design decisions in architecture, however, scrutinizing colour design through a media simulating contextual characteristics is inevitable during the progression of the architectural colour-design process. Full-scale setups are found articifial by the occupants when it is compared to real life settings. However full-scale setups are still seen as the most appropriate environment for studying colour and ligth relations within the architectural space.

Contradictory to the findings of the previous research investigating two different illumination levels on 3D models (Yilmazer S, et al., 2009), harmony and pleasure set apart for full-scale setups under different illumination levels. However, the findings related with the colour attributes (hue, chroma, value) correspondent with; hue and chroma appear more determinative over the adjectives related with pleasantness and arousal, while value appears determinative over spaciousness. The findings of this study also supported that, hue and chroma are more effective on evaluating spatial quality.

The findings of this study are not only correspondent with the previous research concluded that the level of illumination has significant effects on the appraisals of architectural space, but have further contribution as the results showed that *chroma* appears the most determinative factor over such effects. So it can be said that the technical recommendations (for surface reflectance, for visual comfort and energy saving) which take only *value* into consideration is not sufficient to explain color and light relations in the architectural space.

Acknowledgments

The authors are grateful to Bilkent University, Department of Interior Architecture and Environmental Design in Ankara Turkey, for funding the experimental room. They also like to thank to Çağatay Yılmazer, for his precious help during the experiment.

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Aspects of light: Colour, light and space/form/time

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Abstract

'Colour-as-light', activated as a 'natural light' phenomenon within architectural space/ form/time, helps us to see, both physically/literally and virtually/conceptually, the sunlight that moves within our buildings, through daily and yearly cycles. It reveals sensory information, both material (reflectivity/absorption) and immaterial (shadows/ephemeral glow). It showcases natural light as a 'living', 'breathing', moving environmental element with rich potential for linking human urban experience to the natural world/cosmos.

1. Objectives and Scope

In this practice-based research, experimental installations and commissioned works provide opportunity for observation/documentation. Outcomes situate in the 'real world', and lead to further concrete iterations. Installations explore coloured natural light as a reconnective 'virtual tissue' between urban human life and cosmological patterns. A key objective is the revelation, through colour, of aspects of light in architecture that are largely 'invisible' to our eye/mind when the light is 'white'.[1]

2. Introduction

Natural cycles of lightness/darkness have lost their former hold on the fundamental rhythms of our lives. 21st century urban dwellers live in a 'controllable' or 'out of control' world of artificial light. Many urbanites have limited awareness of nature's solar and lunar patterns.[2] This work explores architecture as a fundamentally 'time-based', 'natural-light-driven' medium – capable of stronger contribution to our experience of and insight into natural patterns, through use of natural light and colour.

3. Experimentation/Methodology

My long-term research/practice has explored architectural 'aperture' as light source, and colour as phenomenological aid to viewing light's movement and effects, across space, form and time. "Colour Chords"[3] was an installation in a *south-facing* line of windows (2' x 24') perpendicular

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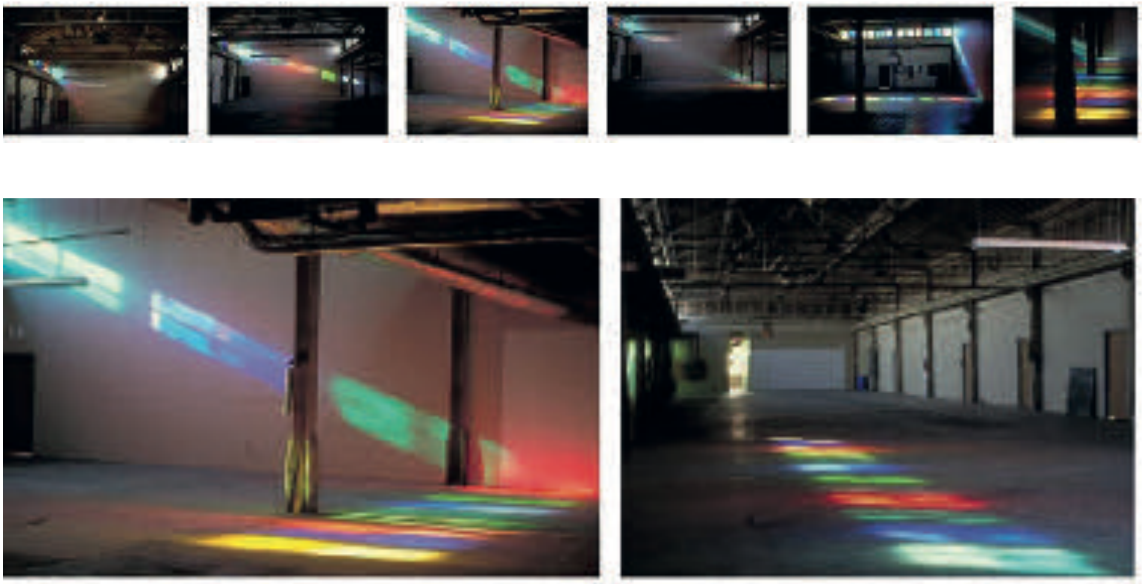
1 This notion of the 'invisibility' of the play of 'white' light is less pronounced, of course, when highly intentional dramatic effects are created by architects - we may think of famed examples ranging from the Pantheon, to Louis Kahn, Steven Holl and Tadao Ando (Ando 2010).

2 A farmer working in the fields has instrinsic knowledge of the changing location and time of sunrise/sunset and sun-angle variance across the year. In a 'pre-electric' culture, moon/stars provided nocturnal patterns for living/ working. Do urban dwellers understand these cyclical patterns? Can our builidngs help them reconnect to rather than obscure natural cycles? Current research points to the importance of light/dark cycles for health/wellness, and the negative impact of ubiquitous night light in cities (Rea 2008). Geograpy, too, has strong impact – e.g. urban areas in proximity to the poles vs. equatorial locales.

3 "Colour Chord Installation", 1400 Dupont, Toronto, Ontario, Canada, 1992 – mouthblown glass installed in 12 windows 2' x 2'.

to and abutting a wall of great height and depth. The wall, along with a 40' x 200' floor space, acted as a projection screen. Sets of colours as 'resonant chords' – four 'chords' of three colours each – made up the linear set. The installation was documented over the course of a year's cycle (Figure 1).



Writing of this work later I noted, "the south facing facade of a building provides a powerful opportunity for work which helps us 'see' the sun's movement across a day and a yearly cycle" (Balabanoff, 1994). Observation and documentation of this project gave tremendous insight into what light was doing in the built form: the first projections appeared on the wall rapidly (early morning, less than an hour); 'stretching' of the squares to increasingly greater lengths occurred as sun rays became more parallel to 'projection wall' plane; movement to the floor plane (parallel/orthogonal) was completed by noon; shifting and angling of the squares into parallelograms occurred along the floor from noon to late afternoon; gradual loss of focus and weakening, and finally disappearance of the projections, ended the day's sequence. There were many other phenomena of note – daily and long-term observation/photo-documentation were my methodologies, along with written notes and explanatory commentaries.

Each subsequent project had different orientations, 'apertures' and built form configurations. In addition, different clients, programmes and users influenced outcomes. Working within a variety of contexts gave longer and shorter observation and documentation opportunities, and led to different strategies for the work. For example, the "Aspects of Light" exhibition[4] (Figure 2) was in place for one month (November), requiring an approach that provided colour phenomena for a gallery visitor who might visit once, for a few minutes, within limited opening hours. By contrast, "Eight Tone Poems"[5], (Fig. 3) a permanent installation for a chronic care facility, required attention to potential impact on cognitively impaired residents and awareness of long-term residency ('home' to some patients for 15 years or longer).

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4 "Aspects of Light", Artspace, Peterborough, Ontario, 1993 – installation mouthblown glass (east/west facing windows), plate glass, galvanized steel frames, gloss and matte painted frames.

5 "Eight Tone Poems", Freeport Health Centre Kitchener, Ontario 1998 – eight 8' x 8' windows, mouthblown glass, acide-etched poems and donor names along corridor/courtyard.

Figure 2 "Aspects of Light"

Figure 3 "Eight Tone Poems"

The most recent project is not a pre-existing building, but a house/studio (Reid and Balabanoff) designed specifically to include a south facing 'aperture' and interior 'projection wall'[6]. The building is conceptually related to the sun's pathway, and the colour/light intervention draws attention to this important aspect of the architecture, while it relates to the surrounding environment and its colour palette.

4. Results/Discussion

If the conventional understanding of window or door is replaced by the notion of '*aperture',* then one may, at least during conceptual design phase of a building, privilege the conceptual 'function' of window or door as *'opening for light'*. This paradigm shift allows renewed focus on light as a critical space/form/time element. Each building site is in *a unique relationship to the sun*, and therefore has *unique opportunities for constructing a relationship to light.*

In the architectural artworks representing my research and findings, the colouring of light increases the visibility and the narrative impact of projected and/or ambient light in architectural space/form/time. The works showcase not only the daily and annual cycles of sun angle and movement through space/time, but also the dynamic and subtle actions of light upon space and form. The *'breathing' of light'* becomes noticeable (gradual shifts of intensity, sudden flares and fluctuations). Diverse geographic locations and atmospheric conditions yield unique light behaviours. As it moves across surfaces and forms, light highlights textural properties, soft and hard reflectivity, planar shifts and form relationships. Complementary coloured shadows are intensified, and challenge viewers to ponder this strange and wondrous phenomenon.

The work points to many possible new directions in intentional and conceptual incorporation of ephemeral and temporal colour as a potent element of space/form/time in architecture and environmental design.

5. Conclusions

Colour can reveal light's role as a carrier of perceptual and conceptual clarity, which is at once powerful and extremely sensitive. Colour helps us see the light that moves within our buildings, which we take for granted, which is 'invisible' to us largely, when it is white. Colour reveals the fluctuating, unpredictable nature of natural light, and showcases natural light as a 'living', 'breathing' 'vital' element of our built environment. Coloured light is a source of deeply satisfying

6 "Silver Arc House", Reid and Balabanoff, 2011, Bayfield, Lake Huron, Ontario

sensual experience that should be explored further in natural light manifestations within architecture.

With colour-as-light deliberately heightened in space/form/time, the story of light in constructed space is revealed, enhancing human experience and interface with the cycles of light which imbue space/form/time with elemental meaning. An understanding and an affiliation with the natural world is gained, which is vital for mental and physical well-being…the potential for further exploration of the power of colour and light in architecture becomes a rich challenge.

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The impact of lighting on perceived quality of fine art reproductions

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oral paper

Abstract

Art reproductions are viewed under various lighting conditions, from the gallery to the museum shop to the living room. It is important, consequently, to understand and quantify the effect of lighting changes. To explore this question, a psychophysical experiment, supported by the Andrew W. Mellon Foundation, was conducted using reproductions of original artwork imaged by three fine art institutions and printed on offset and digital presses.. The experiment generated visual image quality ratings under D50 and 'Horizon' lighting conditions. The results indicate that lighting conditions had a significant impact on the relative rankings, especially for the prints of the historic photograph. For this image, the best renditions under D50 lighting were the worst under Horizon lighting and vice versa. This suggests that prints made to match under one lighting specification may look 'just wrong' under another. Also, far fewer prints were considered acceptable reproductions of the original under Horizon lighting, which is not surprising since the digital files were created assuming a D50 workflow.

1. Introduction

A project funded by the Andrew W. Mellon Foundation was recently completed investigating current practices in fine art reproduction. As part of this project, the effect of lighting conditions on the perceived quality of fine art reproductions was examined. Please visit http://artimaging.rit.edu/ for additional project reports and information.

2. Experimental methodology

An experiment was conducted using printed reproductions of two oil paintings, 'Daisies', 'Night Sky', a paint 'Checker' target, and of an historic photograph, Figure 1. The 'Daisies' painting is a relatively light, or high-key, scene. The 'Night Sky' painting, which features a mixture of blues, was included because research has shown some blues are difficult to reproduce due to the differences in the way the camera and the human eye "see" certain blue pigments, especially cobalt blue. [Berns, 2000] The paint 'Checker' target was constructed for this study by performing draw-downs using the same paints used to make the oil paintings. Patches were clipped from the most uniform areas of the draw-downs for use in the target. The photograph was included to expand the range of media and to represent monochromatic art such as early photography and works on paper, which, according to personnel in the Imaging Department of a major cultural heritage institution, can be surprisingly difficult to acceptably reproduce.

Three major fine art institutions participated in this study. Each institution delivered digital files and information regarding its workflow. If the institution normally would provide guide prints to their print service providers, they were to supply them for this study. Guide prints are often generated as part of the art image reproduction process to give the print shop direction on how the color and contrast of the printed image should appear under specified lighting conditions. Prints from the digital files were then generated on the Heidelberg Speedmaster at the Rochester

Institute of Technology following the ISO 12467 protocol. The same press operator conducted all of the print runs. An additional run was made on an electrophotographic on the same paper used for the offset run. With print sets made on the offset and electrophotographic presses for each of three institutions as well as visually adjusted prints made for two institutions, eight reproductions were made for each artwork.

Fig. 1: The artwork used in the study: Photo, Daisies, Night Sky, & Paint Checker.

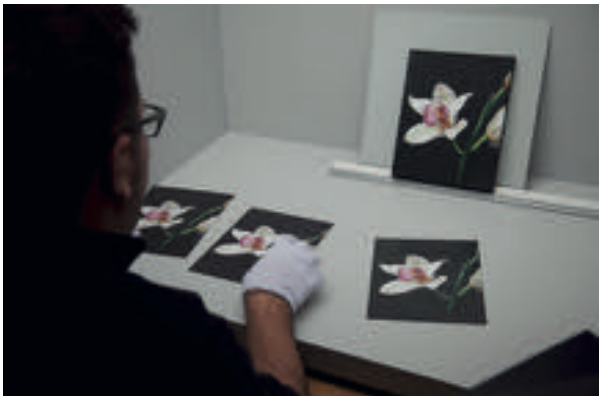

Fig. 2: The experimental setup in the D50 light booth.

For the institutions providing guide prints, adjustments were made on the press by the researchers under D50 lighting conditions to achieve a closer visual match. Only small adjustments were possible on press. Most of the initial print runs produced prints that closely approximated the provided guide prints.

The experiment was conducted under two lighting conditions: D50, Figure 2, and the 'Horizon' lighting setting of a Macbeth viewing booth. A D50 light booth was used because this is the standard lighting condition in graphic arts workflows typically used in printing production. The Horizon lighting condition was chosen because its warm light (similar to Illuminant A) is more representative of that generally used in galleries.

Using the prints made from the delivered digital files, a psychophysical experiment was conducted to generate visual ratings of image quality. The experiment followed a rank order procedure in which each of the 16 participating observers were asked to rate the reproductions from the worst to the best representation of the original artwork. When all eight prints were ranked, the observers were asked which prints they would consider acceptable reproductions, if any. The testing was repeated in each light booth, with the order of the viewing conditions randomized for each observer.

3. Results and discussion

The results of the psychophysical experimentation conducted are shown in Figures 3-9. Figure 3 shows the mean rankings that the observers assigned the reproductions of the image set for each workflow and under each lighting condition. Please note that, in this experiment, the best reproduction was assigned a value of '1' and the worst perceived reproduction received a value of '8', making lower ranking values indicative of better reproduction. The data plotted for W1-W3, W4-W5, and W6-W8 represent the workflows for the three participating institutions. W1, W5, and W6 represent the reproductions made using the electrophotographic press. W2, W4, and W7 represent the reproductions made following the ISO 12467 protocol. And W3 and W8 represent the reproductions made by visually adjusting to the guide print during the print run. These results indicate that, when the rankings are averaged over the entire image set, there is little statistically significant difference for any of the prints under the D50 lighting conditions though the W2 'numbers' workflow may be slightly better than two of the 'digital' workflows, W5 and W6. Under the Horizon lighting condition, however, the W1 'digital' workflow and the W4 'numbers' workflow were significantly better than the other workflows and the W8 'visual' workflow was significantly worse.

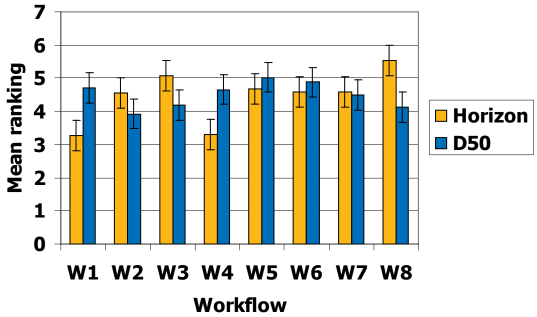

Fig. 3: The mean rankings for prints made using eight workflows averaged over all four images.

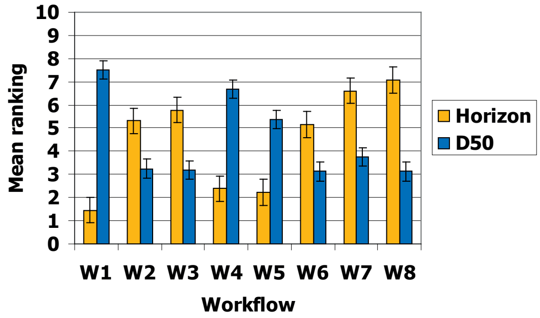

Fig. 4: The mean rankings for the prints of the historic photograph.

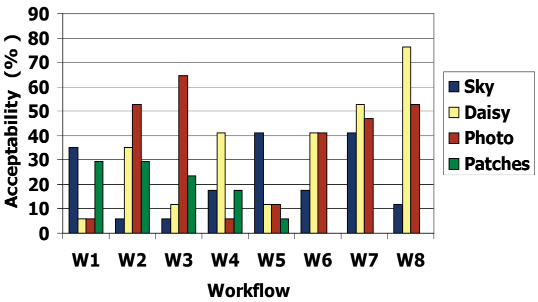

Fig. 5: The percent of the observers that found each print made using the eight workflows to be an acceptable representation of the original when viewed under D50 lighting conditions.

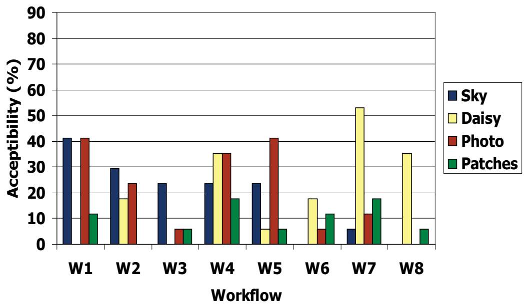

Fig. 6: The percent of the observers that found each print made using the eight workflows to be an acceptable representation of the original under Horizon (CCT of 2323K) lighting conditions.

The results for the 'Daisies' image indicate that the change in lighting had only a minor impact on the relative workflow rankings. For the 'Night Sky' and 'Paint Patches' images, more of the workflows were ranked statistically different under the two lighting conditions. However, the largest effect of the change in lighting conditions occurred for the historic photograph, as can be seen in Figure 4. For this image, the best renditions under Horizon lighting; W1, W4 and W5, were the worst under D50 lighting. The prints from the remaining workflows were equivalently good under D50 lighting and equivalently bad for Horizon lighting (though W7 and W8 were a little worse than the others). All of the renditions were statistically significantly different under the two lighting conditions. This is a key finding of this experiment. It suggests that prints made to match under one lighting specification may look 'just wrong' under another lighting condition. It is an important point to understand when considering where prints will be evaluated and what viewing illuminant to specify in the print workflow.

Figures 5 and 6 show the acceptability results under D50 and Horizon light conditions, respectively. The results shown in Figure 5 indicate that the 'Daisies' and 'Photo' prints are more consistently found to be acceptable than the 'Night Sky' and 'Paint Patches' prints. Five of the workflows for both the 'Daisies' and 'Photo' images yield prints that are acceptable to about a third or more of the observers, with the W8 workflow having the highest percentage of observers, about 75%, finding it acceptable for the 'Daisies' image and W3 having the highest percentage, at over 60%, for the 'Photo' image. The 'Night Sky' image only has three workflows with an acceptability rate of over 30% while the 'Paint Patches' image has none, though W1 and W2 are close. It is interesting that, though the paint patch reproductions used to create the images are rarely found to match acceptably with the original paints, the reproductions of scenes created with those paints can be found to be acceptable three quarters of the time, for a given painting; and for a given viewing condition.

The results in Figure 6 indicate that far fewer print renditions are found to be acceptable under the Horizon lighting conditions. Only three print renditions for the 'Daisies' and 'Photo' images and one rendition for the 'Night Sky' image are found to be acceptable by more than one-third of the observers. And the print found to be acceptable at a highest rate was only found to be acceptable just over 50% of the time. This result makes sense given that the image files were created under the assumption that the prints would be evaluated under D50 lighting conditions. This is another important result of this testing; prints are viewed under lighting conditions other than that specified in the print workflow may be found to be unacceptable reproductions of the original more frequently.

4. Conclusion

The key findings of this experiment were that prints made to match an original under one lighting condition may be clearly unacceptable under another and that prints that are viewed under lighting conditions other than those specified in the workflow are more likely to be considered unacceptable reproductions. These are important points that must be kept in mind both when capture files are created and, even more so, when they are being evaluated. Files created for a D50 workflow that are modified as a result of evaluation in gallery lighting may produce disappointing results.

5. Acknowledgments

The authors would like to thank the Andrew W. Mellon Foundation for their support of the Current Practices in Fine Art Reproduction project of which this experiment was a part. We would also like to thank the participating fine art institutions for taking the time to capture and prepare the image files and all of our observers for spending some of their valuable time in our lab.

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Effect of observers' property on KANSEI impression of blackness in artistic digital images

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Abstract

In this study, we investigated the effect of observer's property on *Kansei* impression of blackness in artistic images by comparing the results of two observer groups, students in the Department of Engineering, and students in the Art Education Course. In the first experiment, we investigated the relation between blackness perception and the RGB values of color images of lacquer ornaments, secondly we explored how the blackness of black area contribute to *Kansei* impression of those images using Semantic Differential method. Finally, in the third experiment, we first obtained a relation between perceived blackness and luminance contrast between the central blackish field and the surrounding field using a simple concentric circular configuration, which is called a 'blackness matching box', and then measured perceived blackness in digital images of masterpieces using the blackness-matching box. All results indicate that observer's interest, knowledge, and experience on arts affect on the perception of blackness, especially in the images with artistic contents.

1. Introduction

Kansei is a Japanese word meaning a 'mental sense of subjectivity', being a higher order function of the human brain. For example, abstractive paint by Paul Klee would give strong impression to some observers, while it is nothing more than a color pallet to other people. We say the former observers have high sensitivity of *Kansei* in color and arts, while the latter observers do not. Generally, it is independent of the level of intelligence.

Role of blackness is important for image reproduction. To investigate the effects of observers' property on *Kansei* impression of blackness is also important in digital imaging of artistic contents. Although many psychophysical approaches have been published on the perception of blackness (Cicerone et al. (1986), Shinomori et al. (1994), Shinomori et al. (1997)), no study has been carried out on the issue. The aim of this study is to investigate the effects of observers' property on blackness perception in artistic images.

2. Two groups of observers

Two groups of observers, "Engineering Students" consisted of students in the Faculty of Engineering, and "Art Students" consisted of students in the Art course in the Faculty of Education participated the experiments. In Experiment I and II, twenty Engineering Students, and sixteen Art Students participated as observers. In Experiments III, ten observers for both groups participated as observers.

3. Experiment I. Measurement of the BB and RB levels

In the first experiment, color images of Japanese lacquer art were used as test stimuli. Figure 1 indicates the experimental procedure with an example of the test stimuli. Observers were instructed to adjust the RGB values in the area of black surface of the lacquer art to determine the two levels of blackness. The first level is the border below which observers see the blackish area as "black" which we call the "BB" level abbreviating a Beginning of Black. The second one is the border below which observers perceive the areas as really black which we call the "RB" level abbreviating a Real Black. The RGB values of other areas such as background or pearl ornament were kept constant.

Results are shown in Figure 2, where gray and black symbols denote the RGB values of the BB level and the RB level, respectively. Different symbols indicate the results of different images. As shown in Figure 2, the RGB values of the BB level for the Art Students are lower than those for the Engineering Students indicating that the Art Students have more severe sensitivity in judging the category of "black". On the other hand, the RGB values of the RB level for the two groups are about the same. It is indicated that to have observers perceive an area as really black, the RGB values of black area have to be lower than 20 which corresponds to approximately 0.01 cd/m^2 (Eda et al. (2010)).

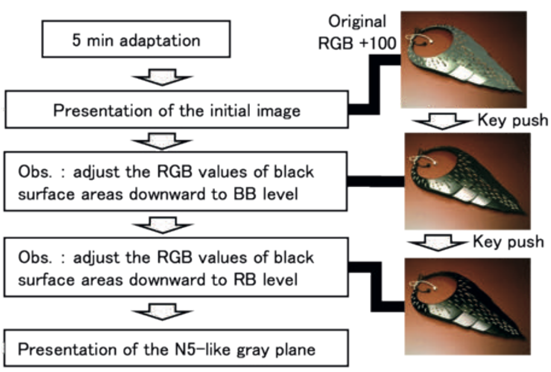

Figure 1. Procedure of Experiiment I

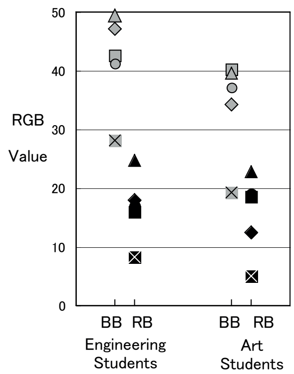

Figure 2. Results of the BB and RB levels for the two observer groups

4. Experiment II. Subjective evaluation using SD method

The second experiment investigated how, and to what degree the RGB values of black areas affect the visual impression of an artistic picture. Five pictures, identical to those used in Experiment I, were employed as test stimuli. From each of them, five test stimuli were developed in which the mean RGB values of the black surface areas varied from the original one (+10, +30, +60, 0:original, and -20) as shown in Figure 3. Thus, 25 test images were used. They were randomly presented and subjectively evaluated using the semantic differential (SD) method with 30 adjective pairs. Figure 4 shows the result of adjective pairs of "Luxury vs Cheap" and "Vivid vs Subdued". Amplitudes between the highest and lowest scores are larger in Art Students than those in Engineering Students indicating that the former is more sensitive in *Kansei* evaluation of blackness.

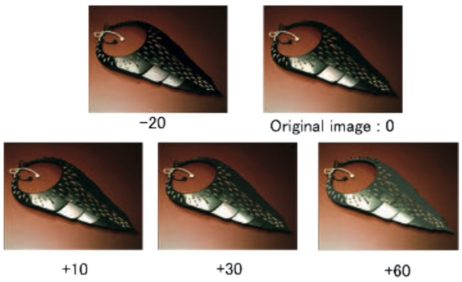

Figure 3. Test stimuli of Experiiment II

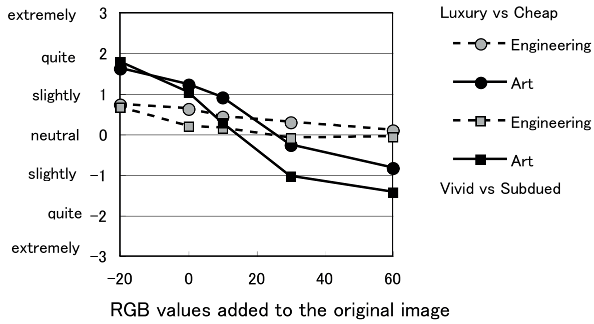

Figure 4. Results of two ajective pairs.

5. Experiment III. Evaluation of blackness in masterpieces

We conducted two experiments here. First experiment was to obtain a measure of blackness perception in a simple stimulus configuration as shown in Figure 5. We constructed a blackness matching box (BM box) in which concentric circles, the central black area (L_c cd/m^2) and surrounding gray or white area (L_s cd/m^2), can be seen by observers. Using the BM box, a basic relation between perceived blackness of central area and the luminance contrast between center and surround (L_s/L_c) was investigated. Results are indicated in Figure 6. No significant difference was found between the two groups.

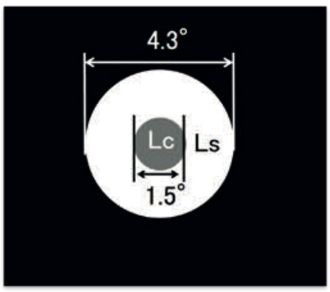

Figure 5. Visual field ofbBlackness matching box

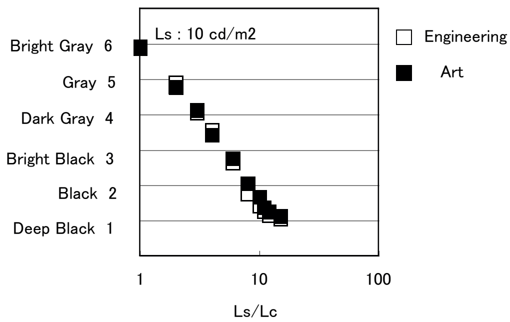

Figure 6. Relation between perceived blackness and luminance contrast Ls/Lc

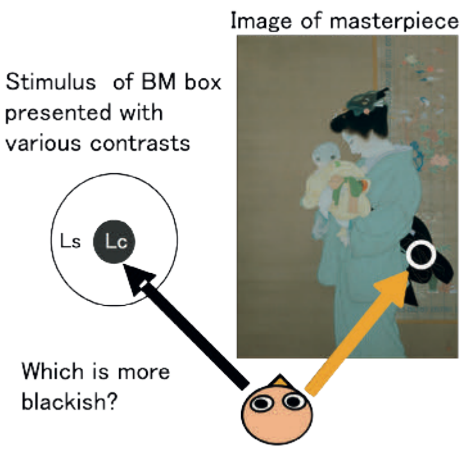

Figure 7. Schematic diagram of blackness comparison

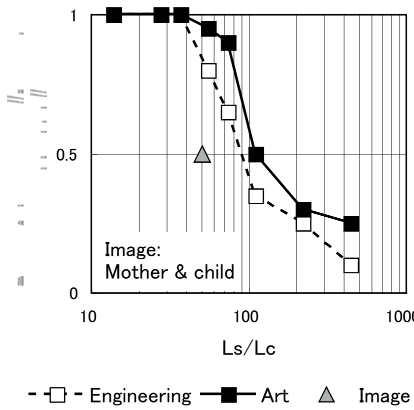

Figure 8. Results of Experiment III

Second experiment was to evaluate perceived blackness of blackish area in images of masterpiece. Our interest is whether any difference is found between the results of Art Students and Engineering Students. Method of constant stimuli was employed to avoid the ceiling effect caused by the limitation of the apparatus. Concentric circle stimulus was presented with a variety of luminance contrast between center and surround using the BM box. Observer was asked to pay attention to the black area in the masterpiece image denoted by a circle, and to judge which is more blackish, the BM box, or digital image, as schematically shown in Figure 7. More details are described in Eda et al. (2009).

When the blackness in the masterpiece images was evaluated, results of both groups showed enhancement of perceived blackness in the masterpieces, i.e., being matched by larger luminance ratio of BM box than the real luminance ratio of the masterpiece images indicated as gray triangle in Figure 8. As shown in Figure 8, the degree of enhancement in the Art Students is larger than that in the Engineering Students.

6. Summary

Perceived blackness in the artistic digital image and the effect of observers' property were investigated in three experiments. Results indicated that observer's interest, knowledge, and experience on arts affect on the perception of blackness, especially in the images with artistic contents.

Acknowledgments

This research is supported by the Grant-in Aid from the Japan Society for the Promotion of Science (No.19500173 and 22500184), and the Eminent Research Selected at Utsunomiya University in 2009-2010.

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Evaluation of the performance of reflective e-books under different illuminations

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Abstract

The performance of reflective black-and-white and colour e-books under varying illumination conditions was evaluated and compared with hardcopies in this study. Physical measurement identified the specification of e-books. A psychophysical experiment was carried out to evaluate the performance of the test e-books in two categories, i.e. image quality and readability (included legibility, text resolution, and text quality). The results showed contrast had significantly effect on image quality, text quality, and perceived text resolution. Using LEDs to view a colour image on display media was at least as good, if not better than using traditional CWF. There was no significant effect on legibility for media or illuminations.

1. Introduction

The reflective e-book (electronic book) medium has become a popular imaging device in recent years. It is anticipated that it will replace some of traditional paper media such as newspapers and magazines in the near future. The advantages of e-book readers include their low power-consumption, portability and reuse. It is thought that changes of illumination conditions (colour rendering, efficacy) and viewing geometry possibly influence the visual performance of reflective e-book readers. The aim of this research was to evaluate the performance of two types of reflective e-books, i.e. black-and-white e-book (B/K e-book) using electronic ink and colour e-book using Cholesteric Liquid Crystal, under varying illumination conditions. Furthermore, the performance was measured in comparison with hardcopy outputted by inkjet printers. Several measuring items were used to character e-books in physical measurement. A psychophysical experiment was carried out to evaluate the visual performance of the test e-books.

2. Physical measurement

Physical measurement identified the specifications of the test reflective e-books. The contrast ratio, chromaticity of peak white, colour gamut, tone response curves, and luminous non-uniformity were measured. The detailed specifications of the test e-books are shown in **Table 1** and **Figure 1 (b).**

Table 1 Specification details of test e-books.

E-book		**B/K type**	**Colour type**
Contrast ratio		8.6:1	3.4:1
Luminous non-uniformity (△L*)		1.5	2.5
Screen resolution		150 dpi	150 dpi
White point Chromaticity	Light source: ACLED	(x, y)=(0.3684, 0.3417)	(x, y)=(0.3671, 0.3328)
	Light source: RGBLED	(x, y)=(0.4018, 0.3678)	(x, y)=(0.4134, 0.3663)
	Light source: RGBACLED	(x, y)=(0.4012, 0.3749)	(x, y)=(0.4104, 0.3734)
Color Gamut [a]	Red		(u', v')=(0.1764, 0.4242)
	Green		(u', v')=(0.1850, 0.5194)
	Blue		(u', v')=(0.2491, 0.4956)

[a] CIE u' v' chromaticity coordinates under D_{65} illuminant

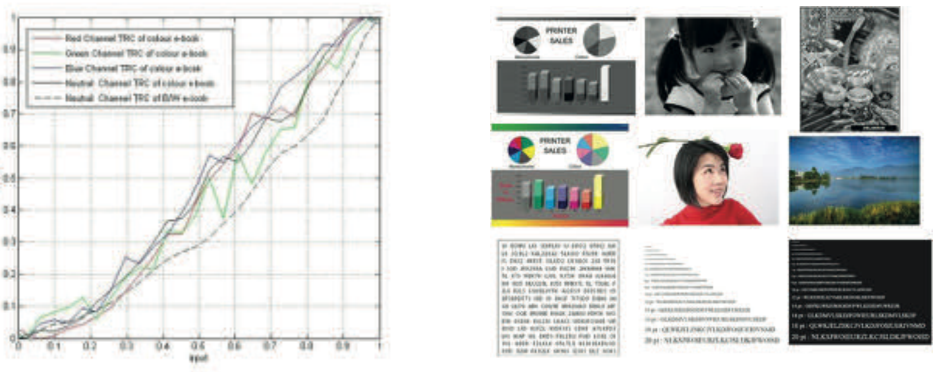

Figure 1 (a) Tone responce curve (TRC)of test e-books. (b) Test images and test charts.

2. Psychophysical experiment

2.1 Experimental design

The experiment evaluated four independent variables, *illumination*, *display medium*, *contrast*, and *resolution*. There were four light sources were used: a 3-primary colour LED (red, green, and blue, RGBLED), a 5-primary colour LED (red, green, blue, amber, and cyan, RGBACLED) , an ACLED (LEDs driven with alternating current), and a CWF (Cool White Fluorescent). Illuminance and CCT (correlated colour temperature) of all illuminations were set in 800 lux and 3600 K. Display media included a b/w e-book, a colour e-book, and hardcopies. Two kinds of paper were used, glossy paper and matte paper. Hardcopies printed by a high-end inkjet printer were produced to simulate 3 contrast levels to match the test e-books individually. The hardcopies with high-contrast were printed by the inkjet printer only using black ink. The middle-contrast hardcopies were printed to match the contrast of the B/K e-book. Low-contrast hardcopies were also printed to match the contrast of the colour e-book. The resolution of all hardcopies was set to 600 dpi. There were 7 medium conditions, i.e. b/w e-book, colour e-book, high-contrast glossy hardcopy (HC_Hardcopy), middle-contrast glossy hardcopy (B/W_Glossy), middle contrast matte hardcopy (B/W_Matte), low-contrast glossy hardcopy (Colour_Glossy), and low-contrast matte hardcopy (Colour_Matte).

2.2 Task and procedure

Visual performance was evaluated in two categories, i.e. image quality and readability. Image quality included two sections, i.e. B/K image quality and colour image quality. Besides, readability was also checked according to three sections of 'legibility', 'text resolution' and 'text quality'. Totally 75 participants (i.e. 15 participants in each section) were randomly assigned to the whole experiment.

For evaluating image quality, six test images (i.e. 3 B/K images and 3 colour images) were used to evaluate B/K image quality and colour image quality respectively. There were 6 attributes to identify image quality, i.e. contrast, sharpness, brightness, detail, naturalness, and business chart legibility. Participants expressed their evaluation on the attributes using categorical judgment. The categorical judgment method used equal interval scales between '1' (lowest quality) and '10' (highest quality). Legibility was evaluated by target searching via reading pseudo-text. The target characters were randomly embedded in the pseudo-text. Participants were instructed to read the text and identify the targets as accurately and quickly as possible. Text resolution and text quality were evaluated by text charts. The text charts included two types of appearances, a positive mode and a negative mode. The text charts included 15 different font sizes of characters (i.e. - 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, and 20 points). Participants identified just recognized-font-size characters as text resolution. Text quality was also assessed by participants using categorical judgment. All of test images and test charts are shown in **Figure 1(b)**.

2.3 Result

For image quality, the results of analysis of variance showed that medium condition had a statistically significant effect for image quality (B/K image quality: $F(3, 3584)=664.743, p<0.000, \eta^2=0.358$; colour image quality: $F(3,3584)=1184.726, p<0.000, \eta^2=0.498$). **Table 2** shows a high-contrast hardcopy example of post hoc test with Tukey HSD. The statistical difference is, however, due to a significantly higher perceived quality of the high-contrast hardcopies compared to the other medium conditions. In other words, contrast had a significant effect for image quality. The light source didn't have a statistically significant effect on B/K image quality for media ($F(3,3584)=1.686, p=0.168, \eta^2=0.001$). However, the light source had a statistically significant effect on colour image quality for media.

For legibility, the results of the analysis of variance showed that there was no statistically significant difference on display medium (searching time: $F(6,392)= 1.172, p=0.32, \eta^2=0.018$; accuracy: $F(6,392)=0.601, p=0.729, \eta^2=0.009$). In other words, both contrast and resolution did not have a significant effect on legibility. Illumination did not have a statistically significant effect on accuracy ($F(3,392)=2.021, p=0.110, \eta^2=0.015$). Illumination had a statistically significant effect on searching time ($F(3,392)=3.513, p=0.015, \eta^2=0.026$). Participants spent less time finding targets under ACLED than RGBLED. For text resolution, the analysis for text resolution showed that medium condition had a statistically significant effect on text resolution ($F(6,392)=23.288, p<0.000, \eta^2=0.263$). In other words, contrast of media had a significant effect on text resolution. There was no statistically significant difference between the resolutions of 600 dpi and 150 dpi, for test samples having the same contrast (shown in **Figure 2 (a)**). Illumination did not have a statistically significant effect on text resolution ($F(3,392)=0.796, p=0.496, \eta^2=0.006$). In additions, for text quality, the analysis showed that medium condition had a statistically significant effect on text quality ($F(6,392)=77.596, p<0.000, \eta^2=0.543$). Again, this difference was due to contrast differences (shown in **Figure 2 (b)**). Illumination did not have a statistically significant effect on text quality ($F(3,392)=1.319, p=0.268, \eta^2=0.01$).

Table 2 The post hoc test with the high-contrast hardcopies.

Independent variables	n	Mean	Std. Deviation	Variance	Turkey HSD groupab
B/K image quality					
Display Medium					
HC_Hardcopy	900	7.9	1.32	1.76	A
B/W_E-book	900	5.79	1.49	2.24	B
B/W_Glossy	900	5.31	1.59	2.55	C
B/W_Matte	900	5.05	1.59	2.54	D
Colour image quality					
HC_Hardcopy	900	8.24	1.14	1.31	A
Colour_E-book	900	5.95	1.6	2.57	B
Colour_Glossy	900	4.88	1.51	2.283	C
Colour_Matte	900	4.58	1.49	2.23	D

[a] α =0.05

[b] Values with the same letter are not significantly different.

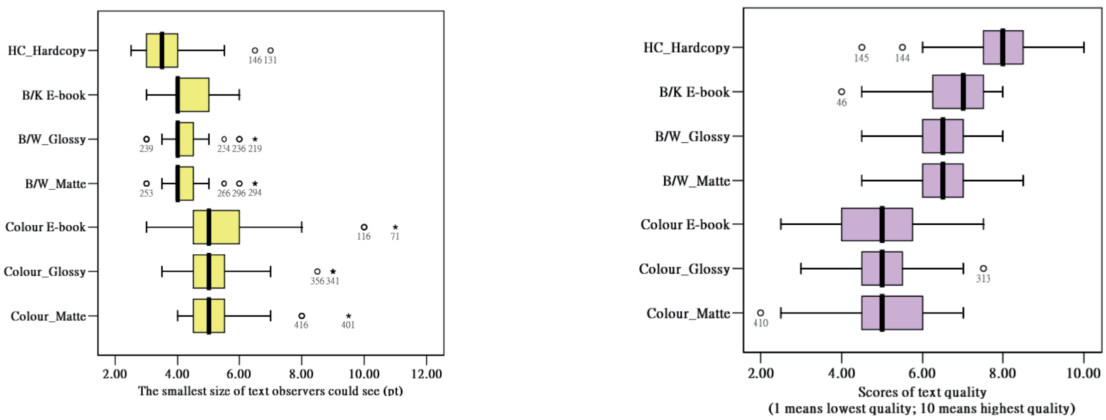

Figure 2 (a) Results of text resolution shows the smallest texts observers could see. (b) Results of text quality shows the evaluating scores observers gave.

3. Conclusion

In conclusion, the ergonomic evaluations of black-and-white and colour e-books in this work revealed that the current specification of resolution is good enough to compete with office paper for reading. However, the current contrast still needs to be improved for both text reading and consumer picture showing. Using LEDs to view a colour image on display media is at least as good, if not better than using traditional CWF. This evaluation of the e-book media may provide manufacturers useful information to improve the performance in fulfilling ergonomic requirements for product design.

Acknowledgments

This paper was supported by Philips Research Europe in Eindhoven during March 2010-September 2011.

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Sparkles, colours and other light effects.
The problem of the photographic reproduction of mosaic

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Abstract

The paper deals with the photographic technologies and the history of the art publishing in colour. The main aim is to discuss the role of colour and light in mosaic alongside the application of colour photography and colour printing in reproducing mosaic.

1. Mosaic surfaces

A famous epigraph, in the Archbishops' Chapel, a small but important Unesco Monument in the city of Ravenna (Italy) decorated in mosaic between the end of the fifth and the early sixth century a.C., describes the strict relationship between the light and the mosaic. It is written: "Aut lux hic nata est, aut capta hic libera regnat". That sounds like: "Either light was born here or, captured here reigns freely". In this sentence the term "light" conveys a religious message, it is a divine light, but it is also related to varied possibilities of visual perception. The perception of light implicates the perception of divinity.

The Byzantine wall mosaics are characterized by the use of small pieces - tesserae - of glass, marble and other materials, vividly coloured, with uneven surfaces due to the hand cutting of them. David Batchelor, describing gems and precious stones, the main value of which - he maintains - consists in their glittering and brilliant appearance, speaks about the fact that the colour plays an active role. "Here, colour is active; it is alive. Colour projects; it is not a passive coating of an inert object; light appears to shine from within; colour seems to have its own power source": Batchelor (2000). This idea could be easily applied to mosaic surfaces.

Moreover glass, marble, enamels, glazes preserves their colour more permanently than how other artistic materials and techniques do; for example fresco, tempera, oil, ink... The permanence of the colours has been considered one of the main aim of the mosaic technique and one of its most important value. Age-long images made of precious stones, marble, glass, gold and silver.

A wall mosaic surface is thus characterized by the presence of different kinds of materials. Each of these materials show its own optical and perceptual features. Several degrees of gloss and transparency can be observed. Pebbles and stones appear matt due to the diffusive reflection of incident light. Glass tesserae and glazes have a high gloss degree, also they can appear more or less transparent. Marble cubes show a sparkled surface due to the sugary brilliance of the crystals. The metal leaf tesserae have a light reflection almost similar to that of a mirror.

As the epigraph recalls, a mosaic surface interacts in a complex way with the incident light due to two main causes. The first one is that the surfaces, often, are not plane; arches, vaults and apsidal conchs are amongst the favourite architectonic parts of sacred buildings to be decorated. The second one is that each single cube has a different inclination angle with respect to the surface. Thus a mosaic surface produces many different incident and reflected light angles. This increases the sense of preciousness of the image, a glittering and high glossy vision. The role of the observer is also very important, indeed the gold and silver tesserae and the high reflective glass tesserae sparkle as the viewer moves around within the building. As Liz James recalls, in an article titled What colour are Byzantine Mosaics?, these features of mosaic were clearly acknowledged by contemporary observers: “The aspect of colour stressed include texture, lustre, and transparency... Text from IV to the XV centuries concentrate on aspect such as iridescence and the shining, gleming qualities, conveying a sense of luxuriance and elation and the dynamism of colour through its concern whit flowing, changing effects”: James (2000).

Then he adds: “Light can be reflected in a variety of ways; indeed, in different light, the same mosaic may appear completely different in its colours and visual effects”: James (2000).

2. Mosaic surfaces and photography

What happens when the colour photography meets the mosaic? What happens when it has to reproduce a mosaic surface? How the moving sparkles and the other light effects are reproduced in photographic and photomechanical printings or in digital screens?

The colour plate published by the Italian publisher Istituto Italiano d’Arti Grafiche could be considered among the first colour reproductions of mosaic by means of photography. Musaicisti ravennati is an issue belonging to the series called I grandi maestri del colore, published between the third and the fourth decade of the Twentieth Century. In this type of publication the images do not illustrate the text, instead the text furnishes the images. Its main features are: large format, in folio or in 4°, a limited number of pages (eight to ten), short texts, the biography of the artist or a historical and critical text to introduce the artistic movement, six to eight full-colour plates on the right hand pages, with the titles and a short critical description of the works of art on the left hand pages. The images are printed using the three or four colour process on separate sheets of paper and then glued to the pages.

The recording of the colour of mosaic by means of three colour process, through the ordinary filters, red, green and blue, was really difficult at that time. Due to the low sensitivities of the photographic emulsion and to the complex surface of the mosaics, several retouches, corrections, maskings of the negatives and of the printing matrices, addition of matrices, ware necessary. Also the distance played an important role. Taking an image of a huge mosaic panel, five meters far, involved the difficulty to resolve the details of each single tile and therefore the loss of the textural features.

The final printed results appear closer to graphic reproductions of watercolour rather than photographic reproductions of mosaic. Flat surfaces instead of texture surfaces. Even if this reproductions appear really different from the original mosaics and from more accurate reproductions, however they show an inner consistency.

A thoroughly widespread printing feature is that of the gold paste pigment applied as an ink in reproducing details originally realized with gold leaf applications. In order to increase the sense of realism of the colour reproduction, the gold tesserae of the mosaic were printed in gold, bronze, copper paste pigments, directly on the sheet of paper, side by side with the dots in cyan, magenta, yellow and black ink of other image details, such as those of glass, marble or stone cubes of the mosaic. This finds a parallelism in contemporary printing processes of reproduction of frescoes or tables where the gold leaf of backgrounds and saints’ halos of the originals were realized in the same way.

Since 1951 Albert Skira, one of the leading art publisher in colour, has published the series Les Grands Siecles de la Peinture, entirely illustrated in colour. The issues are dedicated to the most important themes of the art history. The colour plates are printed in separate sheets of paper and glued within the text. The issues measure 29 cm height. Great skills has been paid in order to realize high quality images according to the contemporary technological possibilities. The gold tesserae are printed in gold paste ink, the flattening effect is partially reduced in comparison to the publication previous mentioned even if the tesserae appear completely uniform, instead of their high variability in inclination, positioning, cutting, light reflection. The tesserae better reproduced are that of lighter and less saturated colours. The greens and the reds appear retouched, printed over. Sometimes the retouches can be seen as a Warhol features: colour going beyond the borders.

Silvana Editoriale is an important Italian art publishing house founded in 1948 by Amilcare Pizzi, the activity of which, in the graphic art industry, began in 1914. It focused on high quality art books, illustrated almost completely in colour. Amilcare Pizzi personally realized numerous photographic campaigns. Several large format series have been published. Among them it could be found books dedicated to mosaic themes, such as the volume on the Byzantine monuments of Ravenna. In printing, the gold paste ink plays again an important role. In a frontispiece it could be read as advertisement: “Forty-five plates in original colours and golds”. Gold paste ink is considered an important tool to get accurate reproduction. Silvana Editoriale is moreover the printer of the UNESCO world art series. A very large format volumes, 49 cm height, published in collaboration with the New York Graphic Society.

As regard with mass market distribution of colour reproductions of artwork, it is only since the sixties that the publishing have entered in its mature stage. The Italian publishers Fratelli Fabbri, Sansoni, Rizzoli and others have started to publish long run series such as Forma e Colore, I Maestri del Colore, I Classici dell’Arte, sold at very reasonable cost. The colour plates, realized by means of the newest technologies, modern photographic films, electronic scanning for colour separations, appear sometimes worse than the previous releases.

Even though Byzantine mosaics are strictly related to the building structure, the most part of these reproductions show each single scene, or some details of them, cut off from the context. One of the last possibility derived from the application of the digital technologies to the reproduction of work of art is that of virtual tour inside the monuments. Shooting panorama images and then treating them with specific softwares allow the observer to move around a point in each direction, just clicking mouse, far or near the walls of the building and their decoration, mosaics, frescos, paintings. In the case of mosaic decorations, even if the enlargement does not usually allow to see each single tessera, the richness of the surface is well rendered due to the high precision and sensitiveness of the modern digital cameras.

The digital capture devices and image processing are currently used in order to create High Dynamic Range images. The procedure may be described as follows. Multiple exposures of the same scene are merged in a single file in order to capture all the luminance range, from the darkest shadows to the highlights. The dynamic range of the image obtained cannot be displayed by the traditional output devices, hence the image has to be processed. The wide range of intensities found in a HDR image has to be compressed into the limited range generated by a conventional display device.

Tests has been carried out using a reflex digital camera Canon Eos APS-C and a tripod. Three shots have been taken at different exposure values -2, 0, +2. The images have been merged and processed using commercial software, Photomatix and Photoshop. The test’s primary objective is that of exploring the possibilities of developing a methodology that could be used to realize cheap, easy-to-do and “accurate” images.

The advantages of employing HDR photography instead of traditional can be explained taking in consideration two kind of scenes to record: 1) images taken in complex ambients such

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as apsidal conchs, where windows and decorated columns are intercalated, where thus the light distribution is characterized by strong contrast between highlight and shadows; 2) images of mosaic details where each tessera has its proper surface features and its way of interacting with incident light. The High Dynamic Range Photography is a valid help to take images in natural light, the illumination under which the object is usually presented, avoiding artefact illuminations that arrange the mosaic in a different settings than the one perceived by the observer.

The main problem of the reproduction through HDR photography is that of the veiling glare. This causes a slight loss in contrast, in order to compensate an unsharp mask is needed. As John McCann maintains: “The improvement in HDR images, compared to conventional photography, does not correlate with accurate luminance capture and display. The improvement in HDR images is due to better digital quantization and the preservation of relative spatial information”: McCann and Rizzi (2007).

The images obtained are not, obviously, accurate in terms of colorimetry and the colour management has not been used. The realization of this kind of reproduction starts from the concept that each reproduction of work of art is a translation of a three dimensional object with its proper materials, optical features, dimensions and so on into two dimensional object by means of other materials, optical features, dimensions and so on. The translation inevitably loses something of the original message and this is the price that have to be paid for the diffusion of the message. The images obtained has been compared with those realized by traditional photography, both analogue and digital, rather than with the original object. They have to work within themselves as autonomous objects.

Figure 1. Comparison between traditional (left) and HDR photography (right) of the same subject.

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Colour constancy through textile veils

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Abstract
The scope of this work is to show that colour constancy under coloured veils, although not very good, is quite remarkable. We used real textile veils and not simulations like in most previous research. The observers' task was to adjust the colours of a test Mondrian until they matched the colours of another Mondrian of the same size and shape, placed at its side in a calibrated monitor screen, but covered by independently lit veils of different colours. Also uncovered Mondrians had to be matched in control trials. Results show a rather good performance of the observers in reproducing both the uncovered Mondrians with small colour deviations and the filtered Mondrians with deviations of about the double size. The relatively good colour constancy seems due to the darkness of the filters and the strong stratification between Mondrians and veils.

1. Introduction
There are many kinds of transparent/translucent objects in the real world, often unnoticed if not observed with scrutiny (Hochstein and Ahissar, 2002). From a perceptual point of view transparency is simply considered as the possibility of seeing something behind and through another object.

The scope of this work is to show that colour constancy under coloured veils, although not very good, is still remarkable (Gilchrist and Jacobsen, 1983); as we used real textile veils and not simulations like in most previous research our results are particularly relevant.

2. The experiment
We used very thin textile fabric to produce impressions of transparency based on natural stimulation. To measure colour constancy we used a matching procedure, consisting in adjusting, in a computer screen, the colour of a comparison area to match the colour of a test area. These test areas were regions of a Mondrian shown in another part of the monitor and observed through coloured veils, hold in place by two pressed glasses, and independently lit.

2.1 Materials and methods
Ten differently coloured veils were used (Table 1 and Figure 1), lit by a filtered incandescent source (approximately CCT 6500°). Their shape was trapezoidal so that, after being pressed between two clear glasses and positioned in front of the monitor at about 45°, their projection at the observer's eye was rectangular, completely covering the coloured Mondrian on the screen; only the white background of the monitor was protruding outside the filtered area.

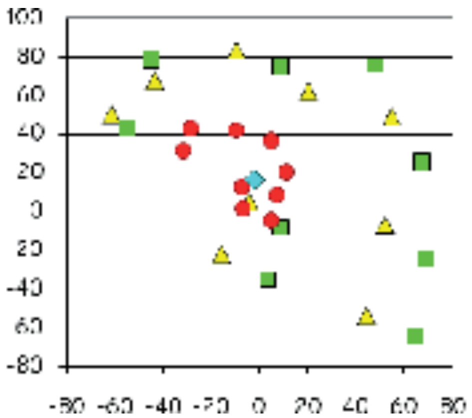
Table 1. The colours of the veils(f) measured in a CIELB colour space against a black background

f	L*	a*	b*
1	6,02	2,40	1,41
2	8,74	17,35	11,19
3	20,20	-11,75	11,99
4	24,64	8,12	22,09
5	25,47	-2,18	16,40
6	5,70	14,34	7,55
7	15,54	-0,74	5,20
8	13,52	12,42	5,72
9	19,59	4,60	15,27
10	21,54	11,11	20,92

Three different Mondrians of 9 square-like areas were presented one at a time, not to favour the memorization of their colours by the observers. They were shown in the left part of a Quato TFT Monitor, calibrated at a CCT 6500°, white 120 cd/m^2, gamma 2.2, gain 1, offset 0. In the right part of the monitor another Mondrian of the same shape, with random grey colours was placed, to be adjusted in the matching procedure.

Using 8 buttons to modify Yellowness, Redness, Blueness, and Greenness either in +1 or +5 steps performed the colour adjustment; moreover other 8 buttons could be used to modify Whiteness (+1, +5), Blackness (+1, +5), and Luminance (+1, +5, -1, -5).

*Figure 1. The nine colours of the three Mondrians in a CIELAB a*b* plane (yellow diamonds = Mondrian 1, red*



squares = Mondrian 2, green triangles =Mondrian 3).

2.2 Procedure and subjects

Four observers, with normal colour vision, volunteered in the experiment, and two of them performed twice the whole experiment. Each veil was put in front of one Mondrian, so that three different veils and one Mondrian covered two Mondrians by the other four veils. In the control trials the three Mondrians were presented uncovered. Observers had to adjust the colours of the test Mondrian so to appear as those of the covered Mondrian if they were uncovered. Before closing the adjustment of a Mondrian, observers were instructed to check that its colour appearance matched in the whole that of the covered Mondrian, and to add further adjustments until satisfied. The sequence of Mondrians and filters were random.

2.3 Results

First, the colours adjusted to match the uncovered Mondrian in the control trials were reproduced with rather good precision, given the inexperienced of the observers and the distance between the two Mondrians (Figure 2). For unknown reasons Mondrian 1 was matched better than the other two (average colour differences: $\Delta E^* = 4.2$, $\Delta E^* = 7.1$, $\Delta E^* = 7.2$ respectively), but only the difference between the first and the third Mondrian is significant ($t_{16} = 4{,}08$, $p < 0.0008$).

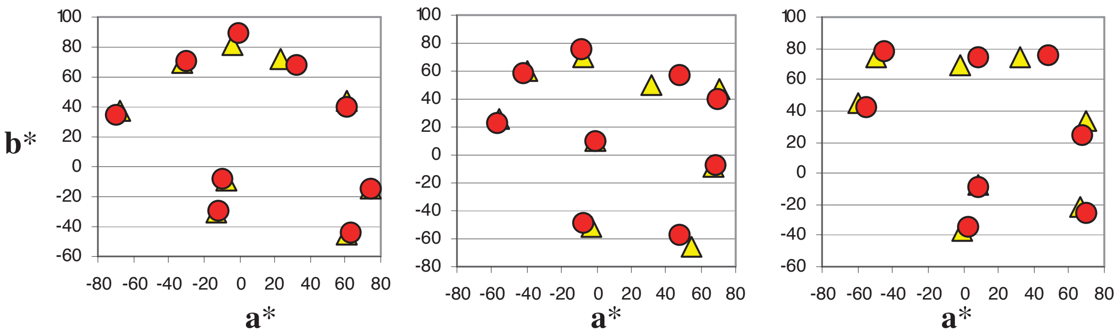


*Figure 2. The colours of the test (triangles) and the uncovered comparison (circles) Mondrians in a CIELAB a*b* plane*

Secondly, the adjusted colours relative to the covered Mondrians were about twice as great ($\Delta E^* = 14.6$) as the adjusted colours relative to the uncovered Mondrians. The presence of the veils is expected to alter the perception of the colours seen behind and through them. On the other side this difference is also rather small in comparison with other research (Da Pos and Rao, 2010). The reason seems to be that the filters were very dark (in our case they were illuminated at quite low intensity), and it is well known for a long time (Cavedon et al., 1985) that dark surfaces appear more transparent than the light ones for the same degree of transmittance (α value in Metelli's model, 1974).

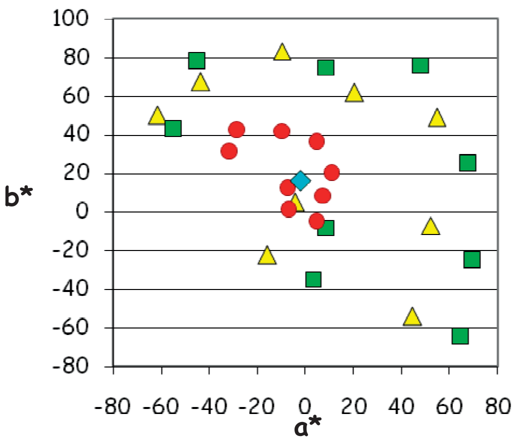


Figure 3. The uncovered colours of the Mondrian 3 (green squares), the reduction colours (red circles) produced by a greenish veil, and the adjusted colours (yellow triangles) are shown in a CIELAB diagram.

According to Metelli's model one can derive the chromatic characteristics of a veil from both the reduction colours (Katz, 1935) given in the display and the colours of the uncovered Mondrian (which should protrude outside the filter in Metelli's model). Also in our case we could derive the lightness of the veils **t** and their transparency extent α, the reciprocal of their density); we found that colour deviations were inversely proportional to the lightness of the veils (Pearson correlation r= -0,40). This means that dark veils favour good constancy. Moreover the veils were little dense, that is quite transparent (values of α well over 0,25, that is rather high transparency), which still favours good colour constancy. Lastly our results seemed to show that colour opponency plays a rather important role, as, according to Hering (1905-1920) a reduction colour cannot split in two opponent colours. Nevertheless the results are not univocal as they can be interpreted as consequence of complementary colours. Specific experiments to test this hypothesis are being performed.

3. Conclusions

Our research aimed at verifying that colour constancy comes true if real textile coloured veils are used to generate impressions of transparency. The colours which were reproduced to match the veiled areas of coloured Mondrians were relatively close the expected ones, probably because of the rather dark appearance of the veils in our experimental conditions. Another reason of the constancy results can be the high transparency degree of the veils, which allowed a perception of the back colours with little interference. Metelli's model seemed to fit very well the conditions of our experiment, although all Mondrian colours were completely covered in our experiment, while they should protrude from the filter in the original model. Nevertheless there are hints that less transparent veils could strongly reduce the rather good constancy results obtained in this experiment, and works in this direction are already in progress.

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Colour constancy in natural and unnatural images

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Abstract

We examined how the state of colour constancy changes depending on the naturalness of images by comparing a photograph with richer information of a natural scene and images with less natural information, such as cartoon and jumbled images. A photograph of a room was taken under fluorescent lamps with correlated colour temperature 2700K. A cartoon and a morphed image between the original photograph and the cartoon were created from the original as well as jumbled images, to examine the degree of colour constancy in images with different naturalness. Neutral perception of in each image was obtained in the experiment. Results showed that colour constancy in the original photograph was generally high and that in the cartoon image was lower. There were larger individual differences for morphed and jumbled images, suggesting that recognition for those images were rather unstable and depended on which clue each observer used for their judgements. It was shown that colour constancy was lower in a cartoon image compared to a normal photograph, suggesting that natural information such as texture and shading would be important for three-dimensional recognition and colour constancy.

1. Introduction

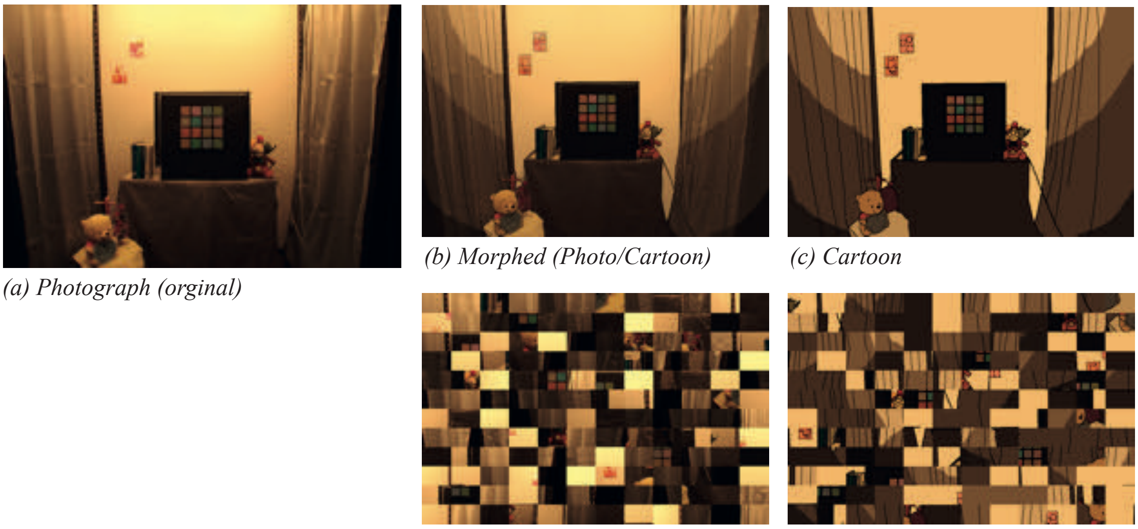
Colour constancy has been studied over many years. It is often explained by mechanisms in lower levels of visual processing, such as an adaptation of the photoreceptors on the retina or adaptation to the averaged colour of a visual field. However, it is also suggested that various factors in higher levels affect colour constancy. It has been shown that recognizing a room as a three dimensional space is important for colour constancy, and that in a two-dimensional images is lower (Ikeda, Hattori, and Shinoda, 2002; Hedrich, Bloj, and Ruppertsberg, 2009). We showed that the colour constancy in a photograph was improved when it was viewed monocularly and exclusively through a hole, eliminating the information in the surroundings. However, it decreased again if the photograph was jumbled (Mizokami, Ikeda, and Shinoda, 2004). We also showed that naturalness in the spatial structure of an environment influenced to colour constancy (Mizokami and Yaguchi, 2007). These results lead us to the assumption that colour constancy is higher-level mechanism, i.e., one influenced by the naturalness of the environment. In other words, a natural environment is important for high colour constancy.

In the case of cartoon images, their unnatural appearance due to less three-dimensional information (such as shading, texture and depth) would result in weaker spatial recognition in them. It is predicted that colour constancy in those images would be lower than that in a photograph. Here, we examine how the state of colour constancy changes depending on the naturalness of images by comparing a photograph with richer information of a natural scene and images with less natural information, such as cartoon and jumbled images.

2. Experiment

2.1 Images and experimental conditions

As shown in Figure 1, we prepared a photograph of a room taken under fluorescent lamps with correlated colour temperature 2700K (a). A cartoon (c) and a morphed image between the original and the cartoon (b) were created from the original photograph as well as jumbled images (d, e), to examine the degree of colour constancy in images with different naturalness. The cartoon was made from the original by adding contours and filled each region with the averaged colour of corresponding region in the original photograph to make the image to be flat cartoon-like appearance. The morphed image was made by the mixture of 50 % original and 50% cartoon. It had information of both contours and shading. The jumbled photograph (or cartoon) was made out of the original photograph (or the cartoon) divided into 12 by 12 pieces and re-arranged randomly. These images were presented on a CRT display controlled by a visual stimulus generator (Cambridge Research Systems, ViSaGe), in an otherwise dark room. The size of images was 28.4 × 38.9 cm (972 × 648 pixels, 13.5 × 18.4° in visual angle), and viewing distance was 120 cm. Each image included the 4 by 4 array of 5 cm square colour patches and one of those was used as a test stimulus for colour judgement. Its colour was able to change along the black body locus from colour temperature 200 K to 12000 K in 50 K steps.



(a) Photograph (orginal) *(b) Morphed (Photo/Cartoon)* *(c) Cartoon*

(d) Jumbled photograph *(e) Jumbled cartoon*

Figure 1: Images used for experiments

2.2 Procedure

In the experiment, an observer viewed an image on a CRT display and adjusted the colour of a test stimulus to appear neutral or closest to neutral, by changing its colour with the buttons of a keypad. There was no time restriction. As the observer made a judgment for the image, next image was presented. In one session, five images (a~e) were presented in random order. Four observers participated and judged five times in each image. Three sessions were conducted and fifteen judgments in total were obrained for each image. Additional 16 observers participated in just one session including three judgments for each image. All observers had normal colour vision.

3. Results and Discussion

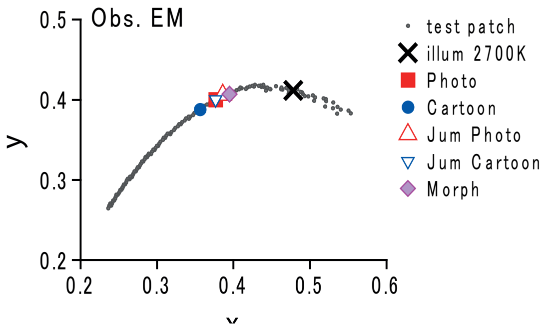


Figure 2 Results of neutral settings for images. Observer EM.

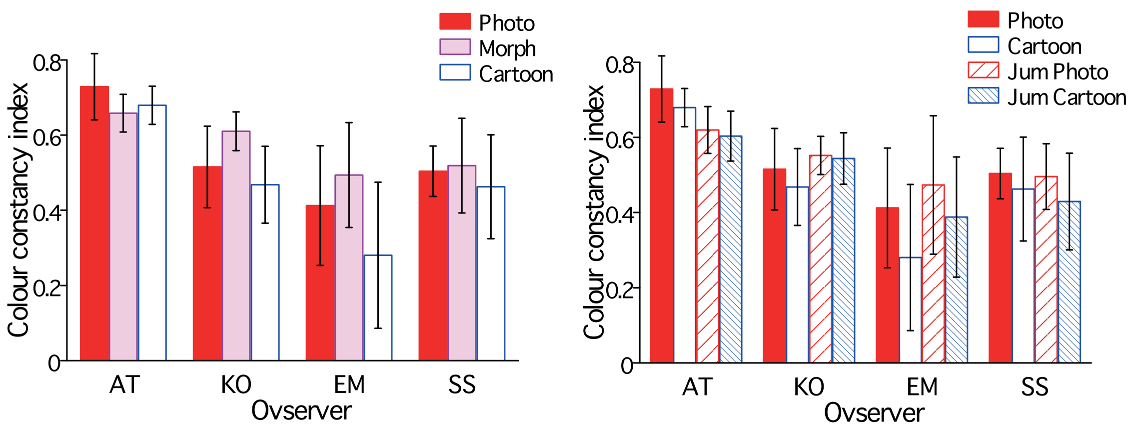
Figure 2 shows the result for five images from observer EM on the CIE1931 chromaticity diagram. Each symbol corresponds to the average of 15 settings for each image. Small dots indicate the available colours of a test stimulus. The illuminant 2700 K is also shown by a cross symbol. Neutral perception for the cartoon image is further from the illuminant colour, showing less colour constancy. However, the difference of neutral perceptions among other images was rather small and close to each other.

In order to compare the results clearer, a colour constancy index (CCI) was calculated from each observer's neutral settings by following equation,

$$CCI = 1 - (a/b)$$
$$a = \sqrt{(x - x_{illm})^2 + (y - y_{illm})^2}, \quad b = \sqrt{(x_{illm} - 0.333)^2 + (y_{illm} - 0.333)^2} \qquad (1)$$

where a is a distance between the chromaticity coordinates of a neutral setting (x, y) and that of illuminant colour, 2700K (x_{illm}, y_{illm}) on the CIE1931 xy chromaticity diagram, and b is a distance between the chromaticity coordinates of the illuminant colour and that of the equal energy white (0.333, 0.333). Colour constancy index is usually calculated based on the distance of a reference (white) and a test illumination. Here, we considered the equal energy white as a reference illuminant since we did not test white illumination in the experiment. Zero indicates no colour constancy and one indicates perfect constancy.

Colour constancy index for 4 observers is shown in Figure 3. Results of the morphed and the jumbled images are shown in separate graphs (a, b) for easy comparison. Colour constancy in



(a) Comparison between morph-levels *(b) Comparison to Jumbled images*

Figure 3 Colour constancy index for each image. Error bars indicate standard deviations of 15 settings.

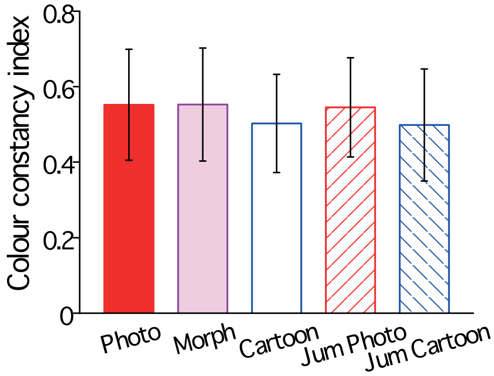


Figure 4 Averaged colour constancy index of 20 observers. Error bars indicate standard deviations.

the original photograph is generally high and that in the cartoon is low. There are larger individual differences for the morphed and the jumbled images, suggesting that recognition of them were unstable and depended on which clue each observer used for neutral judgements. Some observers show the high degree of colour constancy in the morphed images. It is consistent with an impression reported which the depth of the scene in the morphed image appeared to be emphasized more compared to the original. It was possibly due to the existence of textures, shadings, and enhanced contours.

Figure 4 shows the results from 20 observers. Constancy index of the cartoon and the jumbled cartoon were lower than the original photograph, whereas that of the morphed image and the jumbled photograph is similar to the original. There are large individual difference in the morphed and the jumbled images. Some observers showed less colour constancy on them and the others did not. Although the results for the jumbled images do not show strong trends, colour constancy in the jumbled cartoon is lower than the jumbled photograph, which is similar to those in the original photograph and the cartoon image. It implies that the information of shading and texture play an important role on the improvement of colour constancy. Further study is needed to investigate what information influence a realistic three-dimensional impression and colour constancy, and how those factors are integrated.

To summarize, it was shown that colour constancy was lower in a cartoon image compared to a normal photograph. Morphed and jumbled images did not show systematic trends. These suggest that natural information such as texture and shading would be important for three-dimensional recognition and colour constancy.

Acknowledgments

This work was supported by KAKENHI 19860019.

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oral paper

Psychological relationship between colour difference scales and colour rendering scales

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Abstract

The prediction of observer judgements about the colour appearance of typical objects under a light source is important to characterize its colour rendering. In the current colour rendering method, the colour rendering index (R) of a test light source is computed from a predicted colour difference (ΔE) of a test colour sample between the test and the reference light source: R=100-4.6ΔE. This is defined on a technological basis. But it should carry a psychological meaning: a prediction of the observer's judgement R_p about the colour difference quantified by a colour difference formula (ΔE_{pred}). Aim of the present work is to explore the psychological relationship $R_p(\Delta E_{pred})$ experimentally. Light sources included one incandescent reference light source and nine test light sources of different colour rendering properties (20<R_a<100). Different test objects were assessed visually under the test and reference light sources by judging the similarity of each test object between the test and reference colour appearance on a continuous similarity scale between 1.0 and 6.0. Even values were assigned categories (1=very good, 2=good, 3=mediocre, 4=poor, 5=bad, 6=very bad). The mean $R_p(\Delta E_{pred})$ function of 15 observers was nonlinear.

1. Introduction

The prediction of observer judgements about the colour appearance of typical objects under a test light source in a built indoor environment is crucial in order to characterize the colour rendering of that test light source. In the final step of the current standard colour rendering method, the colour rendering index (R) of a test light source is computed from a predicted colour difference (ΔE) of a test colour sample between the test light source and the reference light source: R=100-4.6 $\Delta E_{U^*V^*W^*}$ (CIE, 1995). Latter formula has been defined on a technological basis where the quantity R represents a technical term to quantify the colour rendering property of the test light source.

However, authors believe that this final step of the computation method of the colour rendering index should carry a psychological meaning. It should be a prediction of the observer's judgement R_p about the similarity of the colours of the objects in a scene illuminated by the test light source to the colours of the objects in the same scene but illuminated by a reference light source. In this sense, the aim of the present paper is to describe the results of our recent psychophysical experiments to establish a psychological relationship $R_p(\Delta E_{UCS})$ between instrumentally measured colour differences and the observers' colour rendering judgements. ΔE_{UCS} represents a recent colour difference formula (Luo et al., 2006) which was confirmed to correlate well with perceived colour differences in a visual colour rendering experiment (Bodrogi et al., 2010).

2. Experimental Method

A new experimental setup and method was constructed. Light sources included one incandescent reference light source and nine test light sources of different colour rendering properties with R_a values ranging between 20 and 100. The nine test light sources were mixtures of white LEDs of high and low colour rendering properties and RGB LEDs. All light sources were mounted on a lighting board to provide homogeneous illumination via the diffuser plate on the table where a still life was arranged consisting of a white standard and several artificial test objects. During the visual experiment, homogeneous colour patches, fresh fruits and flowers as well as the observer's hand were assessed. All test objects were visible at the same time in the still life arrangement. The observer was assessing one test object at a time by switching between the test light source (min. 2s) and the reference light source (min. 2s) as many times as required by using the two buttons. The observer's first task (colour difference perception task) was to scale the colour difference between the appearance of each test object under the test and reference light sources in comparison with a colour difference unit on a printed grey scale added to the still life.

The second task (similarity judgement task) was to judge the similarity of each test object between their test and reference colour appearance to establish the psychological colour rendering scale. The observer had to make a continuous judgement by setting a slider on the similarity judgement scale at the user interface of a dedicated psychophysical computer program. A similar slider was used to enter the value of visual colour difference in grey scale units. The judgement scale ranged between 1 and 7. Even values were assigned semantic categories (1: excellent, 2: very good, 3: good, 4: mediocre, 5: poor, 6: bad, 7: very bad) but the observer was required to make continuous judgements similar to the school grade system (e.g. 1.7) in certain countries. The driver electronics of the lighting board was controlled by the same computer program.

3. Result

Mean similarity ratings (R_p) of 15 observers and 7 objects are described (apple, banana, red cabbage, homogeneous turquoise colour patch, orange, pink flower and lemon) as a function of their instrumentally measured mean colour differences (ΔE_{UCS}) between the test light source and the reference light source. Figure 1 shows this function together with the 95% confidence intervals of the mean similarity ratings.

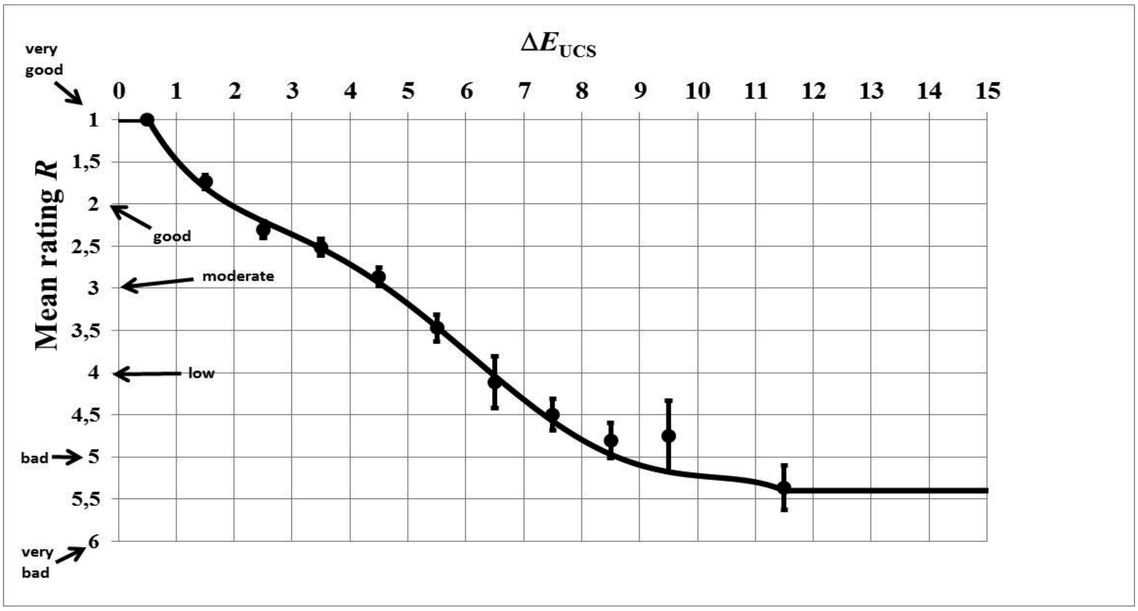

Figure 1. Dots: mean similarity ratings (Rp) of 15 observers for 7 objects, see the left ordinate. Intervals: 95% confidence intervals of the mean similarity ratings. Abscissa: instrumentally measured colour differences (DEUCS). Dash curve: fit curve to the mean tendency of the seven objects, see Eq. (1). Labels to the left ordinate (very good, good, moderate, low, bad, very bad) represent semantic rating categories assigned to the whole numbers of the continuous similarity rating scale

As can be seen from Figure 1, mean similarity ratings (dots) reveal a characteristic nonlinear decreasing tendency. Following function was fitted to the experimental results running within the confidence intervals:

$$
\begin{array}{ll}
R=1 & \text{if } \Delta E_{UCS}<0.5 \\
R=F(\Delta E_{UCS}) & \text{if } 0.5\leq \Delta E_{UCS}\leq 11.5 \\
R=5.4 & \text{if } \Delta E_{UCS}>11.5
\end{array} \qquad (1)
$$

In Eq. (1), F denotes a fifth-order polynomial function.

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Harmonious color group characterized by a colored light source

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Abstract

Color harmony has been one of the essential questions in the field of color science. We examined a simple and scientific method of producing a group of colors which appeared to be harmonious using colored light sources. Color surfaces illuminated by a colored light are changed in a similar way according to the color of the light. If we recognize this visual characteristic shared in the group of colors, we may perceive them as harmonious. An arrangement of color chips was illuminated by a colored light source. In our experimental set-up, a subject viewed the color arrangement as if it was placed on the white screen under white light. The sizes of color arrangements were 1x2, 2x2, 3x3 and 4x4. Since colors were chosen randomly, the color arrangements under the white light source was expected not to be harmonious. Ten subjects evaluated the degree of color harmony and their preference for each of the color arrangements. The result clearly showed that the color arrangements under the colored light conditions were given higher scores of color harmony than those under the white light condition. This indicates that colors characterized by the colored light appeared to be more harmonious. The finding will be considered in relation to a mechanism of color harmony and possible application.

1. Introduction

How can a harmonious color arrangement be achieved? This has been one of the essential questions in the field of color science. Although a large number of studies such as Moon and Spencer 1944, Judd 1955, Ou and Luo 2006 have focused on this topic, there are still arguments about the nature of color harmony(O'Connor 2010) Color is obviously important for design practices in any of built environments and industrial products. A systematic method producing harmonious color arrangement is worth investigating both in scientific and practical purposes. In this study we examined a simple and scientific method of producing a group of colors which appeared to be harmonious using colored light sources.

Many theories of color harmony have suggested that colors having similar visual attributes such as hue or chroma would appear harmonious(Judd 1955). We extended this rule to visual characteristics produced by a colored light and shared in a group of colors. Color surfaces illuminated by a colored light source are changed in a similar way according to the color of light source. A red light source, for example, will add reddish components to each of color surfaces and reduce their greenish components. If we recognize visual characteristics shared in the group of colors, we may perceive them as harmonious. We examined this idea by conducting a psychological experiment.

2. Methods

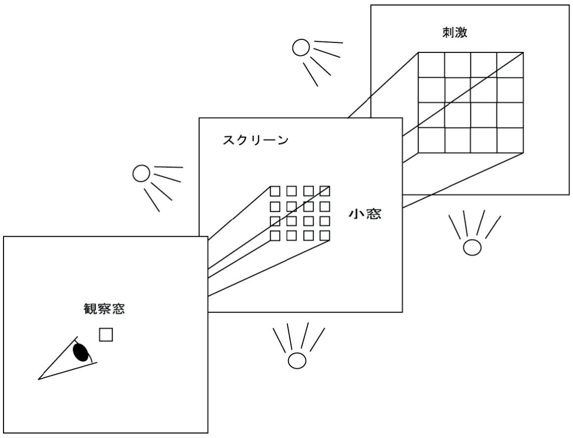
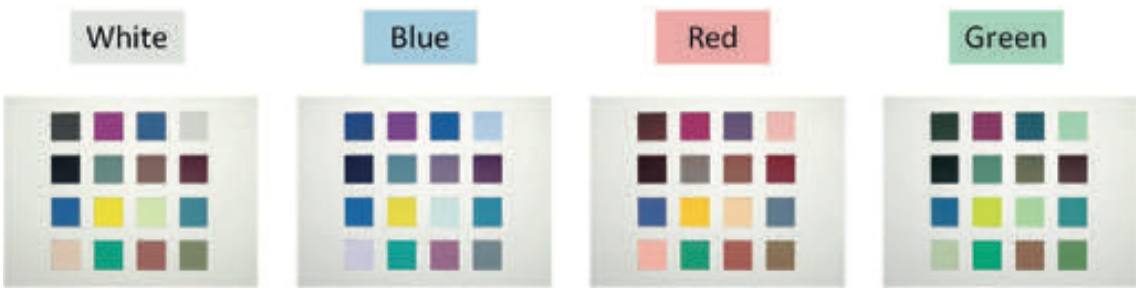


Figure 1, The experimental setup

Figure 1 shows the schematic diagram of an experimental apparatus. An arrangement of color chips was illuminated by a colored light source. A white screen board with a matrix of apertures placed between a subject and the arrangement of colors. The white screen was illuminated by a white light source. The subject viewed the color arrangement monocularly through a small viewing aperture. Using this setting, the subject saw each of colors in the arrangement at the location of each of corresponding apertures on the white screen. That is, the subject viewed the color arrangement as if it was attached to the white screen illuminated by the white light. Note that the color arrangement was actually illuminated by a colored light. The size of color arrangement was 1x2, 2x2, 3x3 and 4x4. A viewing distance from the subject to the white screen was 50 cm. An aperture on the white screen was 2 cm square. We prepared 22 color arrangements for each of 4 sizes by randomly selecting color chips from a set of color chips (Japan Color Research Institute). We used four light source conditions as follows:

Red (x=0.372,y=0.367)
Green (x=0.345,y=0.381)
Blue (x=0.305,y=0.315)
White (x=0.350,y=0.370)

(a)



(b)

Figure 2, Examples of the color arrangements, (a) 4x4, (b) 16x16

In total, 352 conditions (4 sizes x 22 arrangements x 4 light sources) were tested in four sessions per subject. Figure 2 shows examples of the color arrangements illuminated by each of four light sources. They were taken by a digital camera from the subject's viewing point. Ten subjects from Kyoto University participated in the experiment. Their task was to observe the color arrangement through the viewing aperture and to evaluate the degree of color harmony and their preference for the color arrangement by giving a score from -10 to +10.

3. Results

Figure 3 shows results of the experiment. Scores of the color harmony averaged over ten subjects and 22 arrangements were plotted against the size of the color arrangement for each of the four light source conditions. The color arrangements under the white light source were given lower scores of color harmony. Since color chips in the arrangement were chosen randomly, this result was as our expectation. Our main concern in this study was if the color arrangements illuminated by colored light sources red, green and blue were appeared to be more harmonized. As shown in figure 3, the color arrangements under the colored light sources were given higher scores of the color harmony than those under the white light condition.

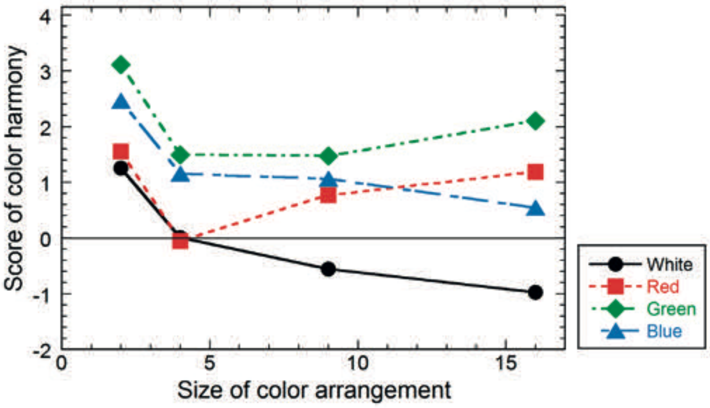


Figure 3, The results of color harmony evaluation

It is interesting that the color harmony for the color arrangements under the colored light sources generally increased as the size of the color arrangement. On the other hand, the color harmony for the color arrangement under the white light decreased as the size of the color arrangement. Figure 4 presents the difference of the color harmony scores between the colored and the white light source conditions. The result indicates that effects of the colored light sources increased as increasing the number of colors in the arrangement.

The results of the preference for the color arrangement are shown in figure 5. The color arrangements under the colored light sources were more preferred than those under the white light source.

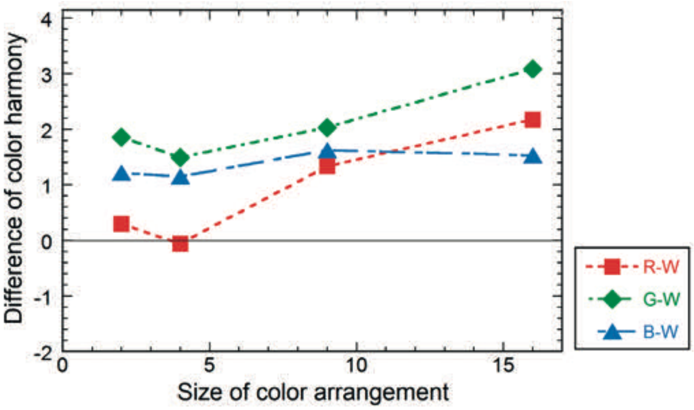


Figure 4, The difference of the color harmony score between the colored and the white light sources.

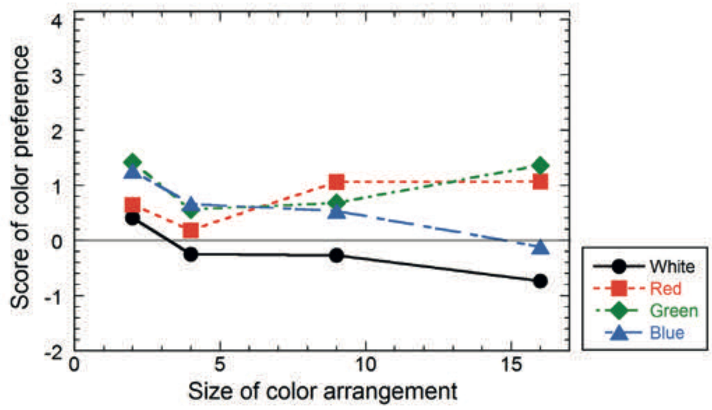


Figure 5, The results of the preference evaluation for the color arrangement

In summary, the results of this study indicated that colors characterized by a colored light source would form a harmonious color group. This effect was more significant for a larger number of colors. Perception of some visual characteristics produced by a colored light and shared in the colors may induce a sense of harmony among the colors. The finding also suggests possible application to produce a harmonious set of colors systematically.

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Successive approximation in full scale rooms. Colour and light research starting from design experience

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Abstract

OPTIMA is a pilot study attempting to simultaneously involve all visual aspects of the room, with an analysis starting from the totality instead of dividing it into different parameters. Its primary aim is to develop and test methods for this, combining a scientific approach and experience based practices of art and design. In the long run we aim to improve the understanding of how artificial light, daylight and the shape and colours of the room interact in achieving different qualities, and the possible conflicts between these qualities. Tests have been made in full scale rooms, using a methodology of successive approximation. The method has shown to be fruitful, and the results include new hypotheses regarding the spatial interaction of colour and light, to be further tested.

1. Introduction

Most research on colour and light in rooms has concentrated on one or a few aspects, striving to keep other parameters constant. Research in otherwise unaltered full scale rooms has improved the understanding of how the character and perception of the room is affected by such as the placement of windows (Matusiak 2006), the colours of the walls (Vogels 2008), the type of artificial illuminant (Billger 1999) or the compass direction of windows (Hårleman 2007). A similar approach is also used in studies of physiological and psychological effects of different room colours or illuminants (Küller et al. 2006).

The spatial interaction of colour and light is, however, multidimensional and very difficult to capture in controlled experimental situations. Studies concentrating on specific aspects of an undividable and complex visual experience can point out important tendencies, but since all sense experience is relative their results cannot be seen as fully valid outside the specific circumstances defined in the study itself. Another approach to investigating visual reality starts from totality and strives to create a holistic understanding through artistic means. This may well capture and convey an emotional and sensory likeness to the multidimensional visual world, but neither the creative artistic process nor its result are meant to meet the standards of scientific scrutiny or a discussion about generalisation. A scientific holistic approach to colour and light starts from the understanding that the total visual experience is more than the sum of its identifiable parts. The challenge of the OPTIMA project has been to find methods for scientific exploration of the undividable totality.

2. Pilot studies aiming at methodological development

The OPTIMA project is funded by the Swedish Energy Agency and its full name is *Pilot studies regarding optimised energy saving, spatial experience and function in lighting planning.* It is carried out in close collaboration with the larger trans-disciplinary project SYN-TES, including colour and light experts from six Nordic Universities and companies working with paint, illuminants and colour standards[1].

OPTIMA starts from the need for energy saving and the subsequent abandonment of traditional incandescent lamps. New light sources can deliver the same number of lumen using much less energy, but so far only little is understood about the quality of the light that they produce and their impact on the total spatial experience in a room. To obtain such understanding, there is a need for new research methods, which cannot rely on previous experience of traditional light sources and likewise have to go beyond measurements of technically quantifiable data. Thus, the main aim of OPTIMA is to develop a methodology for such investigations. This is made through full scale room studies where hypotheses and questions deal with the total spatial experience created by colour and light in interaction.

3. Theoretical and methodological starting points

The methodology tested in OPTIMA is built upon experience based practice as applied within art and design, in interaction with scientifically conducted tests. The method of *successive approximation* has been discussed by Piet Hein, the Danish mathematician, philosopher, designer, poet etc. (Hein 1985). In creative activities like art, problems cannot be clearly formulated until they are solved, and the process can be described as continuously approaching a good solution. Hein describes this knowledge process in a *grook,* his own characteristic form of expression (see box below).

THE ROAD TO WISDOM

The road to wisdom?
-- Well, it's plain
and simple to express:
Err
and err
and err again
but less
and less
and less.

Piet Hein 1905- 1996

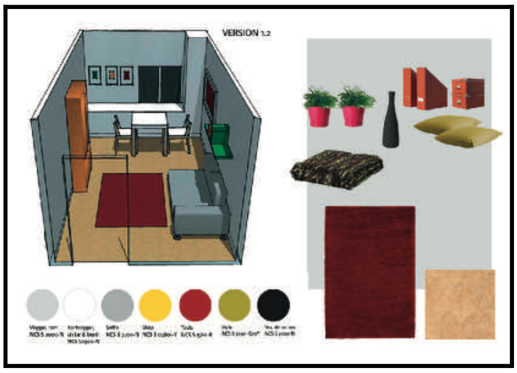

Figure 1 (right): Colour design of one of the tested room alternatives. Design Yvonne Karlsson

Working with the spatial experience of full scale rooms, OPTIMA has used the method of *successive approximation* in a version that has been tested and developed as part of the project. The research team has formulated goals for energy consumption and spatial qualities after preparatory discussions with expertise from colour and light industry. Professional colour and light designers have designed colour and light in the room in order to fulfil these goals. In this, they have based themselves on their own professional experience and not on any given norms or recommendations.

The colour and light design of the room has constituted a concrete, experience based ”hypothesis” which has been scientifically tested and analysed by the research team. The results of this analysis have been discussed jointly by researchers and designers, a process that has lead to new understanding and an improved ”hypothesis” in the form of a revised colour and light

1 Alcro-Beckers, Philips and NCS Colour.

design. After that the new ”hypothesis” has been tested. A continuous repetition of this process has lead to an accumulation of knowledge and to development of new knowledge. Thus, the important result is what has been detected during the process, not the evaluation of the single design alternatives.

4. Studies in full scale rooms

The following quality criteria and functional demands were used within OPTIMA:

- The energy consumption should be minimized
- The room should have a positive atmosphere. Two different specifications were given: In the first design alteranative the room was to be experienced as dynamic and stimulating, in the second as calm and harmonic.
- Reading: Reading of a pocket book should be as easy at the table in the test room as in a reference situation with daylight.
- It should be possible to discriminate between very similar colours: The result of a simplified Farnsworth-Munsell colour discrimination test, carried out at the table, should be as good as in a reference situation in a light box with good daylight simulation.
- Colour rendering: Categorisation of colour samples regarding hue and chromaticness should give the same result as in a light box with good daylight simulation.
- The lighting solution should utilize products and knowhow in the forefront of today´s possibilities and be technically and economically applicable also in larger scale.

The test room (Figure 1) was approximately 18 square meters. It was designed and furnished with the aim of not giving direct associations to any particular room function or style. It had no daylight but a window facing darkness imitating night. Four different design alternatives were tested, each one by 12-15 persons of different age, gender and professional relationship to colour and light. The room was observed by one person at a time, according to a preset procedure with observation protocol and manual for the observation leader. The test persons were asked questions regarding the appearance and experienced atmosphere in the room. There questions were of different types, both open ended and with pre-set alternatives. Test persons were also given tasks regarding reading, colour discrimination and colour categorization. In the analysis of these tests each person’s results were compared to his/her own results in the reference situation. Technical specifications were made through measured illuminance and luminance at several places in the room, the correlated colour temperature, spectral distribution and colour rendering index of luminaries, and the total effect of the lighting expressed in W.

5. Building knowledge through interdisciplinary and interprofessional discussions

The answers and performances of the test persons gave a rough understanding of how the designed rooms managed to meet the design goals. In this, the most interesting results were those that showed that goals had not been fulfilled. For example, test persons pointed out that they experienced a lack of harmony in the room or that they found it difficult to focus when reading. Also, the colour discrimination and colour categorisation tests showed systematic colour shifts that could not easily be explained.

These failures in achieving the design goals gave the start for discussions between researchers, designers and industrial practitioners. This created an interchange of knowledge that could hardly have been achieved without these concrete problems to discuss. It also gave rise to new ideas about possible interaction between colour and light and to new hypotheses to be further tested. In the next step of the process the room was altered according to these hypotheses, tested with new subjects, analysed by the researchers and once more discussed by the whole team.

6. Results and conclusions

The process resulted in well formulated new hypotheses that are to be tested in subsequent, more specified research projects. One of these hypotheses deals with the possibility to enhance subjectively experienced lightness in a room through the systematic placement of surfaces with different colours (co-shading and counter-shading). Another hypothesis formulates how experienced lightness is supported by large contrast distribution between light and dark colours and between chromatic colours of different hue. The discussions also resulted in suggestions regarding the design of LED fittings, in order to achieve a more even spatial distribution of light.

OPTIMA was, however, a pilot study with a mainly methodological aim, and its main result was the evaluation of the successive approximation methodology. We found that the method is very appropriate for investigations of the interaction between light quality, light distribution, chosen surface colours and their placement in complex spatial situations. Through the successive approximation it has been possible to gradually define which aspects of the spatial totality that were important for the test results and the test persons' evaluations of the room. In a longer test series, with time allowing more rounds of evaluation and modification starting from an unaltered demand specification, this method can most likely lead to more specific conclusions than what was possible in this pilot study. A promising, slight, modification of the method would be to start with variations of only a few factors and make developed expert evaluations of the totality in each case. As a second step the qualities of the thus optimised room can be tested in a more traditional way, with a larger group of subjects.

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Lighting colors for cognitive performance

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Abstract

In order to investigate the effect of lighting colors on cognitive performance, two empirical studies were conducted. In experiment I(N=19), seven colors of ambient lightings were provided for each of two minutes. This was carrid out while the subjects were concentrating on math tasks under an additional table lamp. Their brain activities were recorded with electroencephalography (EEG). The ratios of Sensory Motor Rhythm (SMR: 12~15Hz) waves and Mid-Beta (15~20Hz) waves ranging between 3.5 and 50Hz were particularly focused. It was observed the yellow lighting was the best, but there was no statistical significance ($p>0.05$). In experiment II (N=19), the subjects were asked to read essays as shown in a 50-inch-LED display, and eight ambient lightings were provided, two minutes for each. It was observed that the ratios of Alpha waves (7~12Hz) and SMR waves were the highest under blue and purple lightings, and the lowest with the ambient lightings being switched off. However, the difference was not statistically significant ($p>0.05$). The survey results showed that yellow or white lightings should be the best and red to be the worst, showing the incongruence between one's brain activity and survey results.

1. Introduction

Along with the increased marketability of LED in terms of affordable technology and price, we have been often exposed to colourful lighting experiences. Although there is a growing demand for scientific evidence of the effect of the LED lighting, the studies on the effect of the colourful lightings on human are still in its emerging stage. In this study, we investigated the affective effect of ambient LED lightings with spectral distributions. We particularly focused on cognitive, and hypothesized the effect of different colors of ambient lighting on quality of performance. We conducted two empirical studies simulating two typical working contexts: First in experiment I, subjects were supposed to answer to math questionnaires printed on white papers. In experiment II, subjects read essays displayed in a 50-inch-TV. In both contexts, while paying attention to the given tasks, the ambient lighting colors were changed every two minutes. In collecting the subjects' responses to the provided lighting contexts, we tried to obtain both subjective opinions as well as objective reactions of the subjects When proceeding both experiments, we did not only surveyed subjects' opinion, but we also recorded the brain activities using EEG and analyzed the ratio of certain frequency ranges. Also, we attempted to set up an experiment environment as realistic as possible, so that the subjects might feel natural as they imagine themselves present at a home rather than at a laboratory. Moreover, we furnished the rooms with items either in white or achromatic to be free from color effect.

2. Experiment I

In experiment I, we planned to investigate the influence of ambient lighting color on one's attentive state for cognitive tasks, particularly focusing on solving arithmetic and geometry questionnaires. As illustrated in Figure 1, we furnished the experiment room with a desk, bookshelves, a computer, a chair, and a lamp on the desk. Nineteen university students consisted of 15 male students and 5 female students, and their averaged age was 23.60 (SD=2.40). We recorded brain waves, which were facilitated by the Poly G-I of Laxtha Inc., while working on two types of cognitive tasks, such as arithmetic and geometry questionnaires. The subjects spent two minutes for each type. Seven lighting conditions—white, red, green, blue, yellow, cyan, and purple—were provided in random order. Their properties are shown in Table 1.

Since we placed a table lamp on the desk, there are two categories of lighting properties in Table 1: one measured next to the bookshelf and the other one measured on the desk using Chroma Meter, CL-200A. After the experiment, first based on the EEG records, we analyzed the ratio of Sensory Motor Rhythm (12~15Hz; SMR) and Mid-Beta (15~20Hz) waves up to the entire range (0.5~50Hz). It was because the ratio of SMR and Mid-Beta waves should increase when a person concentrates on a cognitive task (Thompson & Thompson, 2003). Second, we collected the scores of correct answers to the questionnaire, so that we might see the influence of ambient lighting colors on both brain activities and math performance.

Table 1. Seven ambient LED lighting conditions and ratios of SMR and Mid-Beta waves collected from each condition of experiment I

No.	*Lighting Label*	*Properties of the ambient LED lighting*			*Lighting properties measured on the desk*			*The Ratio of SMR (12~15Hz) and Mid-Beta (15~20Hz) waves to entire range (3.5~50Hz)*	
		x	*y*	*lx*	*x*	*y*	*lx* [1]	*Arithmetic questionnaires*	*Geometry questionnaire*
1	White	0.331	0.330	50	0.320	0.354	939	26.5%	40.0%
2	Red	0.686	0.308	26	0.332	0.354	919	25.6%	39.7%
3	Green	0.232	0.733	44	0.312	0.366	937	26.7%	39.7%
4	Blue	0.141	0.053	9	0.307	0.335	898	26.1%	38.9%
5	Yellow	0.523	0.459	54	0.330	0.361	944	27.1%	40.1%
6	Cyan	0.166	0.239	44	0.307	0.347	932	26.1%	39.7%
7	Purple	0.360	0.156	29	0.322	0.340	921	26.9%	40.0%

By comparing the ratio of SMR and Mid-Beta waves, we observed that the subjects concentrate the best under yellow ambient lighting. However, we failed to find any statistically significant difference across the different lighting conditions (One-way ANOVA with repeated measurements, $p>0.05$). Further, there was no statistical evidence as to whether math performance was affected by the lighting conditions (One-way ANOVA with repeated measurements, $p>0.05$). As Table 1 presents, although chromaticity of ambient LED lightings varied drastically, the perceived lighting qualities were similar to each other due to the table lamp. Consequently, the differences among lighting conditions were assumed to be too marginal for the subjects to perceive any change in ambient LED lighting.

1 The illuminance level mixed with the Chromaticity and illumination from the table lamp

2. Experiment II

In experiment II, we attempt to investigate the effect of ambient lighting when a person read the texts. A different group of university students consisting of 10 male students and 5 female students participated and their averaged age was 25.63 (SD= 3.08). Each subjects were seated on a sofa and asked to read essays displayed in a 50-inch-LED TV (see Figure 2). While each subject was reading the displayed text, the ambient LED lighting was varied. As presented in Table 2, nine lighting settings—off, red, orange, yellow, green, cyan, blue, purple, and white- were provided in random order and 15 second of break(“off” mode) was inserted between colors. The lighting properties described in Table 2 are the values measured on the table using a Chroma Meter, CL-200A. In experiment II, we recorded the brain activities using an EEG and then surveyed the subjects’ opinion about the lighting contexts. In survey, the three aspects, such as readability, preference, and arousal were rated between -2 (very low) and +2 (very high). As in experiment I, all furnished items were in achromatic colors.

Figure 2. Environmental setting of experiment II

Based on the collected brain waves, as presented in Table 2, we calculated the ratios of Alpha (7~12Hz), SMR (12~15Hz), and High-Beta (20~30Hz: known as the rhythm segment related to one’s highly stressful status) to entire range (3.5~50Hz). The ratio of Alpha waves was positively correlated with SMR waves (r = 0.98) and the ratio of Alpha waves was negatively correlated with High-Beta waves (r = -0.77) respectively. By comparing each lighting condition, it was observed that purple and blue lightings created more pleasant reading ambience whereas “off” created an arousing one. However, we failed to notice a statistical significance ($p>0.05$).

On the other hand, according to the survey results, we found that the evaluation was significantly influenced by the ambient lightings ($p<0.05$). In particular, the subjects preferred cyan lighting (1.21/(-2~+2)) and disliked red lighting (-1.47/(-2~+2)). Moreover, the ratings of readability and preference were strongly positively correlated (r = 0.96, $p<0.05$) whereas those of readability and arousal are strongly negatively correlated (r = -0.96, $p<0.05$).

Table 2. Nine ambient LED lighting conditions, physiological reactions (ratios of Alpha, SMR, and High-Beta waves), and psychological reactions collected from each condition of experiment II

No.	Lighting Label	Properties of the ambient LED lighting			Ratio to entire range (3.5~50Hz)			Survey rating (-2~+2; 5 point Likert-scale)		
		x	*y*	*lx*	*Alpha (7~12Hz)*	*SMR (12~15Hz)*	*High-Beta (20~30Hz)*	*Readability*	*Preference*	*Arousal*
1	Off	0.311	0.376	4.61	21.02%	7.19%	12.24%	-0.16	-0.05	-0.58
2	Red	0.627	0.305	39.4	22.41%	7.50%	10.94%	-1.84	-1.47	1.95
3	Orange	0.543	0.396	61.4	22.38%	7.43%	10.67%	-0.63	-0.36	0.37
4	Yellow	0.482	0.462	75.5	22.02%	7.51%	11.03%	0.68	0.84	-0.84
5	Green	0.203	0.701	59.6	23.26%	7.76%	11.34%	-0.37	-0.53	0.68
6	Cyan	0.157	0.203	63.5	23.18%	7.74%	10.96%	0.63	1.21	-0.84
7	Blue	0.148	0.153	14.8	24.21%	7.99%	10.43%	-1.21	-0.58	0.89
8	Purple	0.315	0.134	45.9	24.46%	8.10%	10.47%	-1.21	-0.95	1.37
9	White	0.240	0.222	83.3	23.67%	7.94%	10.87%	0.68	0.84	-0.84

General Discussion

In general, the effect of lighting color was less influential than once been expected. Based on the result regarding brain activities under different lighting conditions for both experiments, we have found that the effect of lighting color on brain activities was insignificant ($p>0.05$). Nevertheless, the subjects distinguished the emotional quality of lighting color, but it was not congruent to the physiological reactions, such as brain activities. This first asserts that the effect of control of lighting color (e.g. color temperature control) may have been overestimated. Second, both physiological and psychological measurements should be combined to scientifically explain the cause and effect.

Acknowledgments

This research was supported by following programs: 1) BK21 Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (MEST), 2) Woman Scientist Program through the NRF funded by MEST (NRF 2010-0006319).

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Color and cesia: The interaction of light and color

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Abstract

Color and cesia are different aspects of the perception of light that contribute to the visual appearance of objects. This paper and the presentation at the Meeting are aimed at developing and explaining —through the methodic photographic recording of cases under study, visual comparisons and measurements— questions or phenomena produced by the interaction of color and cesia, dealing mainly with matte, glossy and transparent surfaces.

Introduction

Color and cesia are closely connected because of their relationship with light; both are different aspects of the perception of light that contribute to confer objects their visual appearance. Both phenomena interact expanding the countless number of different visual appearances that we are able to perceive. Color is the perception of the *spectral* distribution of light that produces a surface, or the perception of the spectral composition of a luminous source. For instance, a surface whose spectral curve is higher in the zone of long wavelenghts will be normally perceived reddish. Cesia is the perception of the *spatial* distribution of light, it is about how we perceive light that is reflected or transmitted by objects, either diffusely or regularly (Caivano 1991, 1994, 1996). For instance, a surface that reflects light in a diffuse way will be normally perceived matte, if it reflects light with a certain specular component it will be perceived glossy, if it transmits light diffusely it will be seen translucent, and if it does this in a regular way it will be seen transparent.

In both color and cesia the relationship between stimulus and sensation is not fixed but depends on three main factors —illumination, object and observer—, and is affected by other factors such as visual context, adaptation, contrast, etc. The classical variables of color are *hue*, *saturation* and *lightness* (or similar ones). The variables of cesia are the perceived degree of *permeability* to light, *diffusivity* of light, and level of *lightness* (which sometimes I have also called darkness, in the opposite sense). The dimension of lightness is shared by color and cesia, being the link that connect both phenomena.

Fridell Anter (1997) has characterized two classes of color presented by objects or surfaces: *inherent color* (the color that a surface has in the same conditions of illumination and observation by which the samples of a standard atlas used for comparison are in accordance with their notations), and *perceived color* (the color that we see in a specific situation, with any kind of illumination and under certain viewing conditions). It is possible to apply the same concepts to cesia: we can also recognize *inherent cesias* and *perceived cesias*. A clear transparent glass has an inherent cesia that we may characterize, for example, as: permeability P 95, diffusivity D 0, lightness L 95. But the same glass may be seen with different perceived cesias according to the conditions or illumination and observation; for instance, it will appear like a mirror when the illumination from the side of the observer is higher than from the opposite (see Caivano 1994: fig. 1).

Explaining some questions…

The present paper is aimed at developing and explaining some of the following questions or phenomena produced by the interaction of color and cesia:

1. Why a black glossy surface is perceived darker than a black matte surface? In general terms, why any color on a matte surface becomes darker if that surface is given a glossy finish?
   For a certain intensity of incident light, a matte surface produces a diffuse reflection, where the intensity of the reflected light is distributed approximately in the same amount for all angles, while a glossy surface concentrates the reflected light around the angle of reflection, and thus the light reflected in any other direction is relatively faint. Some reflected light is always seen from any direction in which a matte surface is observed (and for this reason it appears with some level of lightness), while if a glossy surface is observed from a non-specular direction, only a few light is reflected towards the observer, and thus it appears darker (see Fig. 1).
2. Why a glossy black surface can reflect a colorful scene with a higher degree of contrast and detail than a glossy white surface?
   In Fig. 2, the text of the image reflected on the black glossy sample can be clearly distinguished, while this does not happen on the white glossy sample. We can collect many cases and experiences that confirm this assert. The main explanation is that below the polished outer surface of the white glossy sample, the white pigment produces light scattering, which interferes with the sharpness of the reflected image. This does not happen with the black glossy sample, because below the outer polished surface, which reflects a good image, light is absorbed, and thus what we mainly see is the sharp reflection of the outer surface, even if it is dark in contrast.
3. How very glossy surfaces of different colors reflect a certain scene? How the color of the glossy surface affects the colors of the reflected scene? In what degree the colors of the reflected scene vary with every color of the glossy surface?
   Fig. 2 shows the case of two surfaces (a black and a white one) reflecting the same object. In the reflected scene, the colors of the object are strongly modified by the reflecting surface. Only black and white are shown in this paper for the sake of brevity and because of reproduction constraints, but the same arrangement, measurements and comparisons were made also for blue, red, green and yellow reflecting surfaces. In all cases, the colors of the original scene are strongly tinged by the inherent color of the glossy surface on which they are reflected. The comparisons are made in Fig. 3.
4. Why a chromatic color on a surface with a glossy finish becomes less saturated when the surface is given a matte finish?
   It is a well-known fact that the glossy edition of the Munsell atlas contains more samples than the matte edition, because the glossy samples reach a higher chroma. The reason is that the matte appearance is produced by diffuse reflection; light is scattered in all directions, and this produces a whitening of the surface color. Since the directions in which the light is reflected are manifold, at any part of the surface there will be some light reflected specularly towards the observer, and these points will look whitish. When whiteness increases, chromaticness decreases accordingly. Then, as compared to a glossy surface seen from a non-specular direction, the matte surface will look less chromatic or less saturated (Fig. 4), and also lighter, as we have seen in 1).

The following three questions cannot be fully developed here and will be addressed during the presentation:

5. What is the degree of variability of the perceived color on an opaque matte surface due to changes in illumination? If this color surface is glossy instead of matte, the degree of variability of the perceived color with changes in illumination will be higher or lower?
6. What is the degree of variability of the perceived color on an opaque matte surface due to changes in the angle of observation? If that surface is glossy instead of matte, the degree of variability of the perceived color with the changes in observation angle will be higher or lower?
7. What is the degree of variability of the perceived color on a transparent color surface in the same conditions as before? And what happens if it is a mirror? What color is a mirror? (a question already posted by Lozano 1985).

The development and verification of these questions is made by means of demonstrations through the methodic photographic recording of cases under study, and making measurements and visual comparisons.

In order to answer the first group of questions (mainly 2 and 3), an image containing white, black, gray and also some chromatic colors was placed in such a way as to be reflected by glossy acrylic surfaces having six different inherent colors (black, blue, red, green, yellow, white), all of them with the same degree of glossiness. These arrangements were photographed under the same lighting conditions and geometry, i.e., the pictures are identical except for the color of the glossy surface. Then, measurements were made of black, gray and white in the original image and in the reflected image upon the glossy surface (Fig. 2 shows only two examples). The glossy surface tinges with its own inherent color the reflected images in such a degree that the colors of the original image would not be recognized without the help of the context. The comparison and results show the great variety of colors that are the consequence of this (Fig. 3).

Applying the conclusions to environmental design

Aiming at establishing a connection with environmental color design, this paper intends to provide some concepts and methods to understand certain aspects of color in architecture and urban spaces, where the materials and surfaces may have many different colors and cesias interacting. Let me describe just one case. In a research being done by a group of students of architecture at Buenos Aires University, coordinated by Roberto Lombardi, the theme of urban color was faced in the following terms: What color is Buenos Aires city? (meaning how the city is generally perceived in the mind of the inhabitants). The usual answer by most people is that the city is gray. Now, the mentioned work consisted in taking pictures of sectors of the city with a certain methodology, and analyzing both the inherent and perceived colors, extracting the corresponding color palettes. The visible result is a great chromatic variety that would challenge this idea of the gray city. The chromatic variety is obviously more reduced for the inherent colors of the materials than for the perceived colors, where we can see an ample and diversified palette. My point is that this wide variety of perceived colors (even on a limited range of materials) is due to the interaction of color and cesia with the conditions of illumination, observation and context. In this paper we have typified and explained some of these cases.

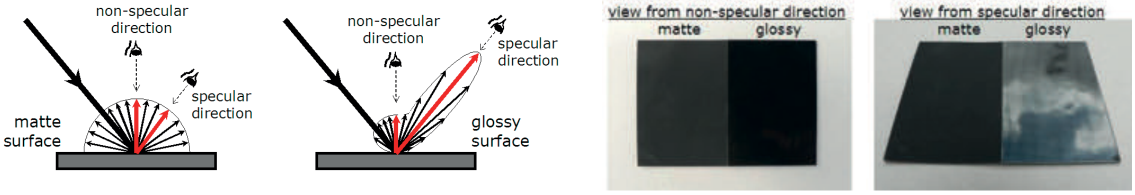

Figure 1. The matte surface shows approximately the same lightness for all angles of viewing. The glossy surface looks darker when seen from a non-specular direction, and appears lighter when seen from a specular direction (because it is reflecting the light source).

Figure 2. Black and white glossy surfaces reflect the AIC 2011 card (with black, white and chromatic colors) and the gray background. Above, the zones where black, gray and white are reflected in each case are extracted and measured.

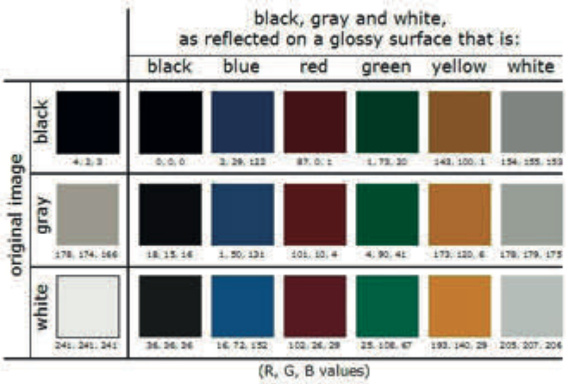

Figure 3. Comparison of colors white, gray, and black in the original image, as they are reflected on the glossy acrylic surfaces of different colors.

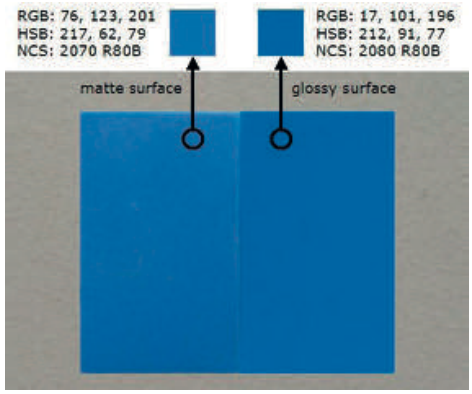

Figure 4. Two samples of the same material; the right one was left glossy, the left one was given a matte finish. It looks lighter and less saturated.

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PERCIFAL: Visual analysis of space, light and colour

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Abstract

This paper addresses the need for better and more accurate methods of recording and analyzing the visual experience of architectural space. PERCIFAL (Perceptive Spatial Analysis of Colour and Light) is an ongoing project that aims at developing a method of analysis that can capture coherent spatial experiences of colour and light. The starting point for PERCIFAL is a method of visual evaluation of space and light, developed by Professor Anders Liljefors at the former department of architectural lighting at KTH Architecture. PERCIFAL is based on direct visual observations and the recording of these observations by verbal-semantic descriptions using a questionnaire. It has been developed primarily as an educational tool, but we see in it potential for a design tool for professionals as well as for an analytical method for research. The first test results, conducted in Sweden, Norway and Finland, show that the method has significant pedagogical merits and that it allows interesting comparisons between physical measurements and visual experiences of space, light and colour.

1. Introduction

PERCIFAL (Perceptive Spatial Analysis of Colour and Light) is a subproject within the Nordic research project *SYN-TES: Human colour and light synthesis; towards a coherent field of knowledge*. SYN-TES grew from a need to share knowledge and find better ways of communicating across disciplines and research areas that deal with the human experience of light and colour in space. The SYN-TES project gathers together experts in lighting, colour, design and teaching from several Nordic universities, research institutions and companies. This paper presents PERCIFAL's background and methodology. In a separate paper Professor Barbara Matusiak et al. present some examples of its use as a tool for visual analysis.

2. Background

Our visual experience of the world consists of a totality of inseparable qualities: space, motion, light, colour, objects, details surfaces and textures. Two essential aspects of spatial experience that are among the most difficult to record and describe accurately, are light and colour. All existing methods tend to reduce the temporal and multidimensional experience of space into either static and flat images or into abstract alphanumerical data. Static flat images, such as drawings, paintings and photographs, the conventional methods for recording experiences of light and colour in space, are able to convey much of the total layout and atmosphere of spaces. They are also extremely useful in recording shape, location and details, but they cannot communicate reliably information about surface colours or levels of illumination. These can be recorded and communicated by photometric means and colour sample matching, but these methods tell us nothing about the spatial context – and therefore the *coherent experience* – of the colours, lights, shadows and surfaces. As Arne Valberg states: “There is a fundamental difference between the physically defined stimulus magnitudes (if they are photometric, colorimetric or other) and the subjectively perceived qualities.” (Valberg 2005:178-79).

We experience colour and light largely as a result of perceptual adjustment and adaptation. Spatial perceptual situations are highly complex; as we move around and through space, our perception and experience of the spatial totality are successively and simultaneously affected by global and local adaptation to varying illuminations and colours. (Noë, 2004 :17). This interaction of subject and surroundings is essential to our perception and experience of the world and cannot be described in photometric terms. The total experience of space, conveyed mostly by visual perception, is the final test of the success or failure of any designed environment. PERCIFAL is aimed at providing a tool for understanding the role of some key visual components in successful spatial design. Such visual experiences as *lightness*, *brightness*, *highlight*, *glare*, *colour* and *shadow* cannot be captured or communicated by measuring. They are relational qualities that arise from the subject’s participation and action in space. They must therefore be addressed and analyzed in the context of participation and action.

3. The PERCIFAL method

The starting point for PERCIFAL is a method of visual evaluation of space and light, developed by Professor Anders Liljefors at the former department of architectural lighting at KTH Architecture (Liljefors, 2006). The cornerstone of this method is the realization that key visual aspects of space and light cannot be described in photometric terms. Originally the method had a purely educational purpose and for several years it has been an important part of the diploma course in lighting design in Jönköping University. This is still a central feature of PERCIFAL and we aim to develop this aspect further. However, the project sees in it also significant potential for a design tool for professionals and a method of analysis for research purposes. The development is carried out under consent of and in collaboration with professor Liljefors. As an essential part of developing the method, the SYN-TES research team members have discussed and carried out their own perceptive spatial analyses starting from Liljefors□s concepts.

The PERCIFAL method is based on direct visual observations and the recording of these observations by verbal-semantic descriptions using a questionnaire. These can be complemented with photography, photometric measurement and colour sample matching for later comparison with the visual observations. When possible, plans and elevations of the space in question are used for marking observer positions and measurements. Before moving to the chosen space, the observers are prepared in a training session lasting about one hour. The purpose of the training is to ensure that concepts involved and the use of the questionnaire are clear to the observers. The method and its background are related and discussed with the group. A “dry run” in the training room or some other preliminary space can also be used as a part of the training. The observers are told that there are no “right” or “wrong” answers to the questions and that they should answer according to their observations, i.e. visual perceptions only.

After moving to the space to be analyzed, the observers are given about twenty minutes to adapt to the lighting before starting observations proper. The observers can each be given specific viewing positions within the space or can be let move freely. The viewing positions are also recorded. The observation time can vary, but usually at least one hour is needed for a comprehensive analysis. The observers’ answers are later analyzed statistically and their remarks summed up by the supervisor(s). The results are shown and discussed in debriefing session with the observers. The debriefing is an important pedagogic aspect of the process.

The questionnaire is divided into the following eight main topics: *1) General impression of the space, 2) Overall level of light 3) Light distribution in the space, 4) Shadows and flecks of light, 5) Reflections and glare, 6) Colour of light, 7) Surface colours, 8) Interaction of space, objects and people*. Under the main headings there are more specific questions, which are either in the form of semantic differential scales or forced choice answers. For example under *3) Light distribution in the space* the observer is asked to answer the following questions:

a) Horizontal distribution of light (between different parts of the space, at the same height from the floor): very even - - - - - very uneven?
Which part of the space is dark/shaded?
Which part is bright?

b) Vertical distribution of light (between building parts at different heights): very even - - - - - very uneven?
Which part of the space is dark/shaded?
Which part is bright?

After each main topic the observer can add further remarks. There are several other places where observers are asked to answer freely in their own words. Sometimes the terms in question are given a short definition to help the observer understand the question and attend to the right phenomenon. For example: *Glare = an uncomfortable brightness contrast in one's field of vision*.

Some questions draw attention to factors that are not intrinsic qualities of the space itself, but rather indicators of visual experience in interaction with the space. Under the heading *Interaction of space, objects and people* observers are asked: *How natural does the colour of human skin/facial colour look in the space?* – an indicator of the chromatic quality of the ambient light; and *How easy/difficult is it to read the below text at normal reading distance in this space?* – the provided text is set in Arial 8pt, medium grey colour. The aim of the question is to assess both the level and chromatic quality of the ambient light.

4. Results and discussion

The authors have so far tried out the PERCIFAL method and accompanying questionnaire with seven groups in nine locations in Stockholm and Katrineholm (Sweden), Helsinki (Finland) and Trondheim (Norway) during spring and summer 2010. The observers were in most cases students of art, architecture and design but also lighting and design professionals were involved. So far the observers have had little difficulty in understanding the task at hand. A lot depends on how carefully the briefing is carried out and it is important to stress that observers should rely on their immediate perceptions rather than their preconceived conceptions of colour and light in space.

Some terms in the questionnaire were more susceptible to misinterpretation than others. For instance the concept of *glare* needed clarification. Glare is an entirely subjective percept, and at the same time one of the most important negative factors in lighting design. The definition of horizontal and vertical distribution of light and shadow, particularly in the case of very high spaces, also caused some difficulties. Light and shadow distribution can become extremely complex and difficult to describe on a single scale. The effects of *cueing* and *expectations* became apparent in the questions concerning *glare* and *glitter*: they tended to elicit observations of many local instances of strong brightness contrasts and highlights rather than an overall analysis about visual comfort/discomfort. Also the whole notion of visual discomfort is highly contextual: car headlights at night can be irritatingly, even dangerously glaring whereas sunlight sparkling on water (with a far greater level of luminance) can be experienced as pleasant and enjoyable. Such problems have led the authors to consider using questions that are less direct (e.g. the ones concerning skin colour and legibility).

This subjective nature of some of the percepts brings us to the question: how reliable is PERCIFAL as a research method? The very aim of PERCIFAL is to help to describe the *coherent* and *holistic* experience of space rather than discreet and individual details. The approach is very similar to that of an artist: nonessential details must be sacrificed for the truthfulness of the whole. We have found that such a method can help to reveal essential aesthetic and visual-functional qualities of space that cannot be addressed equally well by other means. PERCIFAL is a way of collecting and systemizing analyzable data from individual observations. The methods of analysis are still under development, but even as such the method and data retrieved so far have proven to be of great educational value. Most of the observers reported that their perception and understanding of the visual factors in space became heightened as a result of the tests. They became particularly aware of the effect of *adaptation* to the perception of brightness and colour tone. They became also more aware of the meaning of such visual terms as brightness and lightness. The method and questionnaire are under continuous augmentation as the tests continue with more groups and locations. Each test so far has led to improvements and additions to the method.

Acknowledgments

SYN-TES is funded by the Knowledge Foundation, Sweden (Stiftelsen för kunskapsoch kompetensutveckling, KK-stiftelsen).

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Erwin Redl or the matrix indexing of space

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Abstract

The Work of Austrian-born artist Erwin Redl is based on the use of Light as an artistic medium. He exclusively uses LEDs (Light Emitting Diodes) in order to create two and three dimensional works that redefine both interior and exterior spaces.

The purity of the light emitted by the LEDs fills in the exhibiting space and embodies perfectly the mental space of abstraction, in which the artist wants to take the viewer, into sensuous lightscapes.

The slick simplicity of his work generates emotions that are based more on triggering physiological processes than on highly intellectualised aesthetic considerations: even if you do not want to, you get visually and sensually trapped in his matrices.

The Matrix Indexing of Space

Art history has extensively studied the question of light but always in an indirect way, focussing mainly on its interaction with matter resulting in shadows and colours. During the second half of the 20th century, light gradually escaped from the sole pictorial field to become a medium in its own right, which is totally distinct from other materials and artistic practices.

Light is probably one of the most ambiguous and universal medias available to today's visual artists. It allows the artist to visualise and materialise ideas and phenomena such as space and time. In the 1970s the primary concern of artists such as Dan Flavin and James Turrell, was the exploration of how we apprehend the notion of space. Light is a spatially related and transcendent medium, one power of which is the ability to embody and materialize phenomenological aspects of our environment as well as being a septum separating the space where the viewer stands from another one that can be either surrounding or totally oneiric (dreamlike).

The work of Erwin Redl relates to these early works. His LED installations summarise in a subtle and minimalistic manner the mediality of light used as a visual medium. Since 1997 he has investigated the term of '*reverse engineering*' in order to translate:

> *"the abstract aesthetic language of virtual reality and 3-D computer modelling back into an architectural environment by means of large-scale light installations. In [his] work, space is experienced as a second skin, our social skin, which is transformed through my artistic intervention."*

By doing so Redl aims to reduce the viewers' interpretive concerns to the sole notation of their sensations, he forces them to realise how his shimmering immersive installations affect their bodies through the haptic[1] nature of light and the minimalistic geometric design of his artworks:

1 refers to the sense of touch and process of recognizing objects through touch, from ancient Greek ἅπτω , *I touch.*

> *"Due to the very nature of its architectural dimension, participating by simply being "present" is an integral part of the installations. Visual perception has to work in conjunction with corporeal motion, and the passage of time, an additional parameter of motion."*

It is as if after extended looking, the viewer must recalibrate their senses to their form in order to experience the ambiguous materiality of light that exceeds here more than a simple visual sensation, to become an intense physical and sensual experience. Therefore the term aesthesic should be preferred to aesthetic to describe Redl's work as it refers to the mental perception of sensations; as Kenton Smith puts it, Redl creates:

> *"environment[s] in which the visitor tangibly experiences and shapes it by actually entering and moving about the wire grid itself." (Smith 2005)*

Redl does not play only with light and LEDs, he also masters psychological theories in order to disrupt the viewer's apprehension of space. The volumes and planes, which Redl materialises with series of cables, cross-braces and LEDs, evolve constantly over time because of the visitors walking through them, which in turn influences their perception of their immediate environment. Redl likes to remind us that:

> *"Visual perception [of space] has to work with corporeal motion and the passage of time, an additional parameter to motion"*

Once immersed in what he describes as "*submersive environments*", they lose their ability of apprehending the space in which they stand, and sometime even struggle with finding their balance. All these processes are usually immediate and automatic like breathing. People willing to spend time slowly examining his LED installations and their influence over them: may experience a shift in the way they usually apprehend space and time by entering infinite spaces that seems to recede in all directions, as if the walls were mirrors or had even vanished.

The overall appearance of a space as simplistic as a White-cubed gallery will suddenly change, providing no fixed points on which the viewer can stabilised both his gaze and body. To do so, he fills the exhibiting space with wall to wall and floor to ceiling grids of LEDs, creating a pulsating visual network that enacts both the amplitude and regularity implied by all the meanings of the word matrix. Controlling the modulation of light with a computer program, Redl generates a perpetual system of repetition:

> *"The formal aspect of the works is easily accessible. An interpretation and understanding of this aspect is dependent upon the viewer's subjective references. Equally, the various individual's interactions within the context of the installation re-shape each viewer's subjective references and reveal a complex social phenomenon."*

This constant fluctuation plunges the viewer in both introspective and detailed observation of an abstract '*lightscape*', observation that cannot be completed or reproduced. The viewer becomes an active participant in a visual display that, according the artist:

> *"plays games with the human eye, human visual experience and expectation."*

There is no end point to Redl's installations that are comprised of infinite sequences of ebbs and flows. As Kenton Smith puts it:

> *"any expectations of how to relate to space are indeed toyed with as one moves about within Redl's grid. As I proceed from one end of the room to another, flanked by rows of blue LEDs on both sides, I am disorientated and delighted in a house-of-mirrors fashion by my mind's (initial) inability to discern which is in fact on an angle the floor or the rows of lights." (Smith 2005)*

Paradoxically, if one examines the oscillating light carefully, the methodical movement begins to mesmerise one's attentive gaze. The viewer gets easily lost and overwhelmed in a space they cannot perceive any longer. Deprived of nuances, space becomes alien to the viewer whose spatial perception is totally disrupted. Redl likes to say that, the viewer's "*house of cards of perception collapses very easily*."

Periodicity and rhythm are a leitmotiv in the design of Redl's installations and are reminders of his initial training and practice as a musician at Vienna Music Academy. In a text entitled *Why Light?* he draws a comparison between music and his use of light:

> *"Between 1990 and 1993 I developed a theory I termed 'Parallel Music' linking pitch, tempo and rhythm according to the time parameters frequency and absolute note-length. I later developed this theory into 'Parallel Media' which combines sound-frequencies with visual elements using colour-frequency as their basic frequency." (Redl: 2007)*

Light turns time into space, and allows the artist to play with it according the laws of geometry. Light does not only generate open or closed spaces, but a temporal ellipsis in which the notion of time as we know it no longer exists. Fred Sandback's exhibition at the *Dia Foundation* in New York in 1997 played a crucial role in the development of the Parallel Media theory:

> *"[this exhibition] changed my work dramatically. Sandback's installations combined all elements I was interested in – pure structure, spatial abstraction, immateriality, etc. He achieved everything I was dreaming about, a perfect combination of formal clarity with inherent sensuousness of space, something that – up to that point – I had almost exclusively seen in the visual realm of computer graphics." (Redl: 2007)*

From this point Redl has tried to make our spatial reality and 3-D virtual reality meet and collide. His goal has been to make these two realities coexist in the most tangible and sensually disruptive way by immersing the visitor in a composite and alien reality in order to create:

> *"an ongoing exploration of human perception in which visitors to the exhibition are literally put in the third dimension." (Smith 2005)*

Despite the elegant and slick simplicity of his installations, Redl uses the term of '*space raping*' while explaining his attempt to fight against our 'so-conditioned' spatial perception. His work demands the visitor to re-imagine space from a perceptual point of view in order to create and experiment with what he calls '*transpersonal communal spaces*':

> *"Only corporeal motion and the subsequent discovery of all aspects of space (visual, corporeal, acoustic, social, etc.) slowly reveal the nature of the piece. Those aspects are highly subjective, based on private, individual memories of the viewer, yet they are experienced in a communal setting which leads to often very surprising interactions between strangers during exhibitions."*

Redl's approach to light focuses upon the creation of illusory and radiant space in which Newton's laws seem to have been banished. They are simple exhibition spaces made visually tangible thanks to grids and/or planes comprised of thousands tiny bright LEDs that emit a single light frequency – they are therefore perfectly suited to the structural thinking he demonstrates in his exploration of the *Parallel Media* theory.

By doing so he has been trying to liberate the temporal and visual effects of his computer-generated work from the confines of the monitor in order to "*fine-tun[e] the [viewer's] modes of perception.*" In a very impressionistic manner, Redl breaks space and time into light matrices, into installations that evolve constantly according to the viewer's presence and motion.

Even if most of his installations are static, Redl's installations go past LEDs' aesthetic limitations to form visual experiences in which space vanishes to form palpable ether and time becomes geometric and tangible.

Acknowledgments

I would like to thank Erwin Redl for his help and having provided me with full access to various materials such as email correspondence with reporters and visuals.

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Light focusing on design in society and working life

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oral paper

Abstract

The objective of the project is to study and analyse Design approaches and methods in complex situations, such as public and urban settings and furthermore territorial development strategy, thus exploring the possibilities of creating light and colour solutions. It also aims to highlight the design process as a possible methodology for product and service development. The project made use of a design methodology named ITK - Identity Tool Kit -, a comprehensive method to create a more inclusive and easily accessible design method applicable to a wide array of design projects, academic and professional. The case studies here presented reveal how the method was used in the region of Kalmar, Sweden.

1. The background and purpose

The aim of the project was to study and analyse Design approaches and methods in complex situations, such as public and urban settings and territorial development strategy, exploring the possibilities of creating light and colour solutions that take into account both function, ergonomics, psychological and emotional aspects in public surroundings. It also aimed to highlight the design process as a possible methodology for product and service development.

The project stepped out from an initiative launched by the Swedish Ministry of Culture, to encourage the development and spread of design within the country and was the premise to the research LCS-light, colour and space, which is an ongoing international project.

2. ITK , Identity Tool Kit method

The activities of the *Year of Design* in the region of Kalmar were planned and put in execution making use of the ITK (Identity Tool Kit) design methodology. The *Year of Design* was an act, on behalf of the Swedish government, to draw attention to the role of design in the Swedish society; exploring, thus, the cultural, economical, technological, historical, and even political relevance this role may play in enhancing both social and working life.

The *Year of Light,* the subsequent regional umbrella project, aimed at expounding the possible roles of lighting design in the local community, by discussing and reworking the lighting of a number of local public spaces in order to change their visual identity and expression.

The ITK method is an informal process that gives everybody the opportunity to be heard within a working team, and whose primary goal is to draw out a uniform identity idea that may be translated into a powerful and functional graphic identity, regarding the character, tone, colour and shape. The ITK method is essentially based on the connections among the visual, verbal, and the participants' dialogues and choices made during the process. The relations between the participants in a project or team are often complex and sometimes fixed, because they usually represent different interests and see then the purpose of the project differently, further most persons involved in projects lack familiarity with the aesthetic terminology used by professionals, which makes it difficult for them to make the connection between the goal of their work and the work on a new visual identity. These are the basic drives behind the creation of the Identity Tool Kit method. All tools has to be accessible to all participants in order to bridge pre-existing factions within the organization and allow the process to keep focus on the overall goal – what the involved entity is, what it would like to become and how it would like to represent itself. It is carried out through a series of works shops, using images and words to engage the participants in the design process such creating the premises for a management process.

3. The six steps of ITK

The Identity Tool Kit methodology consists of six distinct steps. During most steps "affect boards", collages that expresses the image and sense that the organization wishes to convey, are used to express opinions and concerns.

The process begins by Step 1, the State board, describing what the concern presently stands for, as the current visual identity and the "core value", where core value is taken to describe the spirit of activity of company, which is different from the business idea connoting the purpose of the activities rather than describing them, and this will eventually lead to an articulation of what the future visual identity should express. Example descriptions of terminology to use, would be "environmental", "socially minded", "flexible" etc.

The purpose of Step 2, the Position board, is to describe the context within which the organization operates. In order to frame the context the participants create a matrix using operational dichotomies to describe the organization's context, for instance "expensive / cheap", "simple / complex". After creating the position board the organization is placed on the board in relation to other actors. In order to contextualize the organization in this way the participants are encouraged to think about their relation to their context and become more aware of it, something that can have determinate influence one future actions.

The Step 3, the Future board, is in other words a sort of aspiration board and it is supposed to illustrate the organization's future profile and visual identity. It is produced by the same method, using core values that the organization wishes to hold in the future, using the affect board for illustration. After making the boards you return the matrix from the previous step and mark the place of the desired future position.

At this point it is time to create the basis for a future visual identity by Step 4, the Colour and Shape, trying to translate the affective qualities, shapes and colours present in the future board into building blocks. At this point it is still important to curtail the maximum number of co lour and forms used in order to achieve clarity in the final visual profile.

Then one proceed to Step 5, the Condition/Tone, or what tone the organization wishes to have, let it be funny, serious, aggressive or else, considering that more than three key words risks leading to confusion. This part of the processes builds directly from step 4 and 5 and is aimed at arriving at an idea of the conceptual framework for the future profile and visual identity. Examples: Form – soft; Colours – cold; Tone – dynamic but not aggressive.

Finally we arrive to Step 6, the Guidelines: all the material is compiled as guidelines, creating a new profile that should work both internally and externally. At this stage all components of a new visual identity are present, shape, colours and tone and are, in this way, easily employed by designers in order to create a new visual identity.

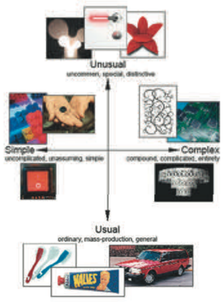
4. The development of the Light Year

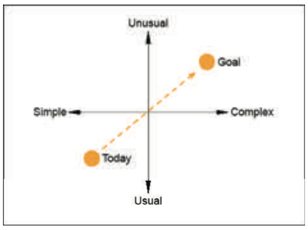
The first phase was characterized by the arrangement of a “Light Year” where a knowledge platform was built and design methods were studied, aimed at lighting up urban spaces in the region. Throughout the course of the Light Year several communication, technical, artistic and educational events including workshops, conferences and other temporary or permanent initiatives were implemented. Since the projects involved a number of people from different backgrounds, such as architects, politicians, representatives from the local lighting industry, engineers, fine artists and interested members of the public, the projects proceeded by applying the ITK method in order to bridge potential communication problems. While working in teams the participants filmed their work in order to be able to later on analysing and elaborating it. During the second phase the design methods and processes were applied in full scale tests performed through workshops on the territory. The second project part of the *Year of Light* involved the students at School of Design,

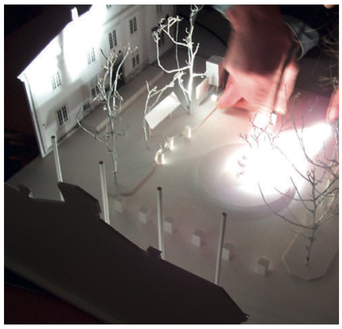
Three particular projects were conceived, firstly, the reworking of illumination of an apartment bloc facing increased levels of social problems; secondly, the reworking of the lighting of the main square in a small town in order to create an increased community feeling and thirdly, the lighting of a public park now completely disused because of the lack of illumination. In addition to the artistic projects, involving fireworks, lights, poetry and dance, several design plans where carried out, such as the street-lighting on Öland, the island opposite the city of Kalmar, which was at the centre of most projects with the active participation of the national road commission and the superintending regional board for local arts. Furthermore light settings were implemented in urban, park and cemetery areas.

5. Concluding remarks

The goal of the project of moving beyond light design and showing the usefulness of design and design method so that design is perceived to be essential for everyone in work and at leisure and as well knowingly work with design and business development and strategic approach was achieved. The purpose of Light year, created by Henriette Koblanck and Jan Ejhed of the Kalmar University Now Linnaeus University, of clarifying the value of design in everyday life was rewarded by the National design prize, and by practical issues of permanent and temporary events such as light festivals, installations, urban lighting and urban plans, and the creation of new work places.







Figures 1., 2., 3.,4., 5., 6., 7., 8., 9., The various phases of the Year of Light

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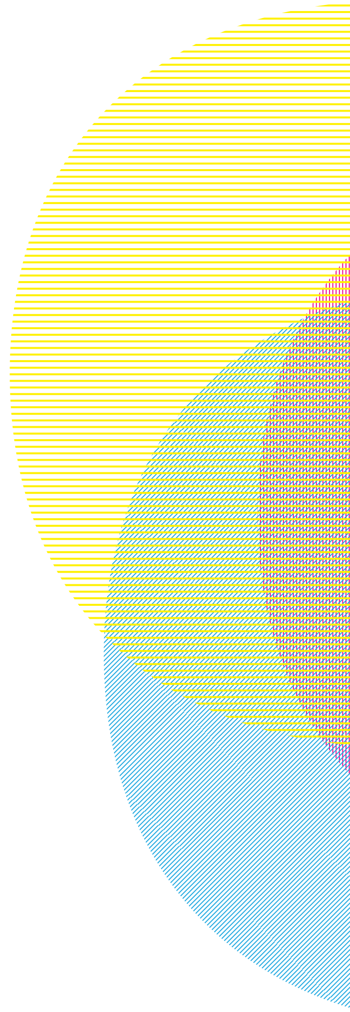

Posters

in alphabetical order

Trichromatic animation

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Abstract
The process described here is well at the heart of the appearance of pigmentary materials and their interactions with light. It is indeed based on the property of colored materials to reflect, in a selective way the colored radiations of light, or to absorb them. The innovation is here based on a more subtle and more complete process, using the trichromy, i.e. all the possibilities of the white light, which is split in three primary radiations: red – green – blue. One can, indeed, animate a pigmentary surface by the alternate projection of these three colors, and thus reveal three different images on the same support, or create a motion effect. However, in this process, the weakness of blue, compared to green and red, might constitute an obstacle. But that will be compensated by the use of fluorescent colors, instead of ordinary colors. This process may provide very spectacular applications in the fields of lighting, architecture, design, scenography, booths, display windows, etc. We shall propose a step-to-step approach.

1. Bichromatic animation
According to this principle, it is relatively simple to create an animation of coloured surfaces using the alternate projection of red and green, by filtered lights.

Then, the most obvious is to create figures in these two colours like, for example, a small girl playing at skipping-rope, or of boxers in action. According to the alternation of opened red filtering, the action can be accelerated or slowed down.

But we may still refine the process, by using intermediate nuances. The image will be then made up like a mosaic, where each coloured surface will be proportioned according to its reactivity under green light, or under red light. So it possible to superimpose two completely foreign images, with their various gradations.

To control these effects, it is necessary to draw a table, in which we will represent various coloured nuances, restoring the values, sought between the extremes of green and red. Then, these colours will be connected with white, black, or gray, under these various lightings.

However we shall observe that we do not completely reach a pure white, or a pure black, and that we shall speak more about a very light gray, or a very dark gray. It is necessary to take it in consideration, for the background colour.

But we also observe that, in this table, white can be replaced by yellow, and black by blue. Yellow will be light under green light, as under red light. And under these two lights, blue will be dark.

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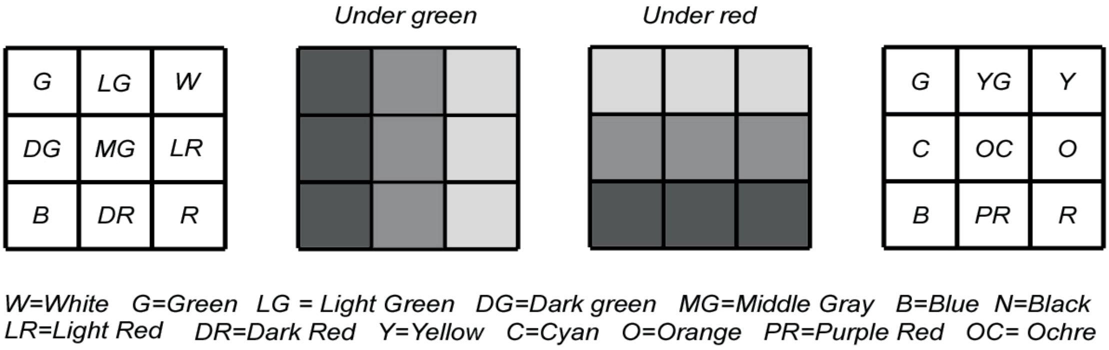
Table 1. Bichromatic animation.



2. Trichromatic animation

The fact that it is possible to also use blue, let us suppose that it should be also possible to use blue light as a third colour, in order to bring an additional distinction to that of green and red. But consequently, we cannot be satisfied any more by a two-dimensional representation, and it is necessary to think in space, since we have three sizes to take into account, as from now on.

We may thus draw a right-angled dihedron, where these three sizes will appear, graduated in scales from 0 to 256. It becomes thus possible to provide which shall be the exact colour we seek under these three values. To the limit, we could even deal with extremely small surfaces, solving all the cases of figures for three superimposed images, being distinguished in delicate graduations, according to three lightings.

We will place there the pigmentary colours, according to their relations to the three illuminants: **green – red – blue**. We may scan, for this purpose, the pigments to be used and control their values in a digital way, under RGB.

But if the colour set of the dihedron could be theoretically compatible in all the values sought, we soon observe we are limited by the quality of the pigments really usable, and of the usable coloured filters.

This is why the colours really usable draw a curious figure inside this theoretical dihedron. As result, it becomes necessary to preserve only the “hard core”, presenting all the combinations.

Thus trichromatic animation is possible, and we may consider using three really different images. That will, more especially, suggest the idea of a three-phase movement. But since we then deal with strongly grayed colours, the effects will be rather subtle, and will appear as lacking power.

It is especially blue lighting, which poses problems. Because if blue can darken under red and green lighting, it is more difficult to lighten it up under blue lighting. It is due to the fact that, to be sufficiently selective, blue filtering shall be relatively dark. And if a less dense blue filter is used, to allow more light to pass, it does not then become sufficiently selective. The result is a dilemma, which seems difficult to solve. There is a serious disadvantage, making trichromatic animation more difficult and less spectacular than simple bichromatic animation.

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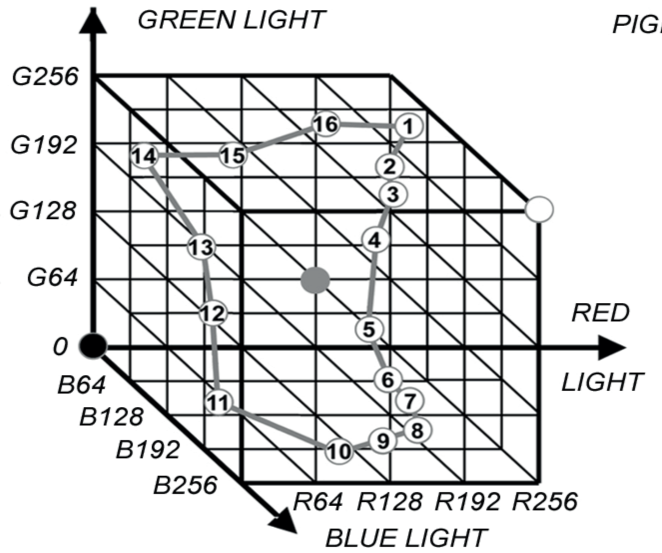
Table 2. Pigments in trichromatic animation.



PIGMENTS IN TRICHROMATIC ANIMATION

1 -	R256	G227	B26	Yellow
2 -	R225	G163	B9	Yellow-orange
3 -	R249	G113	B3	Orange
4 -	R235	G53	B3	Red-orange
5 -	R226	G29	B35	Red
6 -	R208	G14	B100	Magenta
7 -	R210	G22	B134	Red-purple
8 -	R170	G11	B113	Purple
9 -	R80	G0	B102	Purple-blue
10 -	R61	G23	B145	Ultramarine
11 -	R0	G30	B202	Cobalt blue
12 -	R0	G110	B218	Cyan
13 -	R41	G146	B103	Green-blue
14 -	R26	G124	B3	Green
15 -	R118	G211	B17	Green-yellow
16 -	R171	G221	B0	Yellow-green

3. Use of fluorescent colours

However a solution coming from the use of fluorescent colours may be found. We then observe that fluorescent colours are miraculously illuminated under blue lighting, and even a relatively dark one. What this miracle is due to?

Thus in fluorescent colours, under blue lighting, red remains red, yellow remains yellow, green remains green and blue remains blue, contrary to the occurring with ordinary pigments.

That is due to the **Stokes' law of fluorescence**, according to which: "The wavelength of the light emitted by fluorescence or phosphorescence is always greater than the wavelength of the light absorbed on excitation."

It then causes a shift between the wavelengths of excitation and those of reemitting. In other words, the more the illuminating light is of the shorter wavelengths, i.e. towards blue, the more the set of the other fluorescent colours becomes visible, being of longer wavelengths. Conversely, the result is that the more the exciting light is of greater wavelengths, i.e. towards the red, the less the fluorescent colours will be re-emitted, and will appear to die out. Thus, under red lighting, only the reds of fluorescent or ordinary pigments will be illuminated. But under green lighting, fluorescent red will be also visible, which is not the case with ordinary pigments.

The most interesting would be then to use a sufficiently powerful fluorescent blue, so that it may be illuminated correctly under blue lighting, and darkens under other lightings. But it remains difficult to find blue fluorescent pigments of a beautiful quality. And it is normal, if we remind that fluorescent blue is of short wavelength. The shift can thus only operate with purple blue, or with ultraviolet rays.

The use of ultraviolet rays is quite possible, but encounters difficulties of application. Indeed, an ultraviolet lighting shall be mechanically occulted, because not being able to die out and re-ignite at short intervals.

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4. Ordinary colours and fluorescent colours

This can be compensated by other applications. We may, in particular, exploit the difference between fluorescent pigments and ordinary pigments within the same colour. For example, if we simultaneously use a fluorescent red and an ordinary red, astonishing effects may result. Thus we will observe, under red lighting, that ordinary red, like fluorescent red, merge with the white of the paper. On the other hand, the same fluorescent red will remain red, under blue or green lightings, whereas the ordinary red will die out, and become black. The same will occur for green: under blue lighting, fluorescent green will be visible, but will become yellowier, whereas ordinary green will appear as black. According to this principle, we may use this difference, and obtain various results. But it would be necessary to associate a little of black to fluorescent colours, so that they can be equalized with ordinary colours, according to the various lightings.

Table 3. Ordinary colors and fluorescent colours under various lightings.

LIGHTS ↓	Ordinary Blue	Fluoresc Blue	Ordinary Green	Fluoresc Green	Ordinary Yellow	Fluoresc Yellow	Ordinary Red	Fluoresc Red
BLUE	Middle Grey	Dark Grey	Black	Yellow Green	Black	Yellow	Black	Red
GREEN	Middle Grey	Dark Grey	Middle Grey	Light Grey	White	White	Black	Red
RED	Noir	Black	Black	Black	White	White	White	White
PURPLE	Purple Grey	Dark Blue	Black	Green	Red	Yellow	Red	Orange Yellow

5. Polychrome animation

Instead of seeking an animation by movement, we may seek a progressive illumination, like that through the various hours of the day until the night illuminations. We may use, for this purpose, fluorescent colours within the entire spectrum, while mixing them. And we shall not be limited any more to the three colours of the trichromatic process. This may be also extended to various illuminants, such as: **blue, turquoise, green, orange, red and crimson**, i.e., while also adding illuminants in the intermediate colours. Crimson or purple is especially interesting to close the loop between blue and red, and to create a perpetual motion. Under a purple crimson lighting, fluorescent and ordinary blue colours will be visible, although dark. Fluorescent red will appear curiously as yellow orange, and ordinary yellow becoming resolutely red! Yellow, orange and turquoise illuminants are less interesting, but allow a soft transition between various lightings. We still may use phosphorescent colours, illuminating themselves in the darkness, to complete the whole of this device.

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Instrumental and sensory analysis of goniochromism

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Abstract

We aim to develop a protocol of characterization which identifies the iridescence in the existing colorimetric formalism. We characterized a set of 32 samples both instrumentally, through spectrophotometry, and visually, through sensory analysis. The correlation between the results of these two characterization methods should lead to the aimed protocol. The instrumental evaluation allows dividing our set of samples in populations (e.g. plain, glossy, iridescent...); the visual one reveals the relative importance of these different attributes of the appearance.

1. Objectives and scope

Iridescent materials present striking colour changes under different illumination-viewing conditions. They are used in various domains: cosmetics, automotive..., so that their control is becoming a technological issue. The researches in this area consist in studying the parameters influencing their aspect, the different processing conditions and characterization methods (Perales, 2010). We focus on these last ones. The present colorimetric formalism is particularly well suited to coloured light sources and plain objects. In these cases the measured light spectrum doesn't significantly depend on the measurement geometry. From a stimulus light spectrum, one can compute the coordinates of the perceived colour, represented as a dot in a colour space. In the case of an iridescent object, the reflection spectrum strongly depends on the measurement geometry (Höpe, 2010); so that it is possible to associate to this object a cluster of points in the colour space. New tools have to be developed to characterize and control such objects.

Here we describe a few instrumental methods to identify the colour change of iridescent objects relative to the various observation configurations (illumination, observation and material). Then we present a sensory analysis experiment aiming at defining their different attributes. The correlation between instrumental results and human evaluated attributes should lead to a protocol characterizing goniochromic objects without appealing to a visual evaluation.

2. Materials

We based our study on a set of 32 samples:

- Plain samples: the main physical phenomena are absorption and scattering;
- Glossy samples: the main physical phenomena are absorption, scattering and specular reflection at the interface between air and the material;
- Sparkling samples: the main physical phenomena are absorption, scattering, specular reflection at the interface between air and the material, and specular reflection on metallic pigments;
- Iridescent samples: the main physical phenomena are interference reflection, absorption and scattering.

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On a material point of view, the two first ones rather correspond to traditional pigments and dyes, the two last ones rather correspond to flake pigments. Here the three first ones are only considered as a reference for iridescent ones. This classification is only a first presentation, note that some samples are e.g. both sparkling and iridescent.

3. Characterization

3.1 Instrumental characterization

These goniochromic materials require unusual instrumental methods; the ordinary colorimetric instruments with a single geometry of measurement are not enough to characterize the variety of perceived colours. In order to investigate the different spectral responses of the materials, we used a **multi-angle spectrophotometer** (X-Rite MA98). It allows measuring the reflection spectra in 19 geometries; thus we get 19 points in the CIELAB space. All reflection spectra are measured out of the specular direction, at least 15° from it. In order to have access to more geometries, we used a **conoscopic colorimeter** (Eldim EZ-Contrast): for a given, adjustable, incidence, for every viewing angle (roughly 28800 viewing directions in a cone of 80° semi-aperture), we get the colorimetric coordinates of the light reflected in this direction. The measurement duration with a conoscopic system is much shorter than with a goniometer. For each incidence angle, we get a cluster of nearly 28800 points in the CIELAB space; here only 20° and 45° incidence are presented.

The most classical method to characterize goniochromism is to look at the **evolution of the spectral response with the measurement geometry**. Here, from 19 spectra: for plain and glossy samples, only the amplitude of reflection spectra vary; for metallic samples, the more the detector is close to the specular direction, the more the spectrum is peaked; for iridescent ones, close to the specular direction, spectra present peaks whose wavelengths change with the measurement geometry.

For a given incidence, the **evolution with the wavelength of the intensity diffusion function**, i.e. of the angular distribution of the reflected light in the plane of incidence, is an indication of iridescence. An important evolution of the spectral position of the reflection peak with the measurement geometry is a feature of interference. Here, from 19 spectra: for plain and glossy samples, only the amplitude of the intensity diffusion function vary with the wavelength; for metallic samples, around the specular direction there is a strong spectral selection: the specular lobe appears only in a given wavelength range; for iridescent ones, around the specular direction there is a strong spectral selection, whose central wavelength changes with the measurement geometry.

To characterize goniochromism, a promising approach is to study the **topology of the cluster of points in the CIELAB space** (size, shape and volume…). Here, from conoscopic colorimetric measurements, the general aspect of the cluster seems to depend on the appearance (more detailed study in progress). From multi-angle spectrophotometry, we computed the lightness, chroma and hue range widths of the cluster of points (see Table1). Hue range gives the most information about the appearance of the sample. The plain and glossy samples present a small hue range width compared to the iridescent and metallic ones. The presence of a sparkling particle broadens the hue range.

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Table 1: Lightness, chroma and hue range widths of the cluster of points in the CIELAB space. Values on several samples are averaged.

	Plain	Glossy	Metallic effect		Iridescent	
			Not sparkling	Sparkling	Not sparkling	Sparkling
Lightness range	41	28	93	77	61	43
Chroma range	18	42	56	27	28	41
Hue range	5	20	30	79	150	172

From this instrumental work, we confirm that we can distinguish between the four samples families: plain, glossy, metallic and iridescent. This seems to lead to a few pertinent features characteristic for iridescence, which could be correlated to visual characterization main features.

3.2 Visual characterization

The visual evaluation consists in a sensory analysis experiment. It aims to define the sensory attributes characterizing the goniochromic materials. A 15-assessor panel has been trained to establish an objective, descriptive profiling of our samples.

In a first time, the panel freely sorted our samples. The following dendrogram (see Figure1) represents the resulting classification. Of course the panel distinguishes between the four samples groups; what's interesting is how they classify them. This dendrogram reveals that, among these four attributes of appearance, sparklingness is the most striking, whereas iridescence requires attention.

To do the descriptive profiling of our samples, the panel trained and selected a set of relevant descriptors which characterize the iridescent samples from the others ones: the lightness, chroma and hue variation, the intensity of sparkling, the density of spangles, and the brightness. The judges established a protocol for evaluating these descriptors. A sample is evaluated under the D65 light source of an individual sensory evaluation cabin, both in movement and in a few different static geometries (see Figure 2). The quantitative evaluation has been done these very last days; its results should be available in a few days.

4. Conclusion

To identify iridescence, we characterized a set of 32 samples, including non-iridescent ones as a reference. From instrumental results we can distinguish between iridescent and other objects; hue-range width seems to be a pertinent parameter. Visual evaluation shows how iridescence is linked to other attributes of appearance, such as sparklingness; it proposes a protocol that could define sufficient geometries for further instrumental measurements. The correlation between the features defined from our instrumental work and those defined from the sensory evaluation should enable us to improve the protocol. Eventually this protocol should also allow distinguishing between iridescent objects without appealing to the human evaluation.

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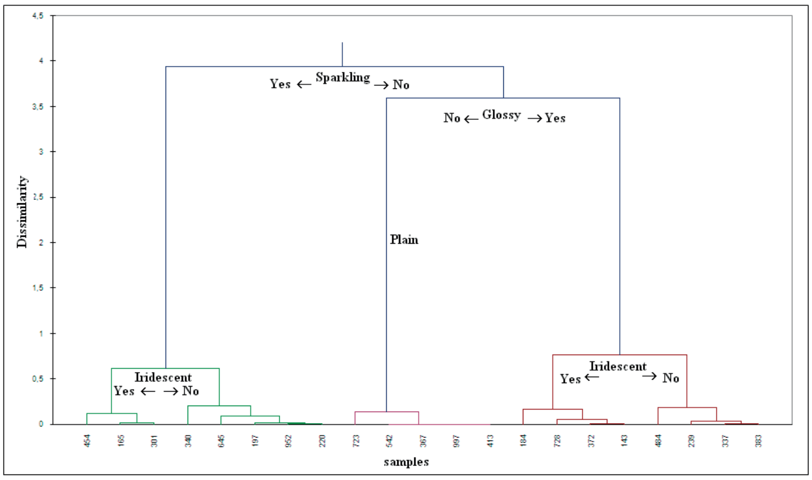

Figure 1. Result of the visual free sorting

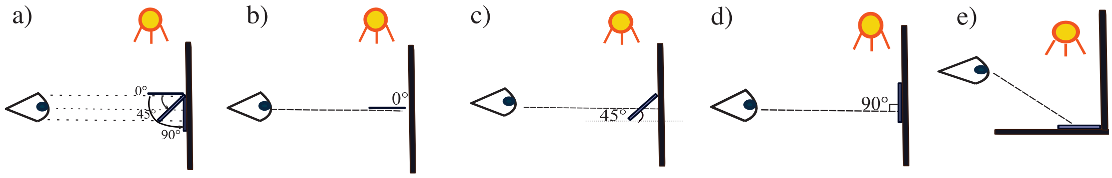

Figure 2. a) dynamic evaluation: the sample is placed at height of the eyes, it is rotated around the contact line between the sample and the cabin; b)-e): static positions: b)-d): the sample is placed at height of the eyes; e) the sample is on the desk.

Acknowledgments

This research is funded by the Nord-Pas de Calais region-France. The authors wish to thank Elodie Collet and Sylvie Chollet from IS and ISA Lille France for her help and Françoise Viénot from CRCC (MNHN-CNRS-MCC) for her encouragements and for offering access to her laboratory equipment.

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The use of matrix Q of the decomposition theory and principal component analysis for color image mapping of a scene

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Abstract

Color scene interchange has been widely considered in manifold applications. In the present study, a new technique comprising of the Cohen & Kappauf (C-K) decomposition theory together with PCA (Principal Component Analysis) method is proposed as a practical tool for color image mapping of a scene. In this technique, the images of the target and the standard are captured under a desired illuminant/observer combination. Matrix Q of the C-K's decomposition theory is computed for the selected illuminant/observer combination. The RGB values of the images can be transformed to the corresponding CIEXYZ values using a transformation matrix. The obtained CIEXYZ values are then multiplied by the matrix Q to obtain the corresponding fundamental color stimulus (R_{fcs}). In a further step, a PCA technique was applied to the attained R_{FCS} vectors of the images. The first three PC vectors of each image was then considered as the Image Scene Mapping (ISM) matrix. Finally, the R_{FCS} vectors of the standard image were reconstructed using the computed ISM matrix of the target image. The obtained results showed that the proposed method is capable of precisely transforming the scene of one image to another.

1. Introduction

Color scene interchange has manifold applications, for example, in modifying color of old and unpleasant photos, coloring black and white pictures, scene simulation, computer graphics, industrial design, and etc. As examples, Reinhard et al. (2004) tried to transfer the color space between images using a vision-based lαβ color space. Welsh et al. (2002) carried out color transformation for colorization of grayscale images. Zhang et al. (2004) tried to balance color appearances amongst a group of images, such as panoramic images and object movies by the aid of color correction methods. Although lαβ is a non-correlated color space, but its axes do not always match to the principal axes of the real image and also lacks stability. Therefore, these techniques might give appropriate results with color similar images but cannot be a feasible choice for color dissimilarities (Saito et al, 2007).

Saito et al. (2007) applied histogram rescaling to transform color scenes between images. Based on their proposed method the scaling procedure was carried out only on the initial and terminal points of the histogram of the target and the standard images. Therefore, the shape (distribution) of the image's histogram did not totally change and probable noise significantly influenced the results.

In the present study, a new technique comprising of the use of the matrix Q of the Cohen & Kappauf (C-K) decomposition theory together with a mathematical PCA (principal component analysis) method is introduced as a practical tool for color image mapping of a scene with a high degree of precision.

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2. Method

The suggested method is based on reconstructing the spectral reflectance data of the images using the C-K decomposition method (Cohen and Kappauf 1982) and applying a PCA (Johnson et al 1998) mathematical technique to change the basic color axes of a standard image to their equivalence in the target image. The simplified procedure is introduced below:

a) Estimating the spectral data of the two images (the standard image and the target image) applying C-K decomposition theory:

- Identify the spectral power distribution (E_λ) of the light source, under which the image was captured.
- Converting the device-dependent RGB values of the digital camera to CIEXYZ values (T) using a transformation matrix. This can easily be done by colorimetric characterization of the camera.
- Calculating the Q-matrix based on the used light source and a defined standard observer.
- Multiplying the Q-matrix by the CIEXYZ values to obtain the R_{fcs} (the fundamental part of the spectral reflectance data) $Q \times T = R_{FCS}$
- Computing eigenvectors and eigenvalues of the R_{fcs} matrix by a PCA technique.
- Sorting the 16 eigenvectors (e.g. for 16 spectral data at 20 nm intervals) in accord to their importance. This is carried out according to the corresponding eigenvalue of each eigenvector.
- Selecting, the first most important three eigenvectors, as the Image Scene Mapping (ISM) matrix. The other vectors would clearly give much less information or detail if any.
- Computing the weighted coefficient (α) of the PCA method for predicting R_{fcs}.

  The above procedure is carried out for both standard and target images.

b) Color transforming

- The new R_{fcs} values of the standard image are reconstructed by multiplying the first 3 PC vectors of the target image by the weighted coefficients of the standard image.

$$\hat{R}_{FCS,\lambda} = \sum_{i=1}^{3} \alpha'_i \times PC_{i,\lambda}$$

- Calculation of XYZ values of the standard image from the computed $R_{FCS.}$
- Transformation of the obtained XYZ values in the last step to RGB values.

  In this way, the color scene of the target image is transformed to the standard image.

3. Results and Discussion

The proposed method was applied for color scene transformation between images. As an example, the result of transforming the color scene of a sunset image to a cloudy sea is shown in figure 1. Figure 2 demonstrates The corresponding fundamental color stimulus (R_{FCS}) of cloudy sea and city sunset images. In addition, figure 3 and 4 show the first 3 eigenvectors of the cloudy sea and the city sunset image respectively.

It can be seen that, the proposed method can give the possibility to transform the color spaces between images. For more clarification the color gamut of the two images were calculated with the convex hull(1996) method. The obtained results are shown in table 1. Furthermore, the color gamuts of the three mentioned images are shown in figure 5. As indicated the small color

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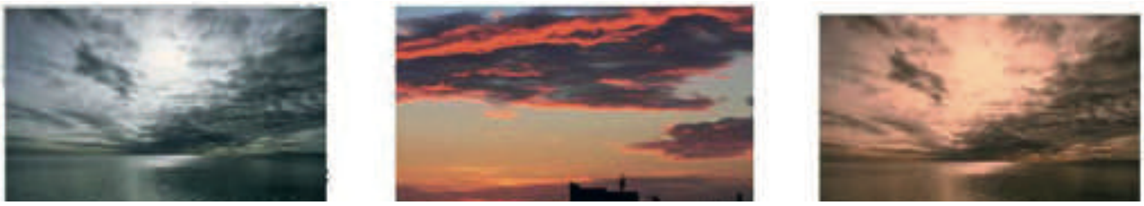
gamut of the standard image is extended after applying the proposed color transformation technique.



A: cloudy sea *B: city sun set* *B to A*

Figure 1: The standard image "cloudy sea" (A), The target image "city sunset" (B), and the resultant image by applying the proposed method to convert the color scene from B to A

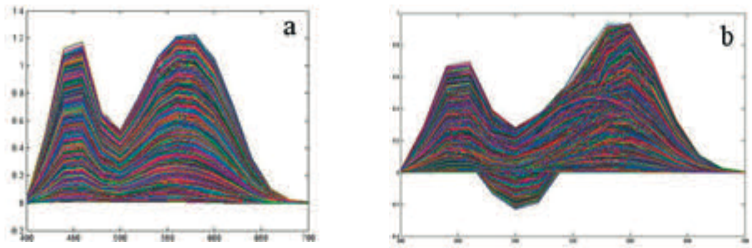


Figure 2: The corresponding fundamental color stimulus (Rfcs) of the(a): "cloudy sea" and (b): "city sunset"

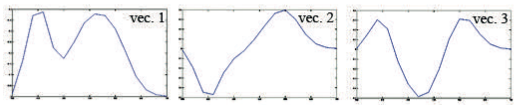


Figure 3: The first three eigenvectors of the "cloudy sea" image

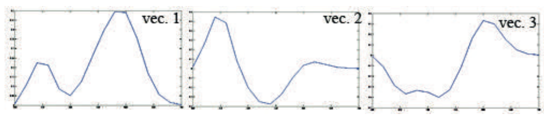


Figure 4: The first three eigenvectors of the city sunset image

Table 1. Gamut volume of standard image (A), target image (B), and final image (B to A)

	Gamut Volume
Standard image: Cloudy Sea (A)	12934
Target Image : City Sunset(B)	148828
B to A	36006

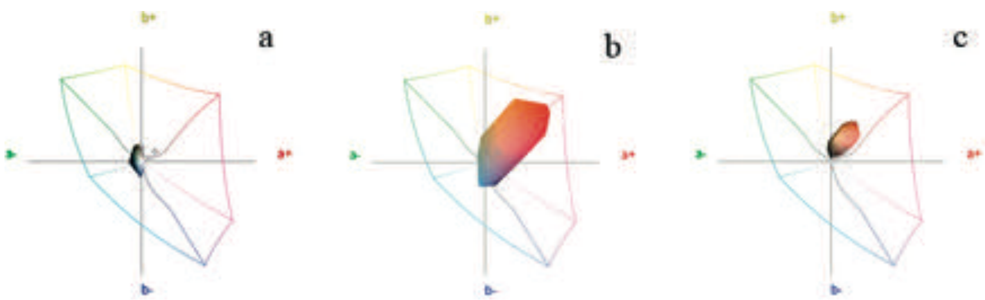


*Figure 5: The CIEL*a*b* color gamuts of a: the standard image (A); b: the target image (B); and c: the transformed image*

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3. Conclusion

It is of interest to change the color scene of an image according to a target image. This study introduced a new method comprising of spectral reconstruction by the Cohen & Kappauf decomposition theory and identifying the basic color vectors by the aid of a PCA method. In this technique, the RGB values of the standard image are transformed to the corresponding CIEXYZ values using an appropriate transformation matrix. Then, the tristimulus values are multiplied by the matrix Q to obtain the corresponding fundamental color stimulus (R_{FCS}). In a further step, a PCA technique is applied on the attained R_{fcs} vectors of the images. The first three PC vectors are then considered to be the Image Scene Mapping (ISM) matrix. Finally, the R_{FCS} vectors of the standard image are reconstructed using the computed ISM matrix of the target image. The obtained results clearly illustrated that the proposed technique has the ability to transform the scene of one image to another with a degree of precision and accuracy.

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New photometric device for discrete angular measurement. Experimental validation by analysis of the glare on buildings

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Abstract

The quantity, quality and distribution of lighting play an essential role in the sensations that we perceive around us [1,2]. In this work a new photometric device is presented. This new device measures simultaneously the total incident illumination and the relative percentage contribution to this amount of each incident direction. The photometric measure is done by means of a set of photodiodes working in parallel with an optical system with a digital sensor of 2Mp. The set of photodiodes measures the total amount of light whereas the digital sensor working with an 180º FOV objective focused to infinite allows to have information of each direction over a hemisphere. The results obtained with this device are of interest to measure stray light, glare effects and light pollution. The possibility of knowing the origin and the amount of energy enables the possibility to analyze complex environments and make energy-saving plans, as well as illumination efficiency and visual ergonomic studies. The presented device has been experimentally validated by means of the study and the analysis of glare effect in a work area.

1. Introduction

The new device presented in this communication allows doing, dynamically and simultaneously, the measurement of the total amount of light and its angular distribution.

Nowadays, one of the big challenges in energetic engineering is how to tackle the energy saving in outdoor and indoor environments [3]. Many infrastructures present a deficient or not proper illumination distribution, being because there is an excess or a lack of light, a non-adapted design, stray light, light from other sources, glare effects... Usually those effects conduce at an inefficient energy management. The presented device is a compact and portable tool capable to analyze the illumination in a defined environment, with a large degree of complexity, which can give information about the energy distribution on the environment and the proportional contribution to it of all the light sources. This communication is divided in three sections: this introduction, the method used to make the measurement and the analysis, where the measurement basics are presented as well as the theoretical context, and finally some results to validate experimentally the device and a summary and conclusions are made.

2. Method

The device characterizes the light emission of the sources in a measurement environment, providing information of the amount and distribution of the light that arrives to the device from all the sources.

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A measurement environment is understood to be a space with light sources, no matter if indoor or outdoor. A source can be a primary source (streetlights, traffic lights, lamps... those addressed to illuminate the environment) or a secondary source (reflections on the environment objects, stray-light, etc. light that comes from anywhere but the primary sources). (Figure 1)

To measure the total amount of light, the device has a set of calibrated photodiodes. These photodiodes work synchronically with an angular discrete sampling system. The discrete sampling system uses a wide field lens focused to infinite and a digital sensor.

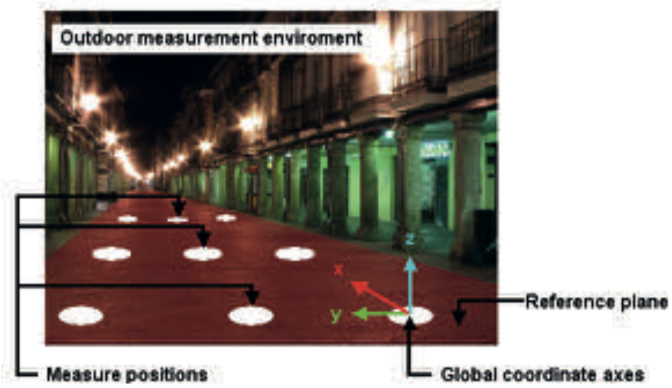

Fig. 1. General schema to show an example of measurement environment (outdoor in this example). In this schema some measurement positions of the device have been marked with white circles. The global coordinate axis are shown. The reference plane is chosen to be the street floor.

If a ray impacts in the entrance pupil of the wide-angle lens with a direction **α**, the ray arises onto a pixel of coordinates (i, j) over the digital sensor, providing an electronic signal associated with a concrete gray level. The gray level is directly related with the energy amount of the ray or set of rays that travels in the direction **α** and reaches the entrance pupil.

In general, the direction **α** of each ray will be a known function of the (i,j) position over the sensor. (Fig 2a-2b).

$$\alpha = r(i, j) \qquad \text{Equation. 1}$$

The energy received in a pixel can be expressed as in equation 2.

$$E_{pixel}(\alpha) = T(\alpha) \cdot L \frac{\pi \left(\frac{D}{2} \right)^2}{f'^2} \cos^4(\alpha) \quad \Big/ \quad \alpha = r(i, j) \qquad \text{Equation. 2}$$

Where **α** is the incident direction, T is the transmittance function of the lens, L is the luminance seen from the device, f' is the focal length of the lens, D is the entrance pupil diameter, and the cosine term is related to the obliquity relation of Smith [4, 5].

Equation 2 relates the amount of incident light and its incoming direction. With this information, it is possible to study and analyze complex light environments.

The geometrical light distribution is obtained in the focal plane over a circle with diameter smaller or equal to the sensor smallest dimension. (fig 2b).

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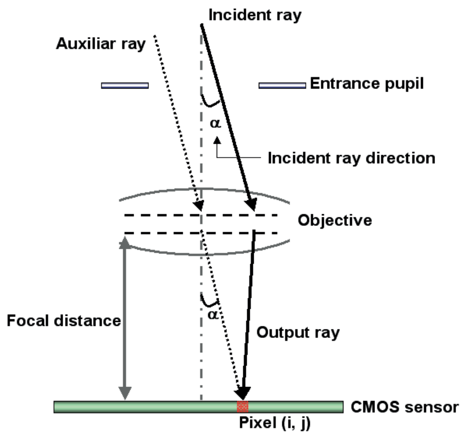


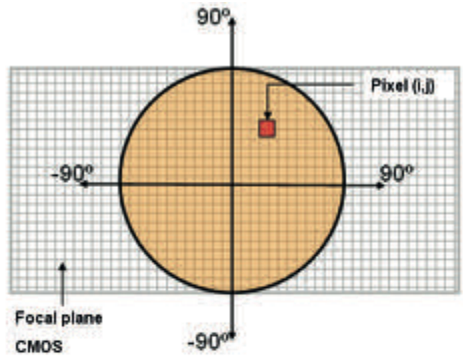
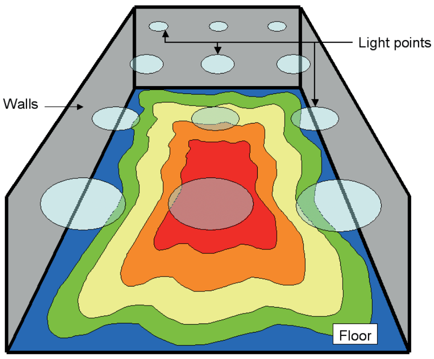


Fig. 2. Schema of a ray direction measurement. All light from this direction will be registered in the same pixel position (i,j).

Fig. 2b. Locus of the illumination angular distribution register over the sensor.Each pixel will correspond to a 0.25x0.25 degrees angular area.

3. Results

Glare effect is a typical case of an improper adjusted illumination. The device presented in this work has been validated experimentally by means of a glare analysis in an indoor environment; a computer lab. A suitable illumination in this measurement environment is around 400lx, moreover, illumination can be affected by glare effects (Fig 3a).



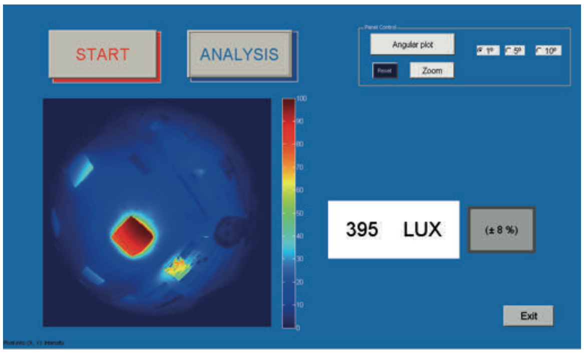
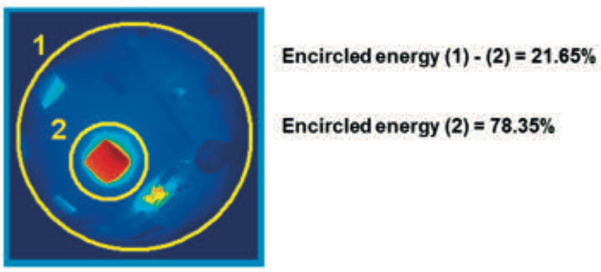


Fig. 3a. Schema of the measurement environment used in the experimental validation.

Fig. 3b. Graphical interface of the developed software for the experimental validation. [6]

The laboratory has 12 light points uniformly distributed in the ceiling. Light points are fluorescent modules; each module contains 3 fluorescent tubes. The figure 3b presents the developed software control interface where appears a photometric measurement corresponding to a work area in the lab; the device has been situated over a work site. The energy total amount measured value is 395 ± 31 lx, and it's in concordance with the illumination requirements for this work areas.



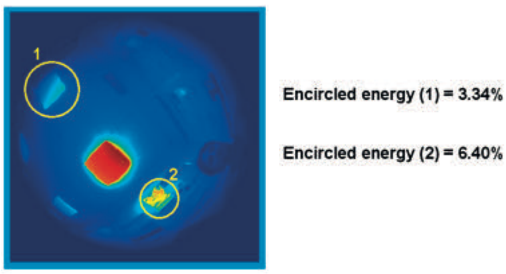


Fig. 4a Comparison between two angular areas of the photometric measurement.

Fig. 4b Analysis of two angular areas corresponding to primary and secondary light sources.

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An example of angular distribution is showed in the figure 4a where a high amount of encircled energy from a light point located just above of the measurement position appears. The developed software allows us to select different areas of interest and know the quantity of energy contained in them. The figure 4a shows that the encircled energy in the circle 2 represents 79% of the total amount of illumination whereas in the circle 1 minus the circle 2 only the 21% is contained.

The light source in the circle 2 could cause a glare effect affecting the users of the environment. However, the incident direction is near the vertical axis, so, to develop daily tasks on this environment (a computers lab), users will never direct their vision to this direction, so this source will not cause glare effects. If this source has been detected to come from some other directions, this could have been a glare source. Then, not only the value of the energy has to be evaluated, but also the incidence direction.

The other sources in the measurement position (circle 1, Figure 4b) represent only a 3% of the total amount illumination; on the other hand, secondary light sources like reflected light on walls (circle 2 figure 4b) represents 6% of the total amount illumination.

Thus, we can conclude that with the new device, a good measurement of the work environment has been done, having as a result that no glare effects are present and a good amount of illumination is obtained to work in good conditions.

4. Conclusions

We have presented a new photometric device capable to analyze the photometric information in a scene simultaneously with its directional distribution. The device is especially useful to analyze architectural lighting installations. An experimental validation has been presented.

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A portable assistance tool for color-deficient individuals with real-time color changing function

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Abstract

This study aimed to develop a portable color-assistance tool for color-deficient individuals. The tool features a color zone that can be adjusted in real time to specify changes in color within the color space. The outcome of this study was the successful development of a portable color assistance tool that increases color visibility and enhances the ability of protans and deutans to distinguish colors.

1. Introduction

Vision-related barrier-free activities, which aim to encourage the use of colors to enable individuals with various types of color deficiency to better distinguish colors, have proven quite successful in recent years. However, they offer little to overcome the problems encountered by color-deficient individuals in daily life. This study focuses on the development of color-changing methods to help protanopes and deuteranopes. In addition, it aims to apply these methods to the development of portable color-assistance tools that can be carried around all the time. It will undoubtedly improve the quality of life for color-deficient individuals. This paper is based on my doctoral thesis, Asada (2011).

2. Methods

Performing the calculations required to detect and dissolve all of the pixels of confusion colors in an image is very time-consuming. The current approach to overcoming this limitation is to change only a selected color range, rather than simultaneously change all of the colors that cause confusion. When viewing an image, an individual focuses on the target objects, which have similar colors and are often found within a single area of the image. These can then be distinguished by changing all of the similar colors to a certain color that is different from those that cause confusion within other areas of the image. Essentially, a method is used that simultaneously changes all colors, including all similar colors, in a certain zone within the color space (also, color zone) to a different color.

There is a limit to the size of one color zone, but shifting color zones over the entire color gamut of the image means that colors can be changed, and thus distinguished, regardless of the actual color of the target object. In addition, changing colors in real time ensures that the target object appears in the image due to differences seen before and after changing the colors; thus there is no need to actually point out the target object. Assigning a number or other identifier to color zones will help color-deficient individuals to better understand colors as they are perceived by color-normal individuals.

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2.1 Determination of color zone

Colors perceived by a protanope or deuteranope are considered to be points on the surface of two half-planes that pass through the points of spectral color wave lengths 475 nm and 575 nm respectively, both of which include the line connecting the black and white points in the LMS color space (Brettel, Viénot, and Mollon 1997). The point represented by the stimulus value of color-normal individuals is projected to the color projection plane in line with the confusion lines; the point projected is the color perceived by a protanope or deuteranope. Viénot, Brettel, and Mollon (1999) proposed a method that approximates this color projection plane to a single plane to simplify matters. Our study uses this method.

The confusion lines form a straight line group parallel to the L axis for a protanope, and to the M axis for a deuteranope. This study creates a number of planar groups that are parallel to the color projection plane, and sets color zones as the space that exists between neighboring planes in order to precisely segment the confusion lines. The actual calculations used to determine color zones are performed on the u′v′ chromaticity diagram of the uniform color space CIELUV. The color projection plane and other parallel planes form a straight-line group sharing one point of intersection on the u′v′ chromaticity diagram. Therefore, the wedge-shaped area is designated as the color zone (Figure 1).

2.2 Method for changing colors in color zone

Changing the colors of the original image by any significant degree will result in an unnatural image. To overcome this problem, colors within the color zone of the image are only slightly changed from the original colors but maintain adequate distance from their confusion lines. The two methods used to change colors are as follows:

- Change lightness with a fixed chromaticity: the lightness of the original colors is changed, while chromaticity remains unchanged (Figure 2).
- Change chromaticity with a fixed lightness: the chromaticity of the original colors is changed, while the lightness remains unchanged.

2.3 Implementation

The tool programmed with the above-mentioned method used to change colors was installed on the iPhone 3GS and iPhone 4 portable smart phone devices. Using the internal camera, a total of 15 images per second (resolution of 320 × 480 pixels) can be taken and displayed on the screen with real-time color changes.

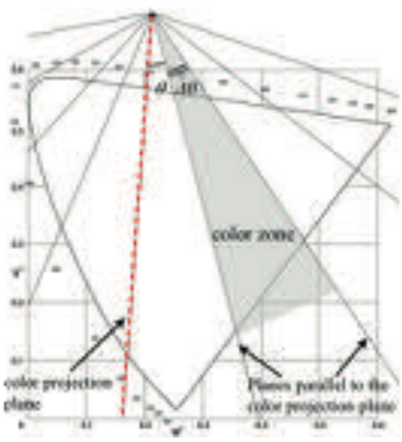

Figure 1. Color zone in u'v' chromaticity diagram

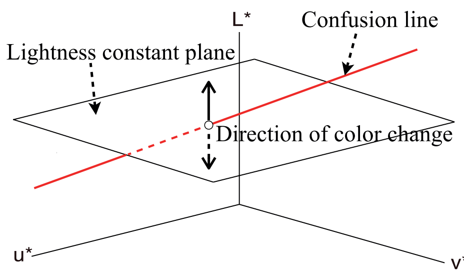

Figure 2. Change lightness with a fixed chromaticity

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3. Assessments

An assessment was made to determine whether the proposed methods that enable color-deficient individuals to distinguish objects were operating correctly, and whether the portable devices with the installed tools had delivered the expected results.

3.1 Results of proposed methods with simulated images

The simulation function was used for images taken with the portable device to check the results of the proposed methods. The images included the Ishihara color test (referred to as Ishihara Plates), which were taken in a bright room with natural lighting, and flowers in a flowerbed (referred to as flowerbed), which were taken outdoors on a cloudy day.

Figure 3 outlines the results of the images of the Ishihara plates, and Figure 4 outlines the results of the images of the flowerbed. In both figures, the top row shows images as perceived by a color-normal individual, while the bottom row shows images as they may be perceived by dichromats (according to the simulation). Both the top row and bottom row show the images in the following order: (from left) the original image, the image with increased lightness of the color zone around red, and the image with changed chromaticity of the color zone around red.

The simulated images reveal that although dichromats cannot distinguish the numeric letters in the original Ishihara plates, they can distinguish them in the same manner as normal individuals after the colors are changed. The images of the flowerbed showed that although dichromats cannot distinguish the red flowers from the adjacent green areas in the original images, they can distinguish them in the same manner as normal individuals after the colors have been changed.

3.2 Assessment of the proposed methods by color-deficient individuals

A total of four test subjects were included in this study; a protanope, a deuteranope, a protanomal, and a deuteranomal. They were asked to change the colors of the images of the original Ishihara plates and the flowerbed using the color assistance tool indoors under a fluorescent lamp. All subjects reported the same results as those obtained with the simulation (described in section 3.1). Although the method used to change colors in this study is based on colors perceived by dichromats, the test subjects with anomalous trichromats were also included to determine their results.

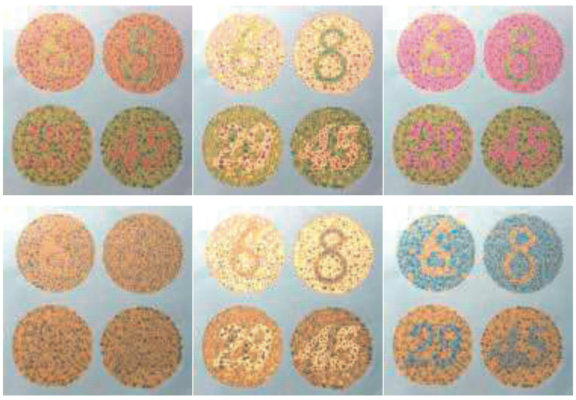

Figure 3. Images of the Ishihara plates

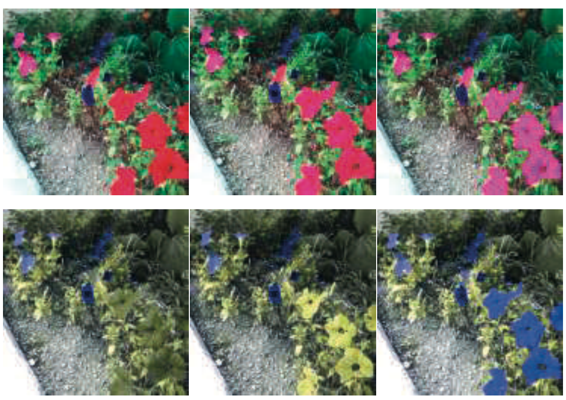

Figure 4. Images of the flowerbed

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3.3 Feedback received from color-deficient individuals after using the tool

The four test subjects were allowed to use the color assistance tool in any way they wished while performing their daily activities for a period of three days, and then asked to complete a questionnaire. The results of this questionnaire (Table 1) were as expected. However, there were also some difficulties reported, such as failure to distinguish colors under a special light source.

Table 1. Excerpts from the questionnaire completed by the test subjects

"I was surprised to see that what I had thought were black raindrops were actually red spots of rust."
"I noticed that bus routes are actually color coded. I had no idea until now."
"I can now see that there is a slight difference in color between a ripe tomato and raw tomato."
"I was able to sort through and buy green and brown garments at a clothing shop for the first time."
"I cannot see the difference between yellow-green and orange when dusk falls on the street."
"I was surprised to see that more red is used in various places around town than I had imagined."
"I can now see the difference between certain colors that I could not see before, and that made me want to discover even more new colors."

4. Conclusion

The method used to change color involved changing the lightness or chromaticity of a certain color zone in real time after segmenting the color space into planar groups parallel to the color projection. This was effective in enhancing visibility and the ability to distinguish colors for protanopes and deuteranopes, as well as for protanomals and deuteranomals, regardless of whether the observed object was man-made or natural.

Furthermore, color assistance tools utilizing these methods can be installed on portable devices that color-deficient individuals can carry on a daily basis.

Future research should focus on finding solutions to the problems faced by color-deficient individuals while using the tool, and on the development of color assistance tools for use by individuals with acquired color vision defects, such as cataracts.

Acknowledgments

We would like to express our gratitude to Koichi Iga, deputy vice-president of the Color Universal Design Organization and all of the test participants.

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Development of multi-angle spectral imaging system using LED illuminant – LCTF device and analysis of Japanese silk textiles

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Abstract

Human visual system perceive a sense of depth and texture from the contrasting pattern on surface. Qualia of texture would be influenced from individual aesthetics. In this study, the spectrophotometric characteristic of "Rinzu" fabrics, that utilized in traditional Japanese kimono, were measured using the original developed device; Multi-angle Spectral Imaging System using LED illuminant - LCTF Device. At the evaluation phase, considered it in a relationship with human movement and light environment, instead of refining for experiment with detached from the context of its occurrence. On considering these measurement results, importance of investigation to the intermediate region between each opposite phenomenon is confirmed.

1. Introduction

Spatial reflectance distribution such like various of specula or diffuse reflection are very important property for the value of design. The Purpose of this study is to investigate the impression as a reaction to texture by separating the unity of comprehensive impression to each scene of ray.

Spatial depth and texture are recognized by human visual system detect the shading pattern of the surface (gradients of optical texture) whatever the target is 2D (ex. photograph) or 3D (ex. actual landscape). Human vision is beguiled by Trompe-l'oeil. Then how do the sensitivity respond to the margins? Though margin is a place without a reproducible object, it is substrate support that required to complement the picture.

By the way clothing textile technology has also developed not only as a tool for mobility, strength of materials but also decorative purposes. For example a lot of silk woven technique can be seen for Japanese costume kimono. Kimono is a simple shape geometrically flat stitched textile that has kept almost same format for over 1000 years. It is in the form of "body wrap " instead of "box in". Therefore, it changes the shape according to human body and movement. So kimono is able to define as a kind of tableau that use the uniform shaped fabric as canvas (figure1). In that sense, the fabric basement pattern have a function to give expression on margin as the texture of substrate support that provide a common element between figure pattern area and margin area. Not only to kill a boredom area, the basement pattern is designed with motif that indicate the theme of whole kimono graphic scene. "Rinzu", a little similar kind technique of damask and one of the weaving technique of typical kimono fabric that uses weft yarn in both warp-free (non-refined silk) and refine after weave, is characterized that emerge glossy shape by weaving pattern. Though the shape of fabric pattern not seen clearly since it appear with shading, changes of temporal and spatial situation appear the various patterns in light of movements with a change of angle to the body when wearing. Therefore, texture of textiles are various. These variety depends on complex combination of material and technique about yarn-making process,weaving, dyeing ,embroidery,sewing.

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This presentation reports the spectrophotometric characteristic of “Rinzu”.

Figure1. A part of picture scroll [Kosode pattern illustration vol1],17 century of Edo era (collection of Nara Prefectural Museum of Art).

2. Materials and Method

According to this purpose,Multi-Angle Spectral Imaging system has developed. It has 6 LED Illuminant that emit the sample by 30° unit between -75° to 75° from vertical direction of sample, Liquid Crystalline Tunable Filter (LCTF) and CCD device with Peltier Cooler to capture the sample from right avobe .This System can measure Gonio-photometric spectral Imaging of 776 by 568 pixels, and Visible range Spectral Image radiance factor from 420 to 700nm by each 10nm unit. Distribution on CIELAB Color Space is calculated from these spectral information and applied analysis of several fabrics characteristics. Also brightness and each wave length radians factor distribution in Images were calculated and was researched correlation between human sense of texture and number of distribution.

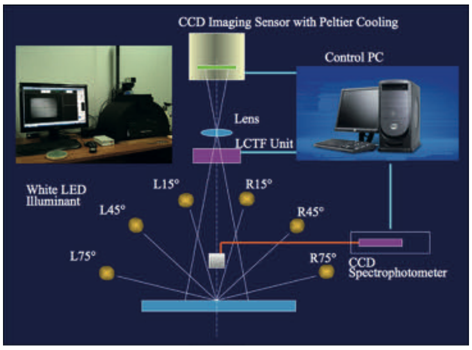

Figure 2. Multi-Angle Spectral Imaging System.

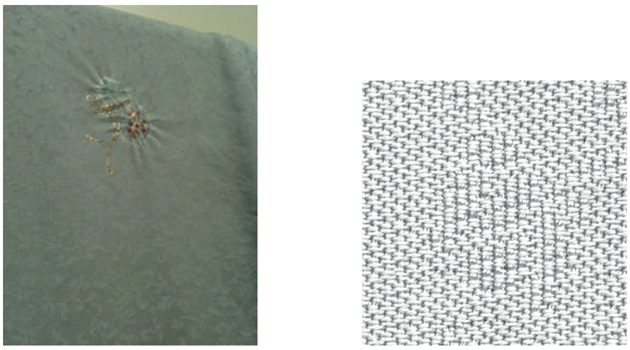

Figure 3. Left: A part of kimono as the measurement sample. Right: Magnified view of the “Rinzu” sample.

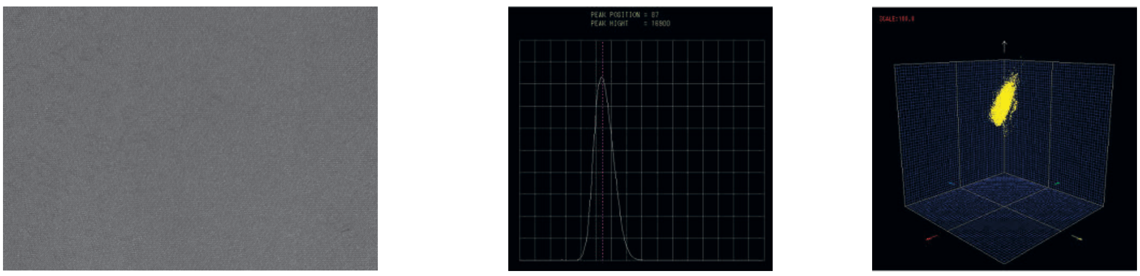

*Figure 4. left: Grey scale image at 15° projection. Vague impression arise from buried pattern reduce of brightness difference. It seems almost plain color because it reduce the difference in the shadow area. Center: Histogram. Right: CIE L*a*b* visualization.*

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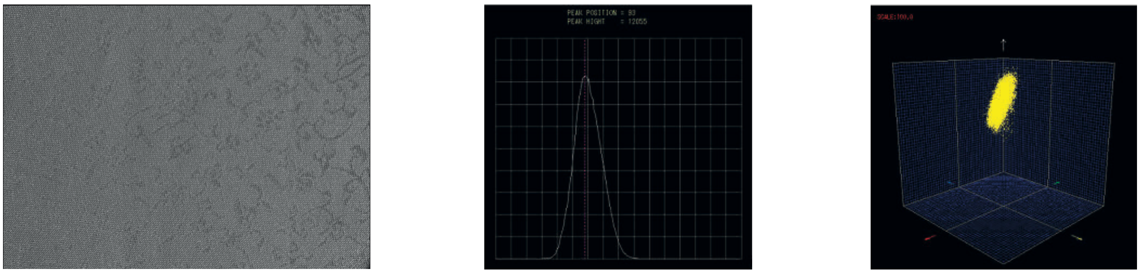

*Figure 5. Left: Grey scale image at 45° projection. Positive and negative inversion can be seen in the incomplete state. Center: Histogram. Right: CIE L*a*b* visualization.*

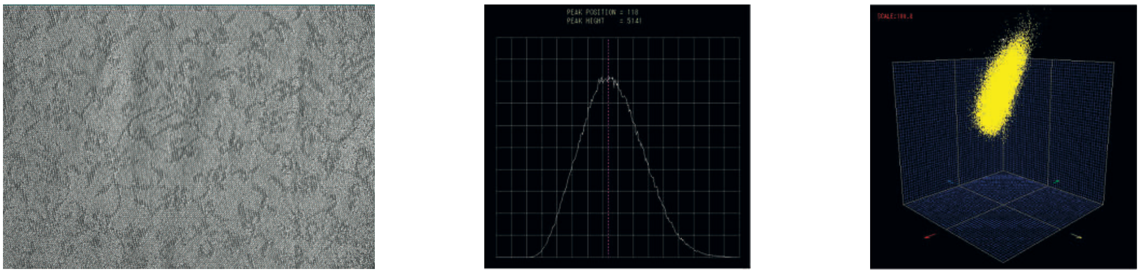

*Figure 6. Left: Grey scale image at 75° projection. Textile patterns are revealed in rich shade because it spreads the differences. Center: Histogram. Right: CIE L*a*b* visualization.*

3. Results and Discussion

Analysing the images of "Rinzu" sample from a different angle measurement, it seems like plain color at 15° projection because it reduce the difference in the shadow. Peak position of histogram is 87/255,and perk hight is 16900. Pointed shape of the mountain since the pixels are gathered in a narrow range of brightness. Positive and negative inversion can be seen in the incomplete state at 45°. Peak position of histogram is 93/255,and perk hight is 12055. Textile patterns are revealed in rich shade at 75° because it spreads the differences. Peak position of histogram is 118/255,and perk hight is 5141. Shape of the mountain is a little smooth. And CIE L*a*b* is a more diffuse form compared to the other degrees.

At first, about human visual system should be considered. Human visual system works by detecting the difference of stimuli. And it use skewness, or a similar measure of histogram asymmetry, in making judgements about surfaces. Expression of crease in the overall look of the kimono brings impressed by certain aspects of the shade area than on the bright area. The inverse aspects of delicate tiling pattern in the shade area appear a distinct contrast to expand the difference between highlights and shadows. It is considered to increase the impression of texture in this way. Additionally, since sensory threshold is adjusted depending on the range of difference between the maximum and minimum, we feel complex impression in the case of see the combination of different set of subtle differences at the same time. Complex impression, rather than from a combination of bold colors and lots of changes are being brought about by focusing on small difference.

Next, let consider the influence of matiere factor to texture. "Rinzu" is characterized that emerge polymorphism change with glossy shape by weaving and condition of wearer. Because of the texture is thinner and softer than "donsu", the state is susceptible to human form and movement. In the mode of clothed behavior, the area illuminated by front light and the surrounding light is strongly sensed as color and luster of the silk fabrics since the presence of support fabrics is weak. Though a color of fabric is felt deeply, the shade area felt matte texture since a sense of gloss is suppressed. However these low-key appearance or moderate features is vital concern for the

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Japanese culture. For example of lack of glitter or overdramatic effection shall be deemed as handsome and elegant. Therefore it should be noted the intermediate boundry that interchange the surface brightness and decline according to the effect of figure-ground reversal on surface. These phenomena become increasingly the attraction of “Rinzu” as the fabric that act demurely.

4. Conclusion

On considering these measurement results, importance of investigation to the intermediate region between each opposite phenomenon is confirmed. To find a knot of science and aesthetic, more variation of the “delicate texture” is willing to consider to ascertain whether the contours that represent using math method is available to guarantee the reproducibility of the aesthetic.

About cultural requirement and method of appearance should be mentioned as conclusion. Typical points of spatial recognition in Japanese culture are;temporary,fragile, delicate,transform ,unit,recycle,horizontal,etc. The factor of determine the spirit of these were acquired in the life of harmony and co-existence with the natural environment of monsoon type weather since a small island that surrounded by sea at the end of the Eurasian continent. And aesthetic of obscurity has been nurtured by traditional housing environment that surrounded by trees, grass and paper, and indirectly sunlight or dim flame. These factor influenced also for craft art including clothes. Trying to simulate the several lighting scene with this device, it might assist to find the effective patterns that utilize the appeal of the movement and shape of the body. Normally we feel a comprehensive impression at the impression of a continuous surface. Trying to simulate the several lighting scene with this device, it might assist to find the effective patterns that utilize the appeal of the movement and shape of the body.

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Eye-catching colors using eye tracking in a mobile communication context

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Abstract

The experiments considering the context of mobile use were performed to find eye-catching colors, and to provide empirical grounds for strengthening the visual information structure. Warm hues that are arranged along the horizontal and vertical axes were most eye-catching. Design using complementary colors gained much attention. We recommend that the results of this research to be used to create effective communication and to increase aesthetic satisfaction.

1. Introduction

Adams and Osgood (1973) found that the perception of color is essential to human visual experience and is the most powerful information channel among the human senses. Previous studies indicate that the dependence on sense of sight is 87 percent among the five senses, and color accounts for 80 percent of this amount. Using different colors is the most effective and intuitive way to prioritize information visually. However, Tufte (1990) mentioned that some color combinations created by designer's subjective judgment do great harm to the visual display. Therefore, an objective basis is necessary with which to choose the correct colors. Eye-tracking technology has been widely used as a scientific tool to improve the usability of websites. However, no work has been done in the mobile phone context. Designing the GUI for a mobile phone does not entail the downscaling of a desktop website to make it fit onto a smaller screen, despite the fact that the same information is displayed. Given this background, eye-tracking experiments considering the unique characteristics of mobile use were conducted.

2. Purpose

This study was carried out to investigate which colors best attract the eye of a viewer. In particular, we attempted to determine which attributes affect the attention of the participants.

3. Method

The subjects were 15 college students of both genders. Their mean age was 25 years (standard deviation: 3.64). All subjects were paid volunteers, and students without color vision problems were selected. The eye-tracking experiment was divided into 3 parts. All 15 subjects participated in each of the parts. Subjects, equipped with an eye-tracking system, were brought to a test room individually (Figure 1).

Total of 60 stimuli were produced. Figure 2 shows that each stimulus consisted of 25 identically sized color chips in a 5 by 5 matrix. Black was used as a background color, as it is the normal background color for mobile phone screen. However, to control a background effect, each stimulus was tested with a white background.

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Figure 1. Experiment environment

Figure 2. Stimuli on a black / white background

Part I consisted of 24 stimuli and Part II, Part III each consisted of 18 stimuli. Each stimulus was displayed on the monitor for seven seconds, and a break of two seconds was inserted before the next stimulus to prevent an afterimage effect. During the break, only a black or white screen was shown, depending on the background color of the next image. There was no pause between each part of the experiment. The total time required for the entire experiment was approximately nine minutes. The subjects were asked to select their preferred color from among 25 colors, and it was to determine if there was any correlation between the colors that attracted their attention as well as their preferred color as stated. In this way, the concentration of the participants was continually focused on the experiments. For the analysis, the first 3 seconds were investigated to detect the eye-catching colors.

3.1 Part I

Part I was intended to determine which hue catches the most attention. Accordingly, 25 different hues of the same tone were shown together. Visual stimuli were sampled from the Web Safety Color palette. A total of 24 hues were selected based on the HSB color system, describing a color by showing three fundamental properties of the color: the hue, saturation and brightness. These three parameters determine a single color.

The hue varied in degrees from 0° to 360°, allowing 24 hues to be sampled by increasing the hue angle by 15°. Colors with a saturation value of 100% were defined as those with a 'vivid tone' in this study. As gray is a color that has no hue, an appropriate vivid gray was selected and added. Therefore, 25 samples with vivid tone were created (Figure 3). In addition, each sample in light, dark, and moderate tones was produced from its respective vivid tone sample by controlling the tone value based on the RGB color model (Figure 4).

A total of 25 hues in each tone were randomly arranged in three different ways to avoid position bias. Each stimulus was equally tested on both a black background and a white background. Thus, 24 (4*3*2) stimuli were used for Part I. Stimuli with vivid tone were shown first. Other stimuli in the light, dark, and moderate tones were then experimented in consecutive order.

Figure 3. 25 samples in a vivid tone

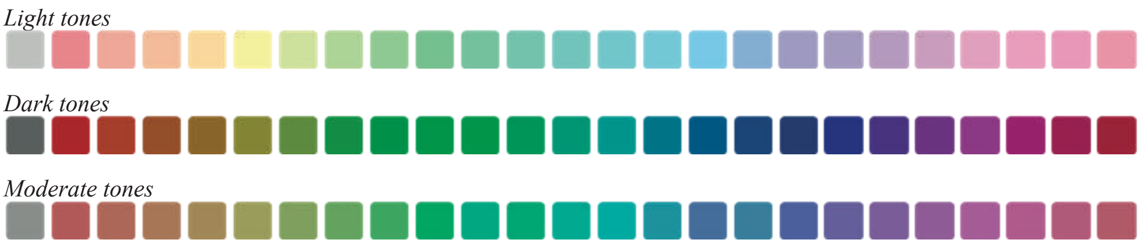

Figure 4. 25 samples in the light/ dark/ moderate tones

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It was found that warm hues gained the attention at first. A position effect was also observed in that color chips on both the horizontal and vertical axes (Figure 5). Participants fixated on color chips that were located on the right side within just a little range.

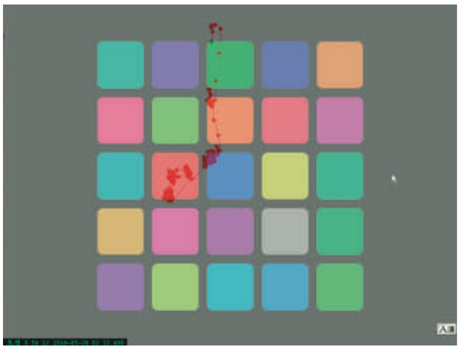

Figure 5. Participant's eye movement path

3.2 Part II

In contrast to Part I, Part II sought to determine the tone that initially attracted the visual attention of the subjects. In this part, 25 different tones with the same hue were tested altogether. A total of 25 tones with red, blue, and gray hues were chosen by dividing the range of the tone equally. Samples with the same hue were randomly arranged in three different ways for avoiding any position bias. Each stimulus was equally tested on both a black background and a white background. Thus, 18 (3*3*2) stimuli were used in this part of experiment. First, 6 stimuli with a red hue were presented. Another 12 stimuli with blue and gray hues were also shown in that order.

There was no statistically noticeable change reagarding eye movement by tone. However, it was observed that the colors arranged along the both axes caught held attention the most.

3.3 Part III

Single-color chips were used for Part I and II, whereas Part III was conducted with two-color combinations: an icon color and a background color. This part sought to investigate whether color combinations have an influence on participants' attention in a manner different from that of single colors. When comparing between single colors and two-color combinations, 6 stimuli in the vivid tone of Part I were used as background colors for this part. Red, green, and blue icons were added to each single-color background (Figure 6). A total of 6 stimuli, with camera, call, and Wi-Fi icons of a red hue were tested first. Another 12 stimuli with the same icons but of green and blue hues were also shown in consecutive order.

Figure 6. Sampling examples for part III

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Although it was found that warm colors were eye-catching colors according to the results of Part I, the results of Part III proved different result. It was clearly seen that combinations of complementary colors caught the eye first.

4. Discussion

The findings from the three-part eye-tracking experiment can be summarized as follows. First, warm colors are more eye-catching than cool colors. Second, colors arranged along both horizontal and vertical axes hold the attention easily. Third, a design using complementary colors will gain a person's attention. During the experiment, subjects were asked to select their preferred color to verify if their color preferences have an influence on visual attention. While there was no correlation between the colors that attracted their attention and their preferred color as stated, results of analysis of physiological responses revealed three significant differences. Using complementary colors is clearly eye-catching, but it must be well planned. Otherwise, it easily may be jarring. We believe future study should derive guidelines for the use of complementary colors from aesthetic point of view. This study can help mobile GUI designers to achieve better planning when using colors with a specific contextual aim in mind.

Acknowledgments

This research was supported by BK21 Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology.

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Color change of objects controlling spectral distribution of light and spectral reflectivity of color material

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Abstract

Slight color change of objects with illumination change sometime bewilders us. But we can utilize this color change for design or eye catch if the color change is very clear and have a variety. In this study we try to find out color change of objects using data of many white lights with different spectral distribution and data of color materials with characteristic spectral reflectivity on our color simulator. As a result of simulation, we found out many clear color changes of color materials within the particular combinations of white light and color materials. According to the results of the simulation, then we have made substantiative experiments in order to make sure that the object color changes practically occurs using real light sources and real color materials. The results of the substantiative experiments showed us that many color changes we found out on the color simulator actually could be seen using real lights and real color materials. In the case of Japanese traditional dye goods there is one which color changed green, orange, purple and grey very clearly in four different white lights with different spectral distribution. These results of our study suggest that we can realize very clear color change by controlling spectral distributions of light without being aware of illumination color change.

1. Introduction

Color of object is determined by the combination of spectral distributions of illuminating light and spectral reflectivity of color material (Fairchild, M.D. 2005). In general, good color rendition is favorable feature of illumination and color appearance change of the objects in the artificial illumination should be avoided (Ohno, Y. 2004, He, G. et al. 2011). As in the case of choice of dress, for example, customers will be bewildered if the color of the dress changes when they wear the dress and go out of the clothing shop.

On the other hand, color change is very attractive as in the case of blinking neon signs and color change of the actor and actress or stage settings in the color spotlights on the theater. So, if we change our point of view, color change of objects in different illumination could be very attractive production if we use it in an effective manner. Color changes of the objects in the color spotlights on the stage are effective to some extent but are not so amazing because of color constancy. However, if the color appearance of the object clearly changes in the same color light, especially in the case of white light, we would be very surprised and stare into the object as this phenomenon is unexpected one and mysterious for most people.

In this study we try to find out clear color appearance change of objects by simulating color of objects on our color simulator using data of some white lights with different spectral distribution and data of some color materials with characteristic spectral reflectivity. If we can find out clear color change on the simulator we then make substantiative experiments using real light sources and real color materials in order to make sure that the object color changes we found on the simulation practically occur in the real world.

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2. Color change simulation

We prepared 7 white lights which are consisted of three peaks within the wavelength from 410 nm to 670nm with 10 nm increments and each peak values are controlled to make white lights (Four of them are shown in Figure 1). As color materials we prepare spectral reflectivity data of some typical oil paints and some Japanese traditional dye goods measured by the spectrophotometer.

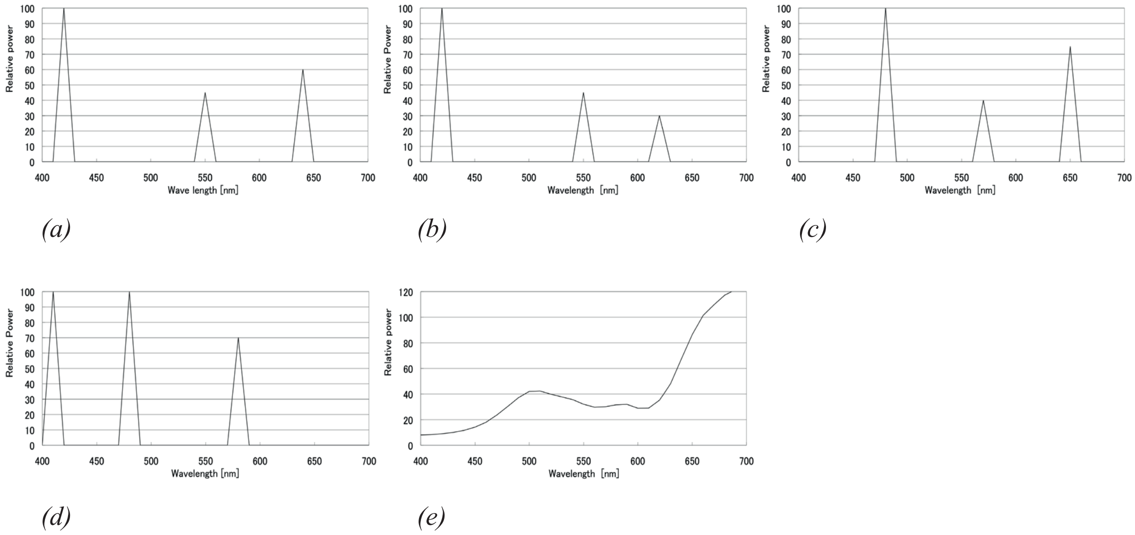

Figure 1: Spectral distributions of four white lights with three diferent peaks and spectral reflectivity of Japanese traditional dye goods "Kikujin". (a): white light with spectral peaks at 420 nm, 550 nm, 640 nm, (b): white light with spectral peaks at 420 nm, 550 nm, 620 nm, (c): white light with spectral peaks at 480 nm, 570 nm, 650 nm, (d): white light with spectral peaks at 410 nm, 480 nm, 580nm, (e): spectral reflectivity of Japanese traditional dye goods "Kikujin".

We simulated color appearance of them in 7 white lights we prepared. One of the very distinct changes of color appearance simulated on our color simulator is shown in Figure 2. In this case dye goods "kikujin", which is pale green in the day light, change its color appearance green, orange, purple and grey in the white lights with peaks at (420-550-620), (420-550-640), (410-480-580), and (480-570-650) respectively.

3. Substantiative experiments of color change

According to the results of the appearance simulation, we have made substantiative experiments in order to make sure that the object color changes practically using real light sources and real color materials.

As a light source we use programmable spectral light source (OL 490 Agile Light Source, Optronic Laboratories). We can change spectral distribution of light freely with PC control.

As the results of the substantiative experiments, we could make sure that the distinct color appearance change simulated on our color simulator really happens real world. Color appearance changes of Japanese traditional dye goods "Kikujin", for example, it changes its color appearance green, orange, purple and grey in the white lights from programmable spectral light source with peaks at (420-550-620), (420-550-640), (410-480-580), and (480-570-650) approximately the same color as the colors simulated (Figure 3).

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(a) *(b)*

Figure 2: Result of color simulation of Japanese dye goods "Kikujin"which is originaly pale green in daylight. (a): left = "Kikujin" in white light (420-550-620), right = "Kikujin" in white light (420-550-640), (b): left = "Kikujin" in white light (410-480-580), right = "Kikujin" in white light (480-570-650)

Color appearance change in this case is not small color change as color fade-out but wide range change from green to purple and achromatic color grey (Figure 3 (e)).

The results of the substantiative experiments showed us that many color changes we found out on the color simulator actually can be seen using real illuminations and real color materials and we can find out some other color change with illumination change using color simulation.

4. Discussion

This result of our study suggests that we can realize this clear and wide range color change by controlling spectral distributions of illumination without being aware of illumination color change. We can utilize this color change in our method as an effective and attractive color design. In case of scenic art we can change stage set only with stage illumination multifariously and in an instant. We can also use them in shop display and fantastic change of interiors of the room.

Although color pattern change is easily realize on the color display monitors or color illuminations we do not surprise at diverse change of color pattern on the display monitors or color illuminations because we are get used to it everyday life. Color illumination also change colors but we have color constancy to stabilize original color. On the contrary, color changes of non-illuminator are unexpected phenomenon and then they are very attractive and fascinating and are suited to use in design fields.

Obstacles to the practical realization of this method in various fields might be the product development of cheep illumination equipments which can change spectral distribution easily and quickly. Programmable spectral light source is suited to use for light sauce as it is very flexible but is very expensive and not so bright. In this moment combination of LEDs with different peeks in emission wavelength might be optimum choice for light sauce because LED have relatively steep peek in spectrum distribution. Discovery and supply of color materials suited for color change in this method might be another barrier of practical realization. In the case of Japanese dye goods "Kikujin", which also means pale yellow-green color, over-dye with yellow dye "kariyasu" and Japanese indigo made double peeks in spectral reflectivity curves and that should be the most effective feature of this dye goods to change color appearance so dramatically in different white illuminations which have different peeks in spectral distribution. So the multiple dye and mixed use of paint is one of the simple and effective way to find out to make color materials which are

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good for the dramatic change of color appearance in different illuminations with different peeks in spectral distribution.

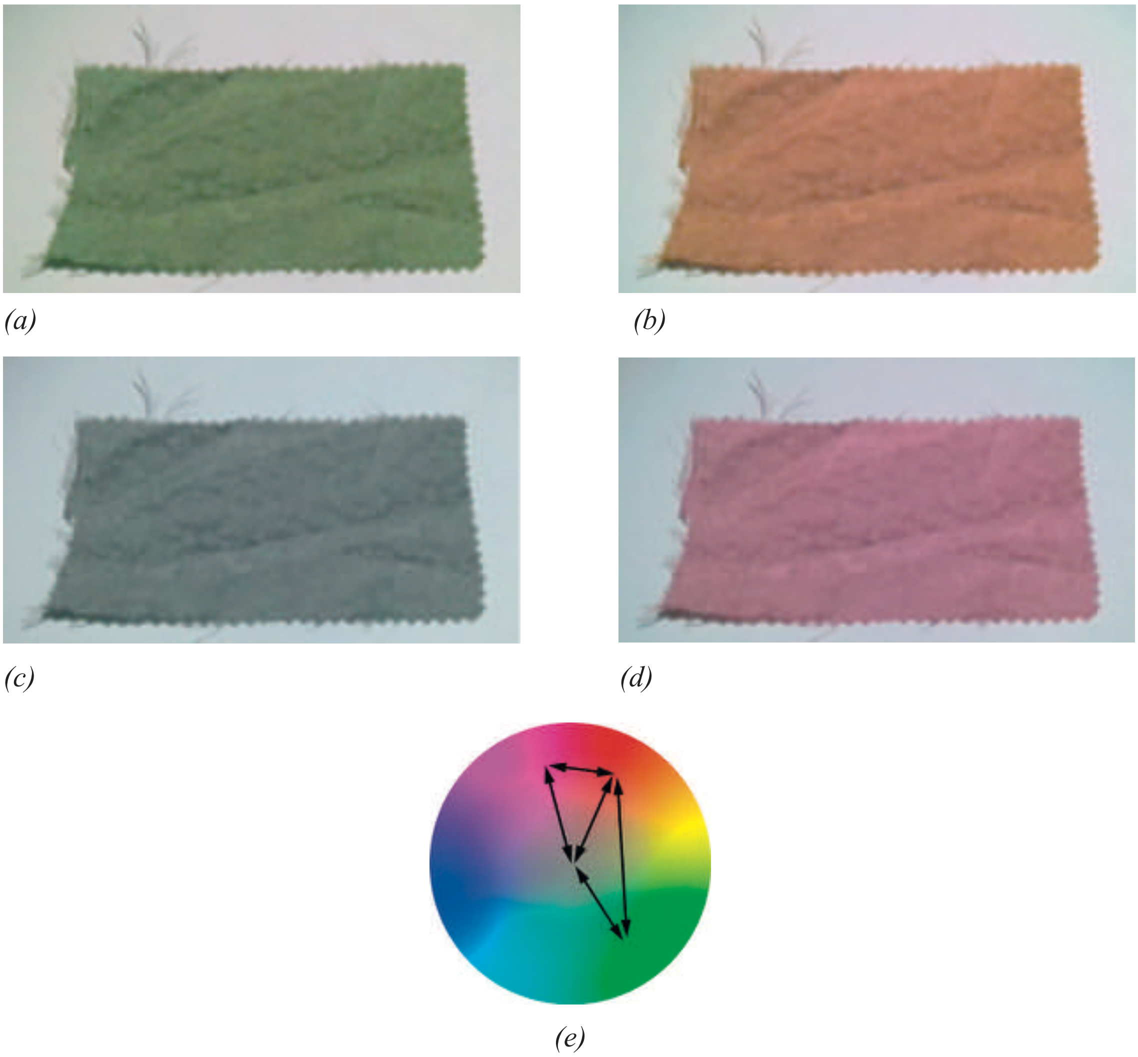

Figure 3: Samples of color changes of Japanese traditional dye goods "Kikujin". Each picture is color corrected. (a): "Kikujin" in white light (420-550-620), (b): "Kikujin" in white light (420-550-640), (c): "Kikujin" in white light (410-480-580), (d): "Kikujin" in white light (480-570-650), (e): color change of Japanese traditional dye goods "Kikujin" in four different white light.

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A perceptual approach to the chromatic complexity of contemporary city

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Abstract

The aim of this paper is to present the first results of a research finalized to outline and verify a method of reading the urban colour component based on the perceptual data. For this purpose a circumscribed urban area, a square on the outskirts of Milan, was identified as a case study on which conduct colour readings in relation to the different spatial conditions.

1. To read the chromatic complexity of contemporary city

This research begins from a series of considerations with respect to the practice consolidated in the colour plans of Italian history, which have, since the late Seventies, represented a first response regarding the need to develop tools able to regulate and plan, and also to enhance, colour on an urban scale with special reference to historical centres.

Without wishing to enter the specifications that, however, characterize the various colour plans drawn up, the things I would like to focus attention on are inherent to some limitations implicit to this urban colour approach that is likely to confine the same colour planning to the role of a static control tool of the original or traditional colours of the city seen as historical centre, according to more or less rigid patterns of intervention, and paying no attention to the several transformations that the city continues to assume (Boeri 2006). I don't refer only to the new urban areas, but also to both the coexistence within the historical centre of buildings of different periods and the increasingly more complex aggregate of planned and spontaneous urban signs, which contribute to the definition of public and social spaces.

Actually nowadays, the colours of the city are no longer linked only to the colours of its buildings, but they are progressively more dictated by the movement of cars and public transport, by road signs and advertising information, by shop windows and signs, and, more generally, by the so-called elements of urban furniture. History cannot possibly be the sole criterion to draw inspiration from in order to find answers to the design needs of this complex chromatic system.

Add to this that any intervention on the urban colour component must be understood as essentially a design process, even when it is the case of restoring an original state through a faithful historical reconstruction, or keeping the colour material on the historic built as part of material culture, or, finally, operating in a continuance with the traditional local practices. And if any colour intervention on the city is a design intervention, then it will have to derive justification not only from history and pre-existent, but also from the ability of colour to resolve the contradictions dictated by the transformations of the city, which involve both the historical urban fabric and the so-called suburbs, where an approach to colour able to return identity and sense of belonging, but also lead to perceptual quality, appears even more necessary.

Within the scenery just outlined, therefore, the problem of the colour planning is in the first place due to the real possibility of reading the colour complexity that characterizes the city, that is to say on how to acquire that information system – indispensable prerequisite – which can lead to project hypothesis.

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Referring to the work of Lynch, the problem I want to put forward is on what would be the most appropriate method to read and return the chromatic image of the city, “a summary that can be a first step in preparing a ‘visual plan’. (...) As a spot survey and analysis, it does not determine a plan, but it provides a basis on which creative decisions can be taken” (Lynch 1960).

2. A perceptual approach to urban colour

The perceptual impression evoked by an urban environment, even if consisting of identifiable series of elements, lies in the quantitative and qualitative interactions among the various elements. In analyzing the colour of an urban area, then, it is not sufficient to proceed in “punctual” terms, as if it were a summation of individual colour components. It should instead be preferable to think in terms of chromatic spatial context leading to highlight, as noted by Lenclos (Lenclos and Lenclos 1995), that system of variables – light, material, shape, size, close by and distant colours – that determines our perceptual experience of places (Boeri 2010).

In order to outline and verify a method of reading the urban colour component based on the perceptual data, a square on the outskirts of Milan, was identified as a case study on which conduct colour readings in relation to the different spatial conditions.

2.1 Analysis of the observation points

Analysis of different spatial conditions was determined by a study of flows and preferential positions of observation that covers the distance, the direction and also the different perspective, which is offered to the observer in motion that is, for example, walking down the sidewalk or travelling on public transport than to the static observer, for example, sitting on a bench or at a table of a coffee bar (Figure 1).

On the basis of the paths and observation points identified, then, a photographic survey was conducted that, through a sort of collage, returns the most common looks and experiences within the square (Figure 2). It is especially the great impact the elements of detail, for instance urban furniture, have in defining the chromatic impression of the square that emerges.

2.2 Analysis of perceived colour

Observations of colour in different times of the day and under different weather conditions have been carried out from some of the viewpoints identified. Not only the stable colours, for example the colour of buildings and elements of urban furniture, were to be considered, but also the mobile colours, such as the colours of shops awnings and trams and buses that run frequently in the square, and the variable colours, such as the colours of flower boxes and plants (Figure 3).

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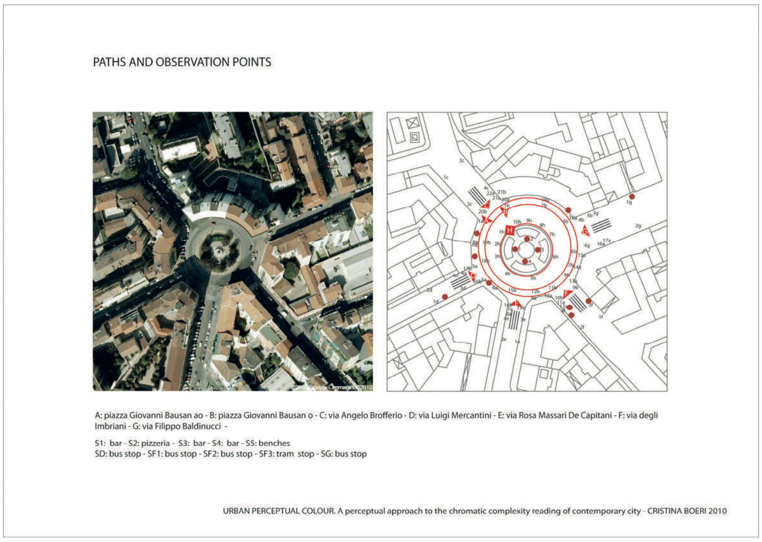

Figure 1. Analysis of the most frequent pathway and observation points.

Figure 2. Example of a photographic survey that shows how a portion of the square is perceived from the most common points of view.

To each colour in the visual field was then assigned a *perceptual weight*, independent from distance and dimension of surface, and, through visual comparison, a standard notation NCS, Natural Color System. In order to facilitate the visual comparison at distance, a "viewer" was created and fabricated that, allowing the isolation of the surface to be surveyed, showed how there is not always a correspondence between the isolated colour and the perceptual impression of the colour not isolated (Figure 4).

Where possible, contact colour surveys were conducted using a NCS Colour Meter in order to compare the perceived data with the inherent colour.

The first partial results of the surveys so far conducted show as the more variability is present between perceived colour and inherent colour compared to variability, though found, among different times of the day and different weather conditions. It must be said, however, that observations are still ongoing and a number of factors, such as the direct exposure to the sun, have not yet been covered.

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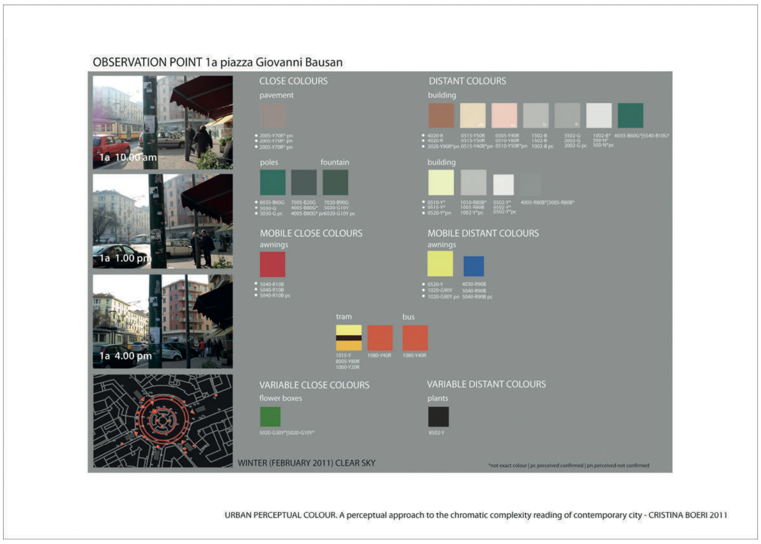

Figure 3 (left): Example of perceptual survey in different moments of a winter clear sky day.
Figure 4 (right): The "viewer" used to facilitate the visual comparison at distance.

The more easily identifiable general trend, which confirms the results of similar studies (Fridell Anter 2000), is that the perceived colour appears to present less blackness than the inherent colour.

3. Results and discussion

This research is based on the belief that the perceptual data is the one actually useful in order to launch a design reflection on urban colour. The method outlined, although still subjected to validation and implementation, is proposed as an alternative to the established practice of conducting inherent colour surveys that not only require specific tools, but also the possibility to reach all surfaces to be surveyed. It is only in a more advanced phase of the plan process and whereas it is believed to work in conservative terms toward the colour presences, in fact, that a specific and punctual colour survey is needed in order to a conservation of the chromatic matter of historical building, as element of material culture, or a faithful remake, as element of collective memory.

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Colorimetric characteristic of ink jet prints in function of environmental parameter

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Abstract

The aim of this work is to determine the range of reproduction and colour deviation of the naturally and artificially aged prints obtained on the printers of different technologies and ecological characteristics. The prints obtained by piezoelectric, thermal and UV ink jet technologies were used. The investigation results point at the decrease of gamut volume of naturally aged prints HP 500 and HP 9000s with the exposition time, opposite to the prints made on Roland UV LEC 300 where the positive trend was determined. The artificially aged samples give gamut volumes which fit in earlier mentioned results. The aged prints HP 500 have greatest ΔE values and belong to the class of obvious deviations.

1. Introduction

Ink jet technology is the printing technology using the ink droplets without the contact with the printing substrate. Criteria are set for the ink jet print quality, eligible features typically including large color gamut, sharp detail rendering, and long-term fastness of the printed image. These characteristics are highly dependent on the properties of both papers and inks and their chemical and physical interactions; Wilhelm, Holmes and M. McCormich-Goodhart (1998), and Blayo and Medlege (2001). Durability of colour prints has steadily improved. Improvements have targeted the following areas: light fastness, thermo stability, water-fastness, humidity-fastness, and pollution gas-fastness; McCormick-Goodhart and Wilhelm (2001) and Steiger and Brugger (1998). Light fastness is one of the most important items in ink jet printing; Možina et al.(2006) and Dobrić, Bolanča - Mirković and Z. Bolanča (2010) and Fricker, Hodgson, and M. Sand(2010). Degradation o dyes as it is known depends on a wide variety of environmental parameters like temperature, humidity, light intensity and spectral distribution. Pigment based inks have better resistance to gas and light and better water-fastness than dyes; Work and Brown (2001). The aim of this work is to determine the range of reproduction and deviation of colours of the naturally and artificially aged prints obtained on the printers of different technologies and ecological characteristic.

2. Experimental

The prints obtained by piezoelectric, thermal ink jet and UV technologies were used in the research. The following printers were used: HP Designjet 9000s, HP Designjet 500 and Roland UV LEC 300. HP Designjet 9000s uses carbon filters to absorb the air volatile organic compounds released during the printing process. The system is designed to absorb VOC from air at rates consistent with the print speed and number of compounds released during printing. HP Designjet 500 uses CMYK water -based ink. The environmentally friendly Roland UV LEC 300 uses safe, low-heat LED lamps. The test form contained ISO and ECI patterns. The part containing the ECI measuring form consists of fields with different combination color values of the subtractive

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synthesis. The information quantity obtained by such measurements enabled the construction of 2D and 3D gamut in perceptual uniform color space. The samples in the first series were exposed to outdoor conditions in the duration from 3 months in interval from seven days. In the secund series prints were exposed accelerated ageing in Solarbox 1500 e (ASTM F2366-05).The instrumental analysis comprised the measurements made by spectrophotometer, followed by the statistic data processing obtained by measurements of each field. Except that, the conversion from CIEXYZ into CIE L*a*b* system was performed in order to enable the presentation of 3D gamut of samples in the threedimensional unified color space. By spectrophotometric measurements the obtained CIE L*a*b* values were used for calculation the color difference, CIE LAB ΔE_{2000}.

3. Results and discussion

Color management allows conservation of color information trought the printing process. The only RGB or CMYK information is not sufficient. ICC profiles contain tables with correspodances between RGB or CMYK and L*a*b* values. Gamut represents the total range of information on color, i.e. tone, saturation and lightness which can be reproduced by the given medium. Gamut limits present the volumes or surface which is determined by the gamut extremes. For objective evaluation of the print quality the ECI values of field samples of different combinations of color values of the subtractive synthesis were measured and the values for the construction of 3D color cubic units were obtained by the computer support and conversion. 3D gamut of prints before and after exposure to the outdoor conditions is presented in the figure. The exposure was done in the cold part of the year from 6.01.till 7.04. 2011. in the intervals of 7 days. The exposure place was near the frequent communication road; however there were no pollution source of industrial origin.

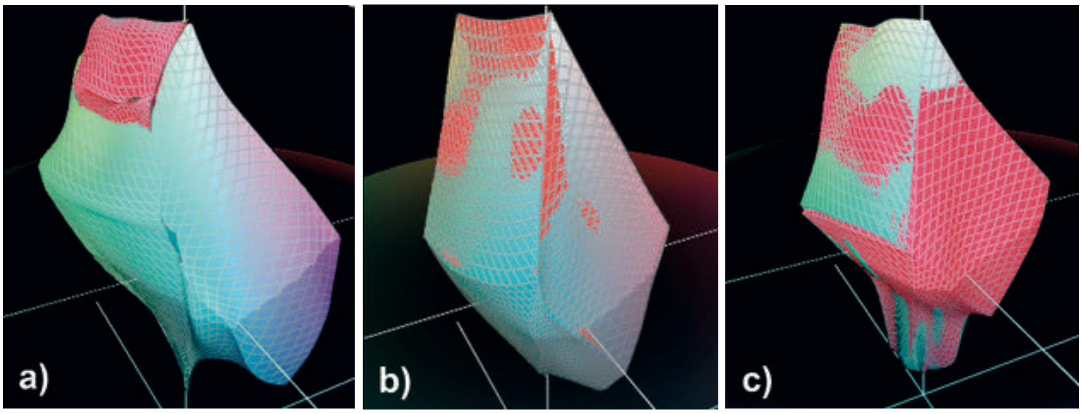

Figure 1: 3D gamut of prints after natural agein in the interval of 70 days:
a) HP 500 b) HP 9000s c)Roland UV LEC 303.

The investigation results show that HP 500 print has the greatest gamut volume (V 414610 g.u) before exposing to the outdoor conditions in relation to the prints made on two other printers. However by natural ageing the gamut volume decreases drastically proportional to the process dynamics flow (ΔV non aged/aged for 7 days -24834g.u,; ΔV non aged/aged for 70 days -302257 g.u.). Because of great instability in the described conditions, the measurements were not possible to be performed for the sample exposed for 91 days. The non aged gamut volumes of prints HP 9000s is smaller (V 282964 g.u.) in relation to HP 500 printer (V414610 g.u.), which points at the lower reproduction quality. The decreasing trend of gamut volume with the exposition time was recorded on prints HP9000s. The gamut decrease by natural ageing is generally smaller according

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the dynamics of the ageing process flow in relation to the HP 500. For the print HP 9000s after the seven days exposure, the calculated difference ΔV for the non exposed/ 7 days exposed print is 5730 gamut units (for the same period ΔV for HP 500 is 25834 g.u.) which is in fact only about 22% of that result related to the print HP 500. Such characteristic is more stressed after the long exposure period of prints to the conditions of natural ageing (ΔV for HP 9000s prints on non exposed /exposed for 70 days is -15567 gamut units, and for HP 500 it is -302257 g.u.). From the presented investigations results it is visible that there is the question of more stable print. The non aged prints gamut volume for Roland UV LEC 300 is 330344 gamut units. In the process of natural ageing there is completely different trend of gamut volume change in relation to the described so far. In dependence on the ageing dynamics the increase of print gamut is noticeable in relation to the value for the non aged print (ΔV naturally aged for 7 days /non aged is 12861 g.u., ΔV naturally aged for 70 days/non aged is 12268 g.u.; ΔV naturally aged for 91 days /non aged is 13317 g.u.). In this case the change of the gamut volume by the dynamics of the natural ageing is the smallest and it oscillates relatively very little about the value for the non aged print mainly in positive direction. In any case the attention should be paid to different trend signs of gamut changes of prints in relation to the exposition period of prints to natural ageing in the described experimental conditions. The obtained results could be explained by the principles of the printing techniques, by the characteristic and the thickness of the ink layer of the used printers (Fig. 2a)

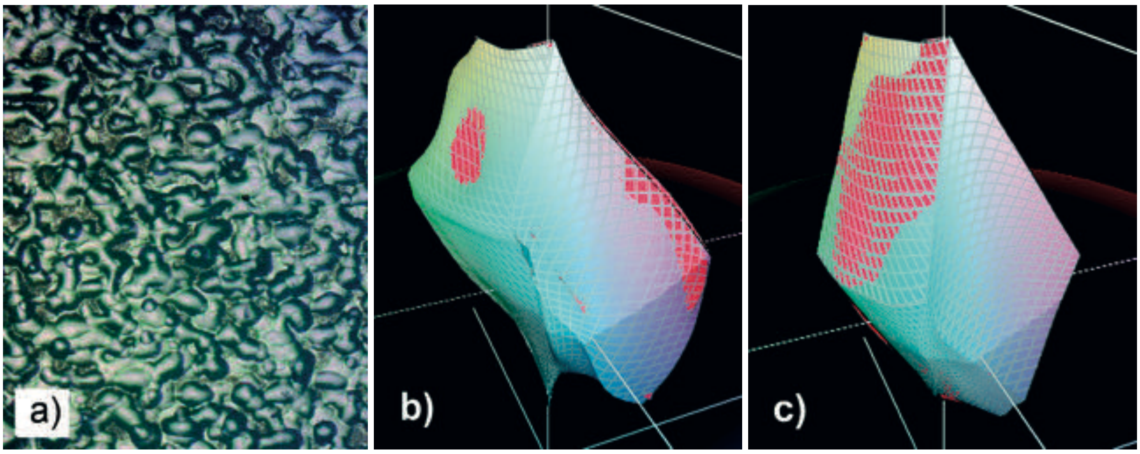

Figure 2.a: Print made on Roland UVLEC 300 with 100% of black ink coverage area
2b and 2c: 3D gamut of prints after artificial ageing a) HP 500 b) HP 9000s

It could be concluded from the results that on the prints dried by means of the UV part of electromagnetic radiation, the process is in the determined degree present during the exposition time of print to natural ageing. Because the obtained gamut values, as already said, oscillate little and have no expressed linear function in relation to the increase of ageing period, it is legitimate to include into investigations the certain meteorological factors. From the extensive investigations in the field of artificial ageing only the results of 120 minute exposition for printers HP 500 and HP 9000s were chosen with the aim of more complex study within the exposition areas comprised by natural ageing, as already discussed. The gamut volume difference of prints HP 9000s non exposed/ exposed to artificial ageing of 120 minutes is 2027 gamut units, while for HP 500 prints, in the same conditions it is 52063 gamut units. These results match the earlier determined result on print stability. For determining the color deviations, the color difference ΔE is used which indirectly describes the loss and deviation of three stimulus information of color of the observed sample. In figure 3 the investigation results of prints from all three printers are presented after the natural ageing of 70 days

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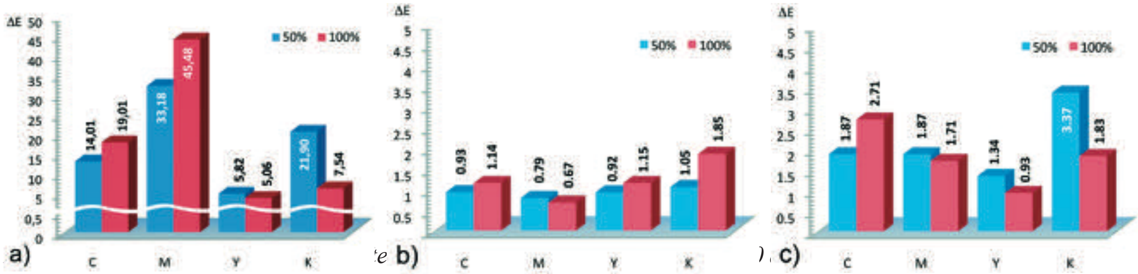
for the color difference ΔE of the characteristic inks CMYK for the area of solid patches and 50% screen value. On the prints HP 500 whose surface is covered with 50% screen, greater difference in ΔE is noticeable, in relation to the print with the surface which are 100% covered.



Roland UV LEC 300

Except that, in this case the values of ΔE (minimum ΔE 5,06, maximum ΔE 45,48) are several times greater in relation to other two printers in the same experimental conditions. From the point of view of the standard observer, these values go over the obvious deviations. On the other hand, in the same conditions HP 9000s gives much better on the boundary of visible results.

4. Conclusion

The investigation results of the natural ageing influence in the winter part of the year point at great decrease of gamut volume of prints HP 500. The greatest stability of prints in experimental conditions is determined for the print HP 9000s. The characteristic of the naturally aged prints made on Roland UV LEC 300 is the increase of gamut volume which is an opposite trend from the prints made on HP 500 and HP 9000s. The artificially aged prints give the gamut volumes which fit in the discussed results of the trends for naturally aged prints. The aged prints HP 500 have the greatest ΔE, which is in the area of the obvious deviations. The greatest deviations are found for M and K.

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Colour and light wall works in architectural space

Pierre BONNEFILLE
Atelier Pierre Bonnefille

Abstract

All my projects for architectural spaces reveal colour, light and again the colour in the changing light of architectural space. Within this act is the revelation of surface texture. Nature is my primary source of inspiration to create, by hand, surface textures designed specifically for each architectural space in which I work. In order to reveal colour and light, I focus on the nature of pigments and the processes of transformation and composition to allow their revelation as a surface texture. At the same time, I study the context through which I will reveal the space in colour and light. I would like to present some of my designs and artworks showing them in moments of light that reveal all their subtleties. Notably, two of my recent works in La Grande Arche de la Defense in which I pondered over the question: when is the true moment of colour? Both mural works for La Defense create a revelation of colour and light in two previously mundane corridor spaces. The transformation of these spaces through light and colour initiates new volumetric sensations and constant chromatic vibrations. They become moments of magic within the existing architecture.

Colour and texture interacting with light pre-occupies my thoughts every day in research and practise. I have developed a language of colour and materiality, which I use to create large-scale wall murals and surface textures for wall paneling, furniture and objects within the domain of architecture and design. In understanding the way in which colour and texture absorbs or reflects light, giving it a specific character, I am able to create unique spaces. Our attention is first attracted by the colour and then gradually penetrates into a world of successive layers and details created by a play of light and texture. Colour becomes texture and light.[1]

Inspiration – nature and time

After finishing my studies in France, (Ecole Boulle and Ecole Nationale Supérieure des Arts Décoratifs in Paris), I created a design studio 27 years ago to research colour and surface textures. I create my own chromatic palettes inspired by the observation of nature and its transformations throughout the seasons. I collect fallen leaves from trees in autumn to study their colour structure and analyse their evolution, their decomposition, the prints and marks of time on natural elements. As well as earth collected from quarries, I also use different qualities of sands, rocks, minerals, tree barks, and beetles that I collect during my travels. My studio is enriched by the collections made over time. Jars filled with colours and materials.[2]

I am inspired by nature and time to create partitions of colour. I look to establish a link with the environment, the story or idea that I would like to express, the construction and circulation of the spaces and the quality and interaction of light. I create surface textures and colour in relief. Textures, which absorb and reflect the light, a complexity of aspect between an eroded profound mat and an absolute brilliance to affirm the particular character of the spaces, which are entrusted to me. I invent my own recipes. In a way, I cook the colours like a chef in a kitchen, choosing the quality of the ingredients in terms of the intended effect. I use minerals, pigments and binders assembled in successive layers to create each artwork. After years of research, I have created my

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own tools allowing me to develop different mixed techniques. With these tools I work the material-colour in all its states: in a paste, with powders or a as a wash. I engrave, scratch, print, rip and age the surface. I develop the surface texture in terms of the scale of the finished artwork. I create a material surface that vibrates, which lives, to compose a score of music with a certain rhythm and intensity.[3]

Fig 1. Model for the La Grande Arche

On the 14th floor of the office tower, 'la Grande Arche', the view is interesting on both sides of the building for the people working in the offices: a view onto the interior of the arch and a view north towards Paris. The access to the light-filled offices is a circulation space without any natural light. The corridor is one hundred meters long and built with the golden ratio. The space inspired me to create a composition using a mathematical construction leading to infinity and chromatic vibrations inspired by the mist, the horizon, the rising and setting sun. The axis from east to west sets up the partition of colours starting with the rising sun and finishing with the setting sun on the wall giving access to the offices. I composed and decomposed the light from the sun, the colours of the light and shadows in the wind. Light is recomposed in a vibrating progression towards infinity. The ceiling and the wall opposite is painted in a silver metallic, like a silver sky, a surface reflector for the colours mixing and changing with the movement of the visitor and the doors opening and closing. Within this tight space the colours and light are constantly fluctuating, like a prism decomposing the light. Rather than observing a sunset from a distance, the visitor finds himself inside a chromatic vibration, enveloped the interaction of colour and light.

Fig 2. Model for the La Grande Arche

On the 35th floor the golden ratio again defines the proportions of the corridor, though this time shorter in length. I used a finite element to generate a sensation of infinity and install a rhythm over the full length of the corridor to reveal an appreciation of colour, light and space. The element wraps itself on every surface of the corridor: the walls, ceiling and floor and varies in length according to the Fibonacci series. The elements are expressed by different states of the materiality of a single colour : blue from within the clouds. Shades of blue as seen from an areoplane inbetween the sky and the clouds. Blue captured at different times of the day; in the morning, at midday and in the evening. The effect of these different bands of blue, each with dedicated light sources, varying in warmth or coolness, give a striking effect to the corridor. Inbetween the bands, the corridor is painted entirely metallic silver and lighting is soft and ambient. With the arrival of each band, the visitor has the impression of walking into a void space and yet it is the blue which gives stability to the corridor. Each band, varying in proportion, colour and light gernerates a unique sense of volume.

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Fig3. Images of the 35th floor of the La Grande Arche

Inspiration – invisible[4]

I like to observe fragments of nature through a telescope or a microscope. During my last trip to Japan, I was fascinated by the incredible flora in the temple gardens – built up of hundreds of types of moss conserved and nurtured since hundreds of years. I search to express the vibrations of the mosses though a series of artworks on canvas exposed in my gallery in Paris. I focused on the idea of the miniscule, things that are invisible to the naked eye, the visible within. From an atom to the galaxy I constantly imagine the incessant transformations of the things that we can't see. The scales of vibrations, the dimension of things that are hidden, the cycles of metamorphose of natural elements.[5]

Caisse des depots

The artworks presented in this exhibition named 'Invisible,' were then developed into a series of large-scale murals for the public circulation areas of three lobbies linking three high-rise buildings in Paris for the offices of the Caisse des Depots. The mural compositions give a new identity to the volumes, creating a strong link between the inside and the outside. To create the volumes and the articulations of colours, I observed the transformation of the colours of the walls under the incidence of the natural and artificial light. Here colour is used as an element of construction, which punctuates the pathway of the visitor.[6]

Fig 4. Images for the offices of the Caisse des Depots

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Place Vendôme

When the lawyers Clifford Chance decided to install their offices in a building complex at Place Vendome in Paris, the partners asked me to work on the client reception rooms. I imagined a geometric play of superimposed colours and material textures in resonance with the stone constructions of the Place Vendôme, in a chromatic palette slightly different from the colours of the stones. The entrance lobby is structured by large mural compositions and punctuated by a red announcing the gallery and the auditorium, which is given rhythm through the juxtaposition of bronzes and golden reds. The texture of the surfaces is voluntarily very strong so as to capture and create a play of light. I continued this play of geometries on the original mouldings in the eighteenth century mansion through a series of fine and powdery surface textures, playing with the mat, the shiny and the pearly. The shifts in colour and light subtlety erases the precious nature of the mouldings in function of the incidence of the light, while creating a strong link with the beautiful architecture of Place Vendome.

Fig 5. Images of the offices for Clifford Chance

Hôtel particulier De Wendel

I would like to present to you another exercise in the same style where however I created a completely different aesthetic for the Wendel Mansion. I found my source of inspiration in a motif in the existing decoration of the building, a 'rinceau de feuillage' or 'the folding tip of a stem' which I revisited in a contemporary manner using a harmony of surface texture, colour and light. At the start of the study, I made an inventory of the existing colours in the building. This study allowed me to develop a palette of colours and textures throughout the various spaces, each time reinventing the motif, fragmented, in the form of large mural compositions. The motif thus become contemporary through its expression and its gigantic format, measuring originally thirty centimeters high, the motif sometimes reaches six meters. I created textures, which are mat, pearly, polished, the motif appears and disappears in function of the movement of the visitor and the changing light.

Fig 6. Images of Wendel Mansion

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The library of colours and textures

In my studio, I created a library of unique colours and textures. A living memory of my creative universe where over time I conserve all the studies and creations made of all my projects and artworks. It is a place of inspiration and work to further develop the language of colour, texture and light in architecture. [7]

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7. Compiled by Melanie Yonge, architect graduated from Auckland University Architecture School in 1998 with honours, assistant to Pierre Bonnefille since eight years.
8. Photos – All photos copyright of Pierre Bonnefille www.pierrebonnefille.com

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Illuminating the psyche

Mary BOOCHEVER [1] *and Chris STAMP* [2]
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Abstract

Mary Boochever is a fine arts professional and an IACC accredited color consultant.
Thesis title: *The Use of Color in Sacred Space*
Chris Stamp is a psychotherapist practicing in Manhattan and East Hampton, New York.
On August 4, 2010, Mary Boochever interviewed Chris Stamp about the use of colored lights in his psychotherapy practice. The interview was structured around the following questions:

1. What kind of psychotherapy do you practice primarily?
2. How do you incorporate colored lights into your therapy?
3. Is there a precedent for this? How did you come to use this method?
4. What correlations have you observed between color and memory?
5. Are there colors you use to soothe or stimulate?
6. What type of lights do you use?
7. Is there a particular sequence of colors that you prefer using? Can you explain?

The lights that Chris Stamp uses are red, yellow, blue and green incandescent floodlights with a dimmer. They are used alone or in combinations to support and emphasize the emotional states that are being evoked.

1. Introduction

Mary Boochever is a fine arts professional whose work has been exhibited internationally. Her teaching experience includes positions at School of Visual Arts in New York, Lacoste School of the Arts in France and Suffolk Community College in Riverhead, New York. She has maintained a painting studio in Sag Harbor, New York for fifteen years and before that a studio in New York. In 1995 her interest in color led her to the International Association of Color Consultants, (IACC), Seminars for Color and Environment in San Diego, California. Since becoming accredited in 2004 she has been working in architectural color design alongside her studio practice. The ways in which color can transform an environment, and the people in it, is a predominant theme in her work.

Chris Stamp is a psychotherapist practicing in Manhattan and East Hampton, New York. The type of psychotherapy that Chris Stamp practices is called Psychodrama, developed by Dr. Jacob L. Moreno, 1889-1974. It is transformative in that the core function of Psychodrama is the raising of spontaneity in an adequate and functional manner. To do this, Psychodrama incorporates strong elements of theatre (Figure 1). Participants explore inner conflicts through acting out their emotions and interpersonal interactions, often on a stage with colored lighting. The lights are used much as they would be in a stage production: to support and guide the emotional states that are being evoked. Chris Stamp's background in theatre as well as his personal journey of self-discovery and healing invest this otherwise little known use of colour in the therapeutic environment with the vitality of a practice born from a combination of creative experience and inner necessity.

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2. Psychodrama

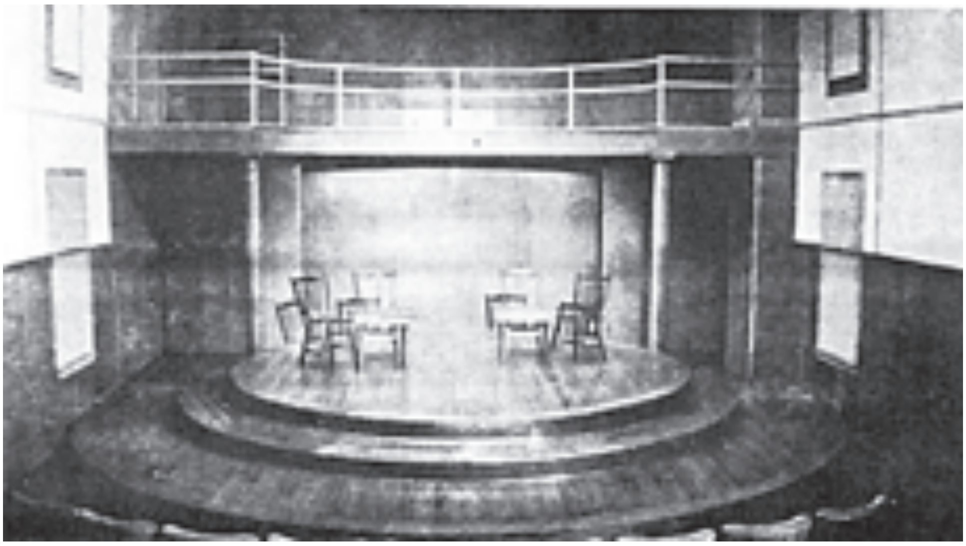

Figure 1. The Theater at Moreno's Institute, Beacon, New York circa 1936.

Psychodrama is a method of psychotherapy in which clients are encouraged to continue and complete their actions through dramatization, role playing and dramatic self-presentation. Both verbal and non-verbal communications are utilized. A number of scenes are enacted, depicting, for example memories of specific happenings in the past, unfinished situations, inner dramas, fantasies, dreams, preparations for future risk-taking situations, or unrehearsed expressions of mental states in the here and now. These scenes either approximate real-life situations or are externalizations of inner mental processes. If required, other roles may be taken by group members or by inanimate objects. Kellerman and Kingsley, (1992)

A psychodrama is conducted by a person, trained in the method, called a psychodrama director. In the interview conducted with Chris Stamp, he explains the process through which the psychodrama director guides the participant through a trigger occurrence to a reenactment of past events leading then to a crisis point and catharsis. The participant is then eased back to the present moment.

The lights that Chris Stamp uses are red, yellow,blue, green and white incandescent flood lights on a dimmer. They are used alone or in combinations to support and emphasize the emotional states which are being evoked; trigger occurrence, reenactment of past events, catharsis, present moment. Colored light is also used to facilitate dream recall.

2.1 Lights

The session begins with bright light. Yellow is predominant, with red, blue and green kept low. This combination is meant to evoke daytime or the life of a child during the day, while the talk is of current issues. The therapist/director and the participant/protagonist begin talking while walking in circles. At this point the yellow, blue and green lights are lowered as the red is brought up. Then there is also a drop, or fading down, where all the lights are lowered as the protagonist enters a trance-like state and deeper into the emotional body. Methods such as, role playing, role reversal and doubling may be used to induce catharsis. When the drama section is over there is a general slowing down with holding and healing touch sometimes easing the participant back into

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the present moment. The lights are brought up again to simulate bright daylight. The client then discusses and shares feelings with the therapist.

Some sessions begin with the recall of a dream. In this case, the participant is asked to lie down, as if in bed. The blue lights are used alone to create a nocturnal, moonlit atmosphere while the dream is remembered. The other steps described in the preceding paragraph are then followed.

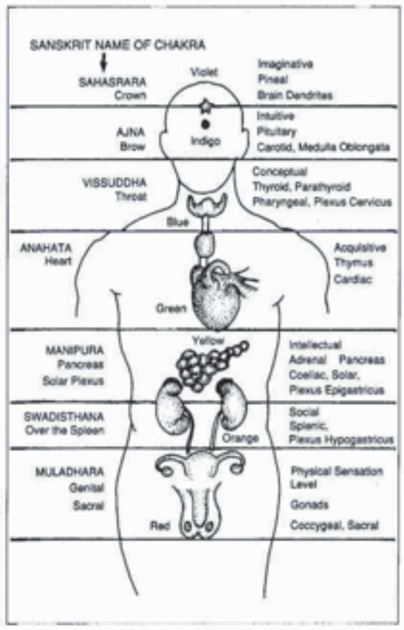

Figure 2. Etheric link between the chakra, personality type, and endocrine secretions. Adapted from a drawing by Christopher Hills, Ph. D.

3. Color and light in healing

The color choices made in Chris Stamp's practice are mainly the result of intuition, built through experience with the performing arts, as well as his interest in healing modalities which treat the energetic field of the body, such as the Hindu concept of the Chakras (Figure 2). For instance, the use of dim red light, in Chris Stamp's words, is meant to be "holding" and "womblike". This would correspond to the red Chakra or in Sanscrit, *Muladhara,* considered to be seated in the genital, sacral area of the body and corresponding to the level of physical sensation. The way Chris Stamp uses color in his practice contains elements of color psychology, but seems more closely aligned with color and light therapies concerned with emotional and physical reactions of the human body based on the rhythmic cycle of day and night. His choice of the primary components of daylight: red yellow, blue and green as well as the attendant moods created by different times of the day support this correlation (Figure 3). In the gradual shift from the red-orange of day to the dark blue of night there is also bodily shift in modes of function, from work to rest.

correlated color temperatures
for common illuminants and light sources

rK°	colo r	correlated illuminant or light source
1000		lower limit of blackbody curve
1850		candle flame
2000		sunlight at sunrise/sunset (clear sky)
2750		60W incandescent tungsten light bulb
2860		CIE A: 120W incandescent light bulb
3400		photoflood or reflector flood lamp
3500		direct sunlight one hour after sunrise
4100		CIE F11: triband fluorescent light
4300		morning or afternoon direct sunlight
5000		white flame carbon arc lamp
5003		CIE D50: warm daylight illuminant
5400		noon summer sunlight
6400		xenon arc lamp
6500		average summer daylight
6504		CIE D65: cool daylight illuminant
7100		light summer shade
7500		indirect northern skylight
8000		deep summer shade
9300		white point of a CRT (television screen)
1064 0		clear blue sky

Sources: Mitchell Charity, MIT; Kodak USA
Note: Color samples grossly exaggerate the chromatic contrast and drastically reduce relative luminance for purposes of visual illustration.

Figure 3. Correlated color temperatures for common illuminants and light sources.

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“Life is basically an energy experience. All of our human interactions, as well as our physiological functions, are vibrational in nature. The sun’s vibrational energy is the most potent life-sustaining force in our very immediate ‘universe’, which we call our solar system. It is now clear that different aspects or frequencies, of this energy have different effects on our moods, behaviors and vital functions.” Liberman, (1991)

In addition to this there is some evidence pointing to the physiological effects of viewing colored lights. The doctoral dissertation in psychology of Robert Gerard, in 1958, presented a comprehensive study of the effects on psychophysiological functions of viewing colored lights. In Gerard’s study, blue, red and white lights were projected on a screen for ten minutes in front of 24 males. “The red light increased the viewers’ respiratory movements, and eye-blink frequency. These same factors decreased under blue or white light.” Liberman, (1991) The subjects reported a sense of relaxation and a lessening of anxiety during blue stimulation, while red stimulation increased their tension and excitement.

4. Conclusion

The core function of Psychodrama is the raising of spontaneity in an adequate and functional manner. It is thought that through raising spontaneity that a system, whether an internal human system or organizational system, can begin to become life filled, creative and develop new solutions to old and tired problems or adequate solutions to new situations and concerns. “I let them act out their conflicting roles and help them put the parts back together again.” Moreno, (1912) Chris Stamp uses colored lights in a way that may affect the client both psychologically and physically. Color and light become a tool in the directors hands with the potential of easing the transition from the conscious to the unconscious.

In *Light: Medicine of the Future*, Liberman states, “ The study of light affirms the interconnectedness of all things. It is a paradigm of the balance between the outside and the inside and is not much different from the cellular physiology or, for that matter, human relationships. Dealing with an energy source that is both visible and non-visible is also a reminder that both sides of life - what we see and what we cannot see - are equally important to our development, growth and evolution. That which is really going on in our lives can frequently be understood only by taking an illogical look.”

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Psychological study on preference of ideal skin color – comparison between Japan and China

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Abstract

The brightness of the skin is considered as one of the most important aesthetic standards for feminine beauty in Asia. The markets for whitening cosmetics, led by Japan and China, are developing extraordinarily fast. In this study, the author tried to compare the difference of preference of ideal skin color between Japan and China. In the first investigation, the subjects were asked to answer a questionnaire about skincare habits and evaluate 10 stimuli of different skin statements. The authors conclude that when evaluating the ideal skin, both Japanese and Chinese women always regard the bright complexion as the top choice. In the case of China, the complexion is even more important than texture at judging the skin.The second investigation was taken on to compare their original skin color and ideal skin color. The results indicate that Chinese women preferred reddish complexion as ideal skin color, while they assessed their own skin color much darker and more yellowish. It was also found that Chinese women had much more preference for skin brightness than Japanese women did.

1. Background

"White complexion is powerful enough to hide seven faults." is a well-known proverb in both Japan and China. It reveals people's strong preference for fairness. Especially for the complexion, white and bright skin color is the favorite of Eastern Asian people and has become the judging standard for beautiful women. This aesthetic standard of skin tone is totally different from Modern West. Therefore, the markets for whitening cosmetics, led by Japan and China, are developing extraordinarily fast these years and take the most possession of the world market.

In fact, there has been psychological research on Japanese and Chinese women for the preference of fair skin by Saito et al. (2001, 2002). The experiment indicates that the woman in this two countries still possess strong inclination of fair complexion,and the skin texture also afftects the personal impressions.This explains why market of whitening products that improve both skin tone and texture continues to expand in Asia.

However, the preference always changes by time.Thus, the authors felt that it was necessary to investigate the present conditions. Moreover, as situations in Japan and China cosmetics sales market vary, the difference of preference on complexion between the two countries was also expected to be proven.

2. Objective

The objective of this study was to understand what kind of factors affect on ideal skin evaluation, and to compare the preference of complexion between Japan and China.

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3. Method and materials

3.1 Skin Image Evaluation

***Subjects*:**
A total of 108 Japanese women aged 20-59 (22 subjects in 20`s, 24 subjects in 30`s, 31 subjects in 40`s, 31 subjects in 50`s) living in Kanto area;
A total of 130 Chinese women aged 20-59 (37 subjects in 20`s, 31 subjects in 30`s, 31 subjects in 40`s, 31 subjects in 50`s) living in Shanghai

***Stimulus*:**
The stimuli were 10 photo images of actual skin with 5 kinds of skin statement variations (fine/texture/spot/aging/pore) and 2 skin tone variations (bright / dark).

Procedures:
The subjects were asked to answer a questionnaire about skincare habits and then evaluate 10 stimuli by 5 levels evaluation of Semantic Differential method, using 12 adjective pairs (beautiful-ugly, likable-unlikable, young-old, feminine-unfeminine, weak-strong, tidy-untidy, elegant-inelegant, well-bred-badly-bred, introverted-extroverted, intelligent-unintelligent, charming-uncharming, refined-unrefined). Finally, rank the 10 stimuli from the best to the worst.

3.2 Skin color measurement

***Subjects*:**
A total of 87 Japanese women aged 20-59 (27 subjects in 20`s, 18 subjects in 30`s, 24 subjects in 40`s, 18 subjects in 50`s) living in Kanto area;
A total of 96 Chinese women aged 20-59 (29 subjects in 20`s, 27 subjects in 30`s, 19 subjects in 40`s, 21 subjects in 50`s) living in Shanghai.

***Materials*:**
A skin tone chart with 145 colors called *Skin Tone Color*,which is produced by Japan Color Research Institute,was used as a scale in the investigation.

Procedures:
First, the subjects were required to choose one color which is most similar to their own skin tone and then to choose their ideal skin color from Skin Tone Color. Finally, the author recorded the Hue, the Value and the Chroma from the forehead, cheek and neck of the subjects to do the comparison.

4. Results

4.1 Questionnaire

In Japan, almost 75% women make up nearly every day, while only 24% Chinese women do so everyday or frequently. When choosing foundations,75% Japanese women will choose the color as the same as their complexion. But over 50% Chinese women answered that they would choose one tone brighter than their skin as favorite. It was because that if the foundation could not make them look fairer and brighter, they don`t think there is any necessity to use foundation.

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4.2 Skin image evaluation

4.2.1 Image profile by semantic differential method

From the image profile of Semantic Differential Method, it was obvious to see that for the same skin status, bright complexion skin were evaluated higher as a whole than the dark ones in both two countries. On the other hand, Japanese women have a strong personal impression for the bright skin tone,while Chinese women think people who have bright complexion looks weaker than dark complexion.

4.2.2 Factor analysis

Charming Factor and Character Factor were extracted for Japan, and Intelligence Factor and Beauty Factor were extracted for China (Table 1. and Table 2.). It shows that Japanese women focus more on external factors while Chinese women tend to associate with the internal spirit when evaluating skin statement.

Table 1. Factor Loading-Japan

Factor	Item	1st Factor	2nd Factor	Communality
Charming Factor	beautiful-ugly	1.141	-0.295	0.891
	likable-unlikable	1.097	-0.239	0.874
	young-old	0.919	-0.141	0.674
	charming-uncharming	0.813	0.074	0.535
	refined-unrefined	0.641	0.264	0.268
	tidy-untidy	0.608	0.312	0.748
Character Factor	weak-strong	-0.187	0.64	0.827
	well-bred –badly-bred	0.35	0.573	0.748
	intelligent-unintelligent	0.247	0.568	0.145
	introverted-extroverted	-0.198	0.503	0.591
	elegant-inelegant	0.485	0.49	0.756
	feminine-unfeminie	0.341	0.443	0.73

Table 2. Factor Loading-China

Factor	Item	1st Factor	2nd Factor	Communality
Intelligence Factor	well-bred - badly-bred	0.853	-0.037	0.88
	elegant-inelegant	0.777	0.083	0.873
	intelligent-unintelligent	0.776	-0.017	0.615
	weak-strong	0.724	0.086	0.538
	refined-unrefined	0.691	0.161	0.629
	tidy-untidy	0.687	0.176	0.692
	charming-uncharming	0.582	0.288	0.71
	feminine-unfeminie	0.569	0.196	0.68
	introverted-extroverted	-0.357	-0.003	0.129
Beauty Factor	beautiful-ugly	-0.028	0.96	0.582
	likable-unlikable	-0.001	0.935	0.685
	young-old	0.326	0.502	0.677

4.2.3 Rank order

The result shows that when evaluating the ideal skin, the women in the two countries regard the the fine status with bright complexion as the top choice. In the case of China, the complexion is even more important than texture when women judge the skin. On the other hand, the skin trouble

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which Japanese women concerns most is the pore problem, while Chinese women gave the lowest rank to the aging problem.

4.3 Skin color measurement

The Hue of the facial skin (including forehead and cheek) of Japanese women is more uniform than that of Chinese women. Although the neck skin appears yellowish when compares to the facial skin, the difference of Hue between the neck and the face of Japanese women is minor than that of Chinese women. In addition, the self-evaluation on the skin color of Chinese women is darker than that of Japanese women, while their aspiring skin color is quite the opposite.

5. Discussion and conclusions

Although bright complexion makes the skin trouble prominent, both Japanese women and Chinese women prefer bright skin to dark skin under any skin status. Once the skin became bright and white, it would bring better impression than the same status with dark complexion, even affecting peoples' judgment on one`s personality. Especially in China, women ambitiously tend to have bright complexion. The bright skin with rough texture is even preferable than ideal dark skin in China. This result reveals the importance of skin color when people are evaluating their status of the skin.

In self-estimation of the skin color, Chinese women tend to select darker and more yellowish skin color than they actually possessed. But when selecting their aspiring color, Chinese women have an inclination to brighter and more reddish than Japanese women do.

As a result, although it has been almost 10 years since the previous research on the preference for bright complexion of Japanese and Chinese women, the same result was proven again in this study. Both Japanese and Chinese women have common aspiration to fairer and brighter skin. Moreover, it was found that the pursuit for fairness and brightness on complexion of Chinese women was quite stronger than Japanese women. Hopefully, this research would contribute to the product development and marketing strategy of the make-ups when the brand is dealing with multi-cultural situations.

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Urban policies towards façade colours

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Abstract

Our research project develops a methodology for the elaboration of colour plans in cities and we necessarily pay attention to public and to municipal strategies. We have narrowed our scope to building façades at *Junqueira* Street, a consolidated urban historic area in Lisbon, Portugal. We have taken the actual colours of buildings and tried to understand why those colours were chosen. Interviews to public services were necessary specially because Lisbon Master Plan does not present colour as an operative strategy. Nonetheless, when someone needs to paint façades he can choose among three possibilities that impose some rules to the city environment that might be read as public acknowledgement regarding colour in cities. Yet those possibilities always close the building in itself to an individual choice that might be alien to any sense of urban wholeness. Formerly, a narrow range of technologies and materials have given cities some kind of "natural" order. However, new technologies and a wider colour spectrum might turn cities into chaotic colour habitats. Therefore colour plans should be ethical, aesthetical and scientific regarding the search for a new identity of the place where the stream of time built on human artefacts could be strong criteria.

1. Colour plans: art, science and technology

Colour plans have been made and implemented for the last 30 years. As Nery puts it "[t]hough debatable the official intervention in such accessory matter ... multiple individual options … would create a chaotic image that can only be avoidable by colour scheme ..." (1987: 573-575). Colour plans have been gaining acceptance and are now common regulatory procedures nonetheless questionable. Overwhelming scientific criteria regarding colour seem to challenge reason at the democratic age that claims for public participation. Yet a narrative justification presenting clear methodological choices might mediate planner and public. Actually, this is the case for colour archaeology as a heuristic method. Such problematics are often widely discussed by many authors (e.g. Aguiar 2003). From this perspective a colour plan may be understood as a scientific and technologic based process on the search for a former artistic expression. Yet, at the acme of the method, *past-present-future* should serve a final judgement that is aesthetic and it cannot be anything else but aesthetic because science brings about *an*-aesthetic frameworks and technology is simply a tool that demands special techniques.

Archaeology of colour necessarily uses technology to carry out scientific conclusions. Colour layers tell a human story. Instrumental colour assessment and prescription using quantitative systems such as the Natural Colour System (NCS) act as a reference to organize data and Computer-aided Design software (CAD) acts as a rich tool to work on with that data. Highly

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detailed simulation images to foresee final environments seem strongly necessary to public participation and make studies clear. In fact, colour is intrinsically *image* and a potential aesthetic substance. Besides, "[a]rt may be defined as a set of processes to obtain certain results, mainly a way of doing, and in that sense equivalent to *techné*, also a set of processes to achieve an end" which is a triumph and therefore exceptional on the art object. *Techné* is constituted into a heuristic pretext and mean regarding the creation of the art object (Rodrigues, 2002: 39). Consequently we have intricately linked art, science and technology at the core of the method for colour plans.

2. The case study

The 1.5 km long Junqueira Street presents a wide range of building typologies such as eclectic and vernacular residential, commercial and industrial architecture, mainly built during the 18th and 19th centuries. The street comprises two distinct well defined spaces, the first to the west ends is a consolidated urban area characterised by mixed commercial and residential uses and the second to east ends is a fragmented fabric shared by old urban palaces and recent industrial plots. Here we will focus our attention on the west street end, the consolidated area managed by "Lisboa Ocidental, SRU-Sociedade de Reabilitação Urbana, EM" (SRU Ocidental).

SRU Ocidental, created in 2004 partially linked to municipality, is responsible for the incentive of the urban renovation of the occidental area of Lisbon. SRU may develop and implement colour plans but they have to follow up proper legal steps through municipality itself. SRU works in close relation with the community and embodies a specific area of intervention which is far larger than our case study. We might say that they work on a case by case approach in what can be qualified as a descriptive planning approach bounded by the Lisbon Master Plan in opposition to 20th century planning meta-theories prescriptive approach.

SRU Ocidental presents three basic options for façade colours selection. The first is to repaint the façade in the existent colour, the second is to paint it in the last colour approved based on the municipality archives and the third to apply a new colour chosen by the owner or his architect and subjected to municipal approval. The latter shows no explicit criteria other than its good match between its adjacent buildings, and differently from the previous options has to pay municipal taxes.

The two first options run closely to each other and are sanctioned by a sense that legal acceptance must rule democratic societies. In the first case it was not formerly imposed to the individual to change colour and therefore it was, somehow, accepted. On the second case there is valid contract between individual and state, that is, a colour agreement. Yet the validity of such contract should combine a written record and a colour record and the latter is far problematic. A colour usually turns into a written representation, a description that might be referable but no actual colour. The contract might have some historical relevance as such but not the colour itself. Besides, we often find no colour information.

In the present case, archival research revealed that several documents from 1940 conveyed information on the exterior state of conservation of buildings that was visually assessed and recorded focusing on colour information. The results show that the prevalent colours were light colours. From a total of 21 painted building consulted in the archives, 14 had colour information and all the 14 colours mentioned were light colours, varying from white to beige to ivory-colour, 12 of them preceded by the word "light".

The third option might bring either, freedom, chaos or even order on a random way whereas the aesthetic is intrinsically intentional. Politics of aesthetics act as a consequence of such

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intentionality. In fact, architects may present new colour solutions to buildings but a sense of urban environment should not be confined to individual choices alone. Besides, a façade is a *public thing* that I must see either I like it or not. Colour plans are fundamentally ethic and they should, nonetheless, create a friendly territory to personal expression. The ethical balance is difficult at the age of the individual. The *public thing* is emphasized by Holston, (1989: 122) who proposes the following definition for the role of the façade in the pre-modern city "... the plane of the façade (its surface and edges) belongs *visually* [emphasis added by the author] to the space and not to the wall. The space of the street "steals" the façades of surrounding walls for its contours … and creates the impression that the building's façades are the interior walls on an outdoor room."

Colour is an important factor on the characterization and individualization of the elements that constitute the *one-all-one* in *all-all in one* and particularly important on a street with such building uniformity. The *three option colour policy* we have found constitute firstly an ethical conflict on the system individual-state-society and such conflict moves into a second, a colour conflict that extensively acts over the whole city environment as we fashion.

Colour plans should rely on different conceptions of public and private space where such conceptions mean that «a human being» is present at the core of the problem. Thus, different agents, institutions, public, individual and collective responsibilities seem inevitable to be put on consideration when defining an approach to colours for the building façades.

3. Conclusions

Human environments have to be ruled by ethical frameworks and colour plans are, first of all, both an ethical instrument and a human creation. Colour plans are very sensible to human life and they constitute a privileged method to reify the aesthetic. They find an overwhelming justification referable to its destiny: the aesthetic experience.

Ethics, art and science meet on an intricate way at the core of the method regarding colour plans. Science and scientific methodologies break down such a complexity into fundamental elements that both science and, finally, the aesthetic act reify.

Archaeology of colour seems to combine art, science and technology. It is a method that aims at the discovery of human artefacts that, as Panofsky (1996: 186) puts it, "… from the humanistic point of view human records do not age." Perhaps, this is the reason why public tends to follow such plans with great attention and it is a strong pedagogic vehicle to embody individuals into a creative participating city.

Yet, at the horizon of events we find the *an*-aesthetic meeting the aesthetic, that is, archeology as an epistemological process meeting the creation of the object of art and the object of art itself which means that archeology reveals finally its own heuristic nature that might converge on the creative process but might not determine it.

Acknowledgments

This project is funded by Fundação para a Ciência e Tecnologia (FCT project number PTDC/AUR-AQI/108794/2008). We would also like to thank Professor Architect Joaquim Marcelino Santos and Architect Raquel Ferraz Nunes for their contribution for this research.

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Light, colour and texture: The appeal of the senses to improve independence among the elderly

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Abstract
The aim of this research paper is to assert the importance of light, colour and texture in the quality of human beings' life, particularly in the performance of aged people's perception of the space. Literature reviews documents the importance of the colour contrast and light characteristics to individual perception of the built environment. Despite the arguments from various authors and the results of dissimilar research projects, the planning of assisted living environments continues being supported by cultural and aesthetical principals and architectural rules which include accessibility; however, attention to the need to understand how people view and perceive the environment still lacks to improve individual autonomy and well being. With the aim of sustaining this argument two examples will be studied to understand how light, colour and texture contribute to the autonomy of aged people by improving the sense of comfort, security, personalisation of the place and motivation for an active and autonomous life. Light and colour are the two sides of the same coin attached by texture which reduces and/or raises the jigsaw of shadows. The presence of colour within the home environment ought to be more than just the use of the white (in the belief that this is a neutral colour and its appliance is always correct) or just the use of a dated colour catalogue provided by any brand! **(Keywords:** Light, Colour, Texture, Home environment, Design)

1. The context
Aging has become one of the most important results of the evolution of the human population; therefore, there have gradually been increasing numbers of people who reach what is also called the "senior citizenship". This soaring proportion of people over 65 is one of the most important rates of civilization, at a moment we witness the world is literally getting older (Barreto, 2003). We live longer today than we did in the past, but yet, maturity does not mean carefree. It rather implies a concern with those aspects the cities, housing, law, economics and contemporary technology do not seem prepared for, regardless of any advances in the promotion of medicine for a longer life expectancy for those people, with the best living standards, in other words, achieving an autonomy to decide about their own independence based upon their own will and activities necessary for their well-being. The elderly go through biological changes and they feel a growing urge to stay at home and, simultaneously, they also need social interaction and, even more than they used to need (Daré, 2010). Modifications of the aspects of housing that benefit these individuals, have placed emphasis on the understanding of the maintenance of their functional level before the activities of daily living (ADLs[1]), complemented by activities instrumental to

1 ADL's - activities relate minimum undertaken by individuals in order to satisfy physiological needs and maintain health and hygiene, including washing, dressing, eating, etc.

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their daily living (ADLs[2]), thus, allowing an independent way of living. The special needs of these individuals, a group that has characteristics more heterogeneous when compared to other groups, should be discussed against a background of a wide range of personal needs of minorities as having various kinds of disabilities, permanent or temporary. Quality of life should be discussed and measured according to the number of outputs of positively valued opportunities, integrating personal and collective plans (Barreto, 2003). In this process, the sight is especially sensitive because it is an organ that is affected in every form - internal and external, being exposed to light, wind, dust, products and situations that include diseases of the body itself. Older people tend to show reduced visual field size, increased absolute thresholds of luminance, reduced visual acuity, and reduced contrast sensitivity, increased sensitivity to glare and poorer colour discrimination (Boyce, 2003). An important factor related to sight is the production of the hormone called melatonin, which is related to the internal network system referenced by a biological clock, which coordinates the body functions within a circle of 24 hours, according to a daily rhythm light and darkness, called *circadian rhythm*. The purpose of the circadian cycle to keep the body on alert during the day - enabled by decreasing the production of this hormone - and contribute to the promotion of a state of relaxation during the night - by increasing their production - which allows for synchronization harmonious with the outside environment. The lighting design is important to compensate for the decreased visual acuity, allowing the identification of horizontal and vertical plans of space, contributing to the maintenance of body balance, reducing the danger of falls, and making a combination between the visual and perceptual system (Casarini, 2010). The characteristics of light are the starting points to recognize the size and the organization of space for the people. The color might be used as improved visual performance of the elderly people in different ways, such as identifying objects, recognizing images and foods, and substituting luminance contrasts, when the colours make the difference between the task and its immediate background, the only way that makes the task visible. Colour difference only becomes important whenever the luminance contrast is low (Boyce, 2003).

2. Study cases

Nowadays the elderly have the expectancy to live a long, active and self motivated existence, notwithstanding the social class and possessions of each person. Physical and sensorial impairments that limit interaction with others and the built environment can be minimized by assisted living environments. Lisbon Metropolitan Area has witnessed the uprising of some assisted living developments, planned and built for the upper middle class population; these venues belong to important economic groups owning private hospital units supporting the residents' needs. We selected an example located on a privileged area of Lisbon. It locates in a site by the beach with a magnificent view to the Atlantic Ocean. The main reason for this choice is the efficient way it addresses the physical individual's requirements – mobility in particular. Unfortunately, there is no attention at all to the colour, texture and lighting features making it an insecure and an unappealing environment to sensorial human faculties. Although orientated to the South and West the building has white facades, and the morphology of the openings is identical in dimension and shape despite of its orientation. This influences the quantity of light that comes into the interiors

2 IADL's - report the activities of day-to-day that involve tools and equipment for their use, reflecting the autonomy of the individual and the integration with the environment, including the activities of shopping, cleaning the house, preparing food, etc.

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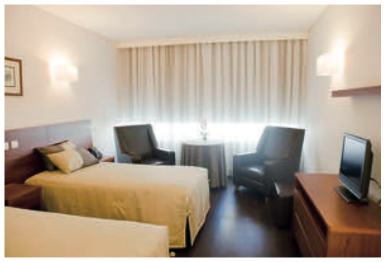
preventing the control of natural light especially in summer time. Balconies do not have area enough to accommodate a table and two chairs so people can use it. The whiteness of the building reminds the hospice nature of the site; this is not the better solution for individuals that need to feel the facilities as a home replacement, constituting a possible source of annoying and anxiety. The main area in the entrance level is of major significance. In fact, individuals living in such places are always waiting for something or someone - relatives and friends, someone else's visits – so the sense of isolation dims. This area is the place to do so and, therefore, should be comfortable and as inviting as possible. This can be achieved by the use and management of light, colour and textures of the layout, equipments and finishes. The images bellow reveal that white prevails everywhere, from the walls, to the ceiling and sofas; the floor has glossy ceramic that reflects the light, causing individual 'glare, limiting the perception of the space and increasing the sliding hazard. The importance of the light control and colour as a communication code is important for all individuals but it is of the utmost importance for elderly and impaired people. For these groups visual communication is crucial to perceive the space and to react and communicate with it and others. It is a clean and sterile environment that seems planned to please the relatives who visit the ones that stay here.





Figures 1, 2 and 3 – Interior environment (Montepio, 2010). The whiteness of the environment do not confere the warm feeling as the floor reflectancy can be confusing for older eyes.

De Plussenburg' building is an awarded example of contemporaneous architecture in Rotterdam. Its located in a neighbourhood conceived to shelter old and disabled individuals. The population inhabiting this building are babyboomers and the health assistance needed (when needed) is offered in a complex next door. This building is composed of two volumes that intersect on the third level. The vertical volume comprises the dynamic lines of the balconies that belong to each home. The horizontal volume associates the facades with the circulation areas, where the facades aim to play with the natural light bringing to the corridor area a pleasant, warm and always different ambience, because of the coloured light from the tinted glasses of the windows. The main hall is small and inviting and uses the same technique for lighting. The corridors are generous allowing the free mobility of wheel chairs and pushchairs as well as the personalisation of each home entrance. The floor is covered by a red carpet that contrasts with the textured white colour of the walls and ceiling. This whiteness however, is only perceived on the lifts area; the rest of the corridor area is mainly illuminated by natural light, which is changing in response to the glass facade, weather conditions, season and day time and especially to the tinted glasses that runs along the path. Light within the houses comes from the balcony and the corridor through the side window on the main door or the small window that allow the natural light into the kitchen area. These windows are important to illuminate interior areas as well to allow a discrete surveillance on individual needs.

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Figures 4, 5 and 6 – De Plussenburg , exterior views to the balconies, main hall and the glaze window facade. (Caramelo Gomes, C. 2011)

3. Conclusion

Light reveals architecture but repeatedly forgets its impact on the user' experience of that space. Light goes beyond the spiritual atmosphere conferred to the space or the functionality to aiding human visual ability, influencing individual's biological and psychological response. Colour and lightening choices must be free from blind obey to fashionable models and marketing campaigns. Rarely both concepts present an objective solution sustained by its influence in user interaction with space. Light, colour and texture stimulate human senses increasing the feeling of comfort and interest to surrounded environment. More than colour or texture on themselves, the major importance relies on the contrast between colours and tints, and the jigsaw of hide/unhide allowed by texture and light. Human being needs sensorial stimulus. A neutral environment conceived for old people must assure the sensation of comfort, security, safety. Light, colour and texture are crucial to visual and tactile stimulation. Pos_occupation evaluation must be done to raise users' participation and increase the experience of objective and sustained choices. The information provided by theoretical and empiric research should be widely disseminated to highlight the importance of the good use of light, colour and texture within built environment. The lessons learned from the examples can be extrapolated to similar environments and standard homes which are, by individual election, the preferable place to grow old.

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Propagation of errors in a color-matching experiment

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Abstract

We revisit the problem of propagation of errors in the pioneering color-matching experiment by MacAdam (1942). The observer made color-matchings by tuning the angle of a Rochon prism in order to match the fixed and the variable half-fields. The average value of the angles was considered to derive the average tristimulus values, whereas the standard deviation of the angles was used to derive the uncertainty interval, thus assuming that tristimulus values obey to a Gaussian distribution function. In this work we do not make any assumptions about the probability density function (pdf) associated to tristimulus values, and we make use of the rigorous statistical theory to derive the true pdf's associated to the tristimulus values Papoulis and Pillai (2002). We also analyze how much deviate the actual pdf from the Gaussian by computing the third and fourth centered moments.We outline a method to derive by numerical procedures the interval of color mismatch. Our results are compared with those obtained by using the common approach to derive standard deviations of transformed magnitudes Nimeroff (1953).

1. Introduction

An important task of the basis of instrumental color discrimination, namely, the uncertainty of experimental data, is commonly carried out using an approximate approach of the theory of propagation of errors. In this work we present a rigorous derivation of the uncertainties of the tristimulus values obtained in a color-matching experiment. We apply the formalism to experimental data from MacAdam (1942) which illustrate that the conventional approach can fail to predict actual uncertainty intervals. A similar procedure has been applied by Carreño and Zoido (1999) althouhg in that case the color-matchings were of the metameric type.

We review the fundamentals of the experimental work for the sake of completeness. Isomeric color-matchings were made using a two degree comparison field, divided semicircularly. The color stimuli presented to the observer in the two halves of the field were obtained using different combinations in pairs of 105 filters. The variation of the color stimuli in the variable field of observation was made using a Rochon prism θ whose angle could be modified at will between 0 and 90 degrees. Let X_{vj}/X_{uj} (j=1,2,3) be the tristimulus values of the color mixture when $\theta=0^0/90^0$. The instrument was designed in such a way that when the angle was set to a certain value, let's say, θ_0, the tristimulus values of the mixture of the two filters at the selected angle were given by

$$X_j=X_{ju}\sin^2\theta_0 +X_{jv}\cos^2\theta_0,\ (j=1,2,3). \qquad (1)$$

The observer operated a knob to produce color variations in the variable field until he considered that both fields were equal from a visual viewpoint. The average value (θ) and the standard deviation (σ) of a collection of 50 equalizations were recorded for different combination in pairs of two filters (see Tables III and I in MacAdam (1942)). We can assume that θ can be considered as a random variable. The uncertainty in the angle settings arised from random fluctuations of the filters and from the light sources used in the instrument. It is worth mentioning that the color-

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mismatch was only attributed to the uncertainty in the angle settings by MacAdam (1942), thus neglecting the uncertainties arising from the values of the tristimulus values of the filters X_{ju} and X_{jv} in Eq. (1). In this work we follow this prescription in order to derive the experimental errors in magnitudes X_j.

It is a common assumption in routine laboratory practice to consider that the angle setting behaves as a gaussian with mean value θ_0 and standard deviation σ_θ, i.e., θ is a $N(\theta_0,\sigma_\theta)$ with associated probability density function (PDF) of the form

$$f(\theta)=1/(2\pi\, \sigma^2_\theta)^{1/2}\exp(-(\theta-\theta_0)^2/2\sigma^2_\theta). \qquad (2)$$

Let us remind here that a gaussian PDF has a null asymmetry while the kurtosis parameter is equal to 3 (see Papoulis and Pillai (2002:148)). The conventional approach (see for example Nimeroff 1953) used to estimate the uncertainty for X_j is to compute the following magnitude

$$\sigma^2(Xj)=\left|\frac{\partial X_j}{\partial\theta}\right|^2 \sigma^2(\theta) \qquad (3)$$

In this work we perform a rigorous statistical analysis of the problem. In view of the fact that θ is a random variable, any function of θ, $g(\theta)$, is a new random variable (see Papoulis and Pillai (2002:123 and ss)). This result applies to the case of tristimulus values given in Eq. (1). The question which naturally arises is to derive the PDF associated to the transformed random variables X_j. This problem is addressed in the current work by using the standard technique described in detail by Ref. Papoulis and Pillai (2002:123 and ss)), provided that the inverse function exists. Once we have determined the new PDFs, $g(X_j)$, we compute the average value of magnitudes X_j, the second, third and fourth moments centered with regard to average according to the following standard formulas:

$$\begin{aligned}\langle X_j\rangle &= \int g(X_j)\, X_j\, dX_j\ ,\\ \langle E_2(X_j)\rangle &= \int g(X_j)\,(X_j-\langle X_j\rangle)^2\, dX_j\ ,\\ \langle E_3(X_j)\rangle &= \int g(X_j)\,(X_j-\langle X_j\rangle)^3\, dX_j\ ,\\ \langle E_4(X_j)\rangle &= \int g(X_j)\,(X_j-\langle X_j\rangle)^4\, dX_j\ .\end{aligned} \qquad (4)$$

The standard deviation is $\sigma(X_j)=(\langle E_2(X_j)\rangle)^{1/2}$, while the asymmetry and kurtosis parameters are $As(X_j)=\langle E_3(X_j)\rangle/\sigma(X_j)^3$ and $K(X_j)=\langle E_4(X_j)\rangle/\sigma(X_j)^4$, respectively. The results should be compared with the predictions derived by using Eq. (3). The values for asymmetry and kurtosis obtained from the numerical integration carried out are of particular interest in comparison to those obtained for a gaussian PDF since the values obtained in the current analysis will inform us about the severity of deviation of the actual PDF from the gaussian PDF.

The interval of color mistmatch $I_j = [X^{inf}_j, X^{sup}_j]$ is determined by impossing that

$$\int_{X_j^{\inf}}^{X_j^{\sup}} g(X_j)\, dX_j = 1-\alpha\ , \qquad (5)$$

Equation (5) indicates us that $100(1-\alpha)$ of the color-matchings carried out by the observer are within the interval I_j. Thus, by selecting a value of α, usually termed as the confidence level, we can determine the lower and upper bound of this interval. Note that owing to the asymmetry of the probability density function, the interval I_j is not symmetric with regard to the average value $\langle Xj\rangle$. Thus we can split this interval into two non-overlaping subintervals which satisfy that

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$$\int_{<X_j>}^{X_j^{sup}} g(X_j)\,dX_j = \frac{1-\alpha}{2},$$
$$\int_{X_j^{inf}}^{<X_j>} g(X_j)\,dX_j = \frac{1-\alpha}{2}. \qquad (6)$$

In view of the linear character of the quadrature operation, the two identities in Eq.(6) are equivalent to Eq. (5). In doing this we assume that (1-α)/2 of the color-matchings are within the subinterval $[X^{inf}_j, <X_j>]$ and the rest are within the subinterval $[<X_j>, X^{sup}_j]$. The values for X^{inf}_j and $X^{sup}j$ can be determined by performing the numerical quadratures indicated in Eq. (6). Note that the use of the conventional approach to derive the intervalof mistmatch which based upon the use of Eq. (3) produces subintervals of mistmatch of the same length.Once we know the intervals I_j, we resort to project the results to the chromaticity diagram and compute the chomaticy coordinates of the average values, and those of the upper and lower limits of the corresponding intervals. Finally, we estimate the euclidean distance from the center to the upper and lower limits of such intervals.

2. Application of the formalism to experimental data

To illustrate the outlined procedure we have carried out the numerical integration indicated in Eq.(4) using standard quadrature functions (see GNU Octave and Wolfram Mathematica for more details) for the pairs of filters with numbers 86 and 14 according to the nomenclature used by MacAdam (1942). The values predicted are $As(X_1)=0.0816$, $K(X_1)=2.9861$, $As(X_2)=0.0843$, $K(X_2)=2{,}9988$, $As(X_3)=0{,}0843$, and $K(X_3)=2{,}9988$. The PDFs show deviation of the asymmetry parameter from that of the gaussian value of zero in the second decimal place, whereas in the case of the kurtosis parameter the deviation from the value of 3 appears in the third decimal place.

Figure 1(a)-(c) displays the PDFs for the different X_j in the case of considering the pair of filters 86 and 14 (see line 18 in the right hand side of Table 3 in MacAdam (1942)). The most remarkable feature is that the new PDFs deviate from the Gaussian character having a non-null asymmetry and a slight deviation from the value of 3 in the case of the kurtosis parameter. The asymmetry can be appreciated in Fig. 1(a)-(c) by noting that we have also plotted the points which lie below and above the corresponding average value by a distance of $\sigma(X_j)$. The visual inspection of Fig. 1 reveals that these points are not symmetrical with regard to the average value.

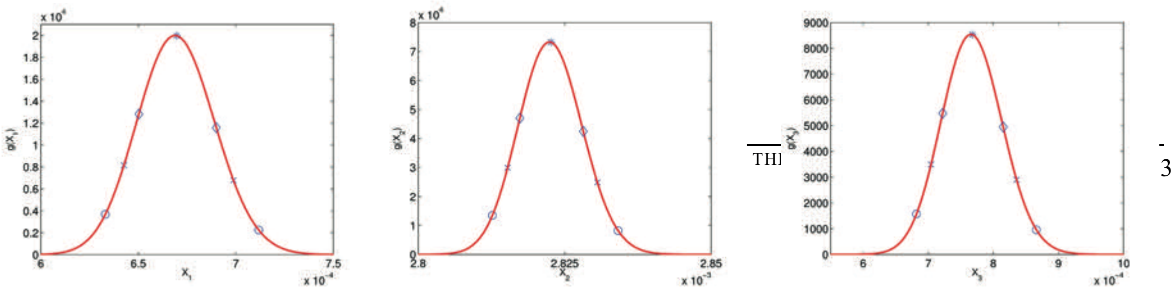

Figure 1. PDFs of the different tristimulus values obtained with filters 86/14 ($0^0/90^0$) with average angle $\theta_0=59{,}30^0$ and $\sigma_\theta=1{,}481^0$. The star indicate the average value $<X_j>$ of the corresponding tristimulus value, whereas diamond, crosess and open circles are used to indicate the positions of the points which provide the limits of the uncertainty intervals for confidence levels $\alpha=0.32$, 0.16 and 0.05, respectively.

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We now summarize the numerical results for the data of Fig. 1.

- The chromaticity coordinates computed through the use of Eq.(1) and those derived by the current proposal differs in the fourth decimal place (0,02 % of deviation).
- The discrepance between the error mistmach computed by using Eq.(1)-(3) and the results provided by MacAdam is in the order of 8,8%.
- The discrepance between the error mistmach computed using the procedure proposed in this work and the results provided by MacAdam is in the order of 9,6%.
- The discrepances between the error mistmatch computed by using Eq.(1)-(3) and the procedure proposed in this work are in the order of 1,7%, 3,4% and 6,7% for conficence levels of α=0,32, α =0,16, and α =0,05, respectively, when considering the upper limit interval, while the discrepancies are of 0,45 %, 0,98% and.0,29% in the case of considering the lower limit intervals and the same confidence levels.
- These results reveal that the use of the conventional approach may produce large infra-estimations of the uncertainty intervals, which can become unaceptable in the case of low values of the confidence level α.

Results for other color matchings carried out in MacAdam (1942) by using different combinations in pairs of filters used show similar or even larger discrepancies between the conventional approach and the data obtained by the procedure described in this work.

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The paths of the rainbow

Jacqueline CARRON
Association Couleur & Vie'

1. Introduction 2. Variations on a luminous spectrum
3. the « Psi Color »
4. The rose of Color

Introduction

Jacqueline Carron : As a painter, I used to think I knew all there was to know about color! That was until at 43 years old, I discovered the manuscripts of Eugene Chevreul.

It was then that I realised that I knew very little and that the field of science knew everything! So it was at 40 years passed, that I moved towards science & was therein seized by the galaxy that is COLOR. During this long life, I will have experienced 3 phases in & around color

1st phase : adolescence & youth : initially on an emotional level when I discover the paintings of the Fauves & Delaunay. 2nd phase: maturity : whereby I discover the field of science & begin to work with it. Therein I am driven back to basics, to the essential & fondamental, resulting in my questioning the very notion of color in painting. The subject becomes color in & of itself & only color occupies the picture plain. This is the phase of rationality & the understanding of research. 3rd phase: advanced age : osmosis between the rational & the emotional, an approach which lends & devotes itself totally to the subtle & ephemerate play within the mobile universe I call PSI COLOR© & « Mobil Color Art » An art in perpetuel transformation renewal, open to the multiple & infinite.

Variations on a luminous spectrum

A range of colors is developed. I choose 19 tonalities along with their brightness & saturation. These 19 tonalities are arranged in columns two by two.
Competing in complementarity, yellows, oranges, reds on the right and green and blue on the left. Dark tones at the bottom, lighter tones at the top.

Ordinate chromatic progressions

n°10

In this first case, the lightest tonality is chosen.
Yellow n°10 serves as the central starting point for this chromatic progression.
The18 other tonalities settle in expanding rotation around this centre, like a galaxy, border against border.

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Observation : The tonalities develop following the logic of the colours of a rainbow. Is it for this reason that the eye accepts this ensemble? One can say that there is an overall reading of an outlined shape. This is caused by the simultaneous contrast of the colors & their degrees of clarity. This form reveals 3 distinct plains created by these light & dark areas.

The first plain (yellows) feels closest & the other two retreat & spiral into the background.

At the same time in a second reading, successive contrasts are discernable, revealing distinct lines between the lighter hues of yellow & green. Thus, this example is a case of mixed contrast.

n°28

In a second example, the central tone is the darkest of the range, purple n°28

Observation :

The generated shape is different & the plains are reversed

Third example: intermediate tonalities

Observation : One can observe that the tone of the central color can each time induce a different visual reading of what is essentially the same ensemble.

Unexpected Progressions

In this image of 2 identical chromatic developments with central starting point of red n° 34, the top one develops towards the right & the bottom towards the left. There is an overall reading of both together whereby the top seems to foreshadow the bottom.

The blue & purple tones seem to advance on a closer plain.

This is surprising when one considers what Cézanne said :

Depth is rendered in terms of tonality, yellows & oranges in the foreground, greens behind & blues & purples the furthest on a 3rd plain. One can observe that the opposite occurs in our example here.

Moreover, for interaction of color, we are again dealing with mixed contrast.

Simultaneous contrasts, followed by successive contrasts around the edges of the tonalities.

(Echelle des clartés de Judd, Newhall, Nickerson)

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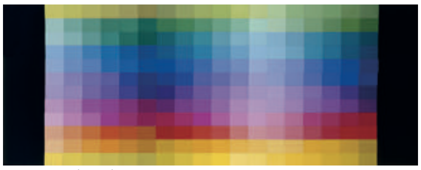
The Psi Color

The Psi Color is an interactive tool born of scientific research in the domain of color, human & fondamental sciences.

Art
Educational
Interactive
Database
A public art

The **Psi Color** is an evolving work surface composed of individual elements together presenting a vibratory chromatic field. The reds & oranges too bright would stick out & subdue the blues somewhat, so for the eye to digest & take in the overall field of spectral color, the orange & red zones have been desaturated & the blue zones saturated.



« Psi Color des 4 »

The **Psi Color** is comprised of individual elements :
Tonalities with their own specific characteristics (T. C. S.) which in turn give rise to multiple colors.
The structure varies according to the number of elements which compose it. It can be used as a base to develop color schemes, graphic design, tonal structures, clarities, saturations.

These individual elements take the form of identical squares 9cm x 9cm.
Once assembled & arranged together they form the « Psi Color »
Individually painted (24 coats) then varnished,
they are magnetised to stick to the sheet metal surface(2mx2m)
Each element or square is treated seperately as a monochrome.
The squares are free & mobile, infinitely interchangeable.

Educational
Enables the comprehension of the mobility of color, Chevreul's laws of contrast .
The Psi color is a hands-on approach to demonstrate the enduring effects of these contrasts.

Database
Through the coherence of its componants, the Psi Color can transform itself.
Its colored orchestrations can be presented in many fashions according to place & context.

disorder

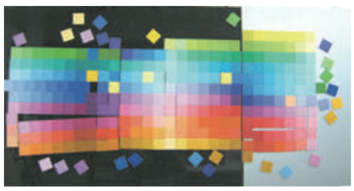


fig.14

Psi Color hot/cold

The use of the Psi Color in fig.14 (3mx2m50) shows the creation of distinct plains through the contrasting elements.

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The yellows & oranges contrast with the blue & purple tones, imposing a mouvement & dynamic. The yellows & oranges come forward, suggesting space & depth & appear larger than the other assembled tonalities that are subdued into the background.


Psi Color « le Bordelais »

Interactive
Breaking a given order, the individual mobile elements are displaced at will. Through their manipulation one can grow concious of contrasts. The Psi Color is a field of infinite play & possibilities in the realm of color.

Contact with the public
Psi Color: mobile colored surfaces from which emanate certain energies.
One will experience particular sensations according to ones nature & expectations.
One may even observe virtual colours created by the simultaneous contrast phenomenon.
With these small ' rainbow fragments' in hand, he/she controls this colour that has been materialised by the painter. Through the playful manipulation of these elements, he/she is central to the creation of multiple & infinite combinations, always surprising & unexpected, color is the link between man, material & the immaterial.
Concept : Jacqueline Carron
Manufacture: J.Carron/ Philippe Carron/ Marie-Pierre Servantie/ Catherine Mogenet/ A.Mundy

The Rose of Color

Saturation is one of the most delicate things to grasp when looking at color because it is the source of subtleties & nuance.
Let us observe how such interaction appears in this exercise in rotational contrast that is the rose of color. 16 saturated tonalities.
Through the addition of layers of colour., the tonalities become progressively desaturated & are led into rotation. This movement anchors itself on each of the 16 petals it is composed of.
Around this corolla are 4 large petals. Behind which are 4 smaller petals. Behind which in turn, are 8 even smaller petals.
At the centre is black & white, symbol of the additive & subtractive synthesis.

On the 360° circle the image pauses every 15° Observe the rose in its full saturation.
Every 45 degrees the petals layer themselves. There are a total of 16 petals.


fig.17


fig.18

In variants *fig.17* darker tonalities are reinforced by the addition of a lighter layer. Lighter tones are reinforced by the addition of a darker layer.
But one discovers different tones. Browns, greens, reds & one refers to these in terms of hue. One notices that the contrasts in succesion ultimately reinforce the differences between these desaturated hues.

fig18 With the multiplication of intermediate juxtapositions, complexity has given way to multiples & a blurred reading. If one looks closely, there are new colors. All the remaining bursts of saturation are encompassed into our global view to give us a general sensation not too far removed from the optical fusion phenomenon!

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In his book *«Art et Science de* la couleur» Georges Roque explains «Rotational contrast is but one particular variant of successive contrast. Rotational contrast is composed of an indefinite number of indentical contrasts in succession, each of which is comprised of two points. Successive rotational contrast is composed of n number of successive contrasts as long as the number of rotations per minute are the same » As a painter I have trouble following such complexities. It requires more rigorous observation & analysis. Moreover, through some of my personal findings between art & science presented to you here, I can understand that the interaction of color manifests itself in every situation. With our physiology & phsycy in a physical world, we adapt to life with this vision that transforms reality. For its natural balance, our human nature needs all the colors of the spectrum. If some are missing, then our eyes naturally create them. It is such observations that brought me to call this art based on color interaction : **Mobil Color Art.** *Jacqueline Carron*

References

1 Eugène Chevreul: Les contrastes simultanés des Couleurs dans la peinture
2 Cézanne: La couleur ça s'apprend
3 Georges Roques: Art et science de la couleur
4 Albers: Interaction des couleurs

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A study on consumer preference to different styles (patterns) and color collocations

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Abstract

This research topic focuses on how product styles, colors and design utilizing the digital inject printing technology will affect consumers' purchasing intention and behavior. Digital inject printing is a revolutionary innovation of fabric printing technology in the textile manufacturing process, through which the data can be utilized to monitor the textile printing quality; and to overcome the traditional fabric printing limitation. This research uses 12 pictures that feature different pattern designs in different styles and colors to analyze how customers will favor each one of the different combinations. Based on the 12 pictures, we will get a better understanding on the elements of the designs that are more preferred by the interviewees. The results show that interviewees in older age, higher monthly income, and greater monthly disposable income, have a distinct preference in images of classic and modern designs in bright, cool/warm color mixing. They also signify their preference of silky, soft and smooth hand-felt material. This research finding on styles and colors and pattern preferences represents provide in-depth insight for future of new product development for different client bases, through the innovative applications of digital inject printing technology. (**Keywords:** Digital Inject Printing, Texture and Surface, Color Emotion)

1. Literature review

Hermeren(1988)[1] and Wanger(1999)[2] both believed beauty experience is an interaction between subjects (consumers) and objects (products), in which subjects represent consumer value and objects represent product design such that subjects will make an evaluation and judgment of objects by their perception. Therefore, evaluation and judgment of objects should be focused on consumers' preference and reaction. Product design plays an essential role in communication between man and object and poses a great impact on consumers' behavior. In the past research on product design, Eckman and Wanger (1994)[3] believed vision and age will lead to consumers' different judgment on products. Dahl, Chattopadhyay and Gorn (1999) [4] thought imaginary visual image produces more available and ingenious design than memorized visual image does. Veryzer (1998)[5] indicated that when consumers' evaluate a product, creativity, familiarity, interactivity, rationality, consistency, uncertainty and beauty all influence evaluation of consumers' purchasing decisions. Literatures and studies indicate that what consumers knew before purchase is just that they want "beautiful objects" and "interesting objects", and they couldn't differentiate the color and shape they want in their mind. Before buying an object, consumers only have a vague picture. Therefore, a product with an external design corresponding to consumers' beauty criteria in their mind has more possibility to attract consumers to buy it (Yamazaki, 1988)[6]. Color is also a key element influencing visual beauty of products in addition to style. Color can be treated as the main factor of product image and a combination of various colors consisting of the whole or a part of product appearance. Colors convey different value signals to consumers

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which reflect the same peculiarity- showing the strong competitiveness of a product. Consumer preference is both consumers' emotional response and an expression of their degree of fondness in the mind (Kolter(2000)[7]). Norton(1987)[8] held that preference is a subjective judgment on products in consumers' mind, the criteria of which can come from the characteristics embedded in products themselves, consumers' applying situation and experience. Various outside stimuli are processed by consumers in their mind and then become feedbacks which compose a set of consumers' value judgment system exclusive to themselves. Among many elements influencing consumers' preference, product design is the most significant one.

2. Research method

This study adopts the method of questionnaire investigation and the questionnaire is designed based on the principle of balancing consumers' preference to design elements and material adopting by the technique of digital inkjet printing, and their purchasing intention. As for the design elements of style and color, this study adopts classic, original, modern and hyper-modern styles together with high saturation, middle saturation, low saturation and non-saturation to produce twelve pictures which further have the six topics as follows:

Topic	Style	Color	Representativeness	Cognition	Effect	Figures no.
1	inheritance	low saturation	realistic	Static	soft	8
2	classic, traditional	warm color	realistic	dynamic	soft	1、2、3
3	elaborate, ink, oriental	high saturation	realistic	static	strong	4、5
4	landscape, natural, conception	cold color	realistic	dynamic	soft	9、10、11
5	modern, building, civilization	dull color	realistic	static	soft	6
6	free,line, abstract	bright color	abstract	dynamic	strong	7、12


figure1


figure 2


figure 3


figure 4


figure 5

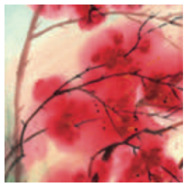
figure 6

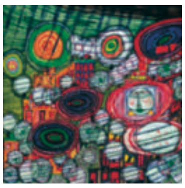
figure 7


figure 8


figure 9


figure 10


figure 11


figure 12

3. Research results

This study composes a descriptive statistics analysis of 364 interviewees' background data and formulates a cross statistics form based on seven variables of age, education level, job nature, profession, job responsibility, monthly income and monthly available expenses together with gender of interviewees.

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Table 1. Cross statistics of interviewees' gender and age

Age \ Gender	Male	Female	Total
26~30	42 (11.54%)	135 (37.09%)	177 (48.63%)
31~35	20 (5.49%)	56 (15.39%)	76 (20.88%)
36~40	19 (5.22%)	24 (6.59%)	43 (11.81%)
41~45	11 (3.02%)	23 (6.32%)	34 (9.34%)
Over 46	12 (3.30%)	22 (6.04%)	34 (9.34%)
Total	104 (28.57%)	260 (71.43%)	364 (100%)

The interviewees in this study are selected at random and their professions aren't screened, therefore, many interviewees are found to be working in areas not related to textile industry when questionnaires were collected and analyzed afterwards. However, the situation doesn't influence study results since this study aims at investigating end consumers' preference to the combination of different styles (patterns), colors and whether consumers are working in the area of textile industry is not the focus of this study.

Table 2. A cross statistics of interviewees' gender and job content

Job \ Gender	Male	Female	Total
Textile-related job	40 (10.99%)	50 (13.74%)	90 (24.73%)
Non textile-related job	64 (17.58%)	210 (57.69%)	274 (75.27%)
Total	104 (28.57%)	260 (71.43%)	364 (100%)

Table 3. Statistics of interviewees' preference to picture style

Picture No.	Like Best X1	Like Least X2	Times Subtraction $D_i = X_1 - X_2$	Square of Times Subtraction D_i^2
#1	33	18	15	225
#2	84	5	79	6,241
#3	79	12	67	4,489
#4	113	16	97	9,409
#5	100	11	89	7,921
#6	59	31	28	784
#7	128	27	101	10,201
#8	90	9	81	6,561
#9	103	12	91	8,281
#10	72	24	48	2,304
#11	46	21	25	625
#12	104	12	92	8,464
			$\sum_{i=1}^{12} D_i$ =813	$\sum_{i=1}^{12} D_i^2$ =65,505

Table 4. Statistics of interviewees' preference to picture colors

Picture No.	Like Best Times X1	Like Least Times X2	Times Subtraction $D_i = X_1 - X_2$	Square of Times Subtraction D_i^2
#1	19	45	-26	676
#2	27	16	11	121
#3	42	6	36	1,296
#4	72	27	45	2,025
#5	49	14	35	1,225
#6	29	37	-8	64
#7	62	34	28	784
#8	37	11	26	676
#9	71	10	61	3,721
#10	26	46	-20	400

#11	20	37	-17	289
#12	70	25	45	2,025
			$\sum_{i=1}^{12} D_i = 216$	$\sum_{i=1}^{12} D_i^2 = 13{,}302$

After finishing the t-test, the study developed the following conclusion:

Interviewees' preferences are quite different to styles of the twelve pictures while they are not significantly different to colors of the twelve pictures. That is to say, color composition of pictures doesn't impact interviewees' preference to pictures.

4. Conclusion and suggestion

The results show that interviewees in older age, higher monthly income, and greater monthly disposable income, have a distinct preference in images of classic and modern designs in bright, cool/warm color mixing. They also signify their preference of silky, soft and smooth hand-felt material. Interviewees who prefer to use such textile products as coats, scarves and ties are those aged over 36 with a monthly income over $40,000 NT (New Taiwan dollars) and averaged available expenses of $10,000 NT-$30,000 NT. They prefer those designs in classic and hyper-modern style with high saturation and warm color or middle saturation and blending of cold and warm color, and they can accept the price of $300 NT-$1,000 NT. Interviewees' preference to other commodities adopting the technique of digital inkjet printing is not significant. Apparently, verification can be made by this study through other analytical methods in order to find a clearer conclusion. This study investigated mainly two visual factors of "style" and "color" based on the factor of product design and didn't take other functional design factors into consideration. So the following research is suggested to investigate other relevant design factors to understand different consumers' preferences to other design factors and the impact of interaction. Furthermore, Consumers' purchasing decisions are perceived deeply impacted by their brand awareness, further research is needed to further explore this critical variable.

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Works of light in space

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Abstract

For many years I have been experimenting systems which make natural light and artificial lights combine so as to create visual installations. Some works are based on properties of our perception, such as the phenomena of colored shadows. The particularities of some materials such as transparency or reflection have also guided me in my choices. I often include in these works some form of dynamic. These creations are subjected to a sort of "staging" of the places or architectural constructions. The drama is born from social life, the passerby is most importantly an inhabitant, a citizen.

1. A few remarks

The exterior aspect of many buildings built since the Second World War is often characterized by heterogeneity in the materials which have been used, which sometimes leads to a visual chaos. This chaos often found itself in the architecture of countries which have deployed a great amount of energy in recent years to build new cities or rehabilitate old ones. To maintain visual coherence, those who are in charge of the operations often call on color designers, but the boundaries of their actions are limited.

Technological development has enabled the creation of large openings. Today windows are an important part of many buildings. Besides the effect on the external coloring of the buildings, the level of illumination inside was often changed considerably. These transformations are not taken into account carefully enough.

These problems are often discussed in terms of functionality or treated in an excessively formal manner. By involving more visual artists it will be possible to deal with these questions by taking the expressive possibilities into account. My approach of environmental questions involves these two perspectives.

2. A New approach

Whether the site be of great size or not is irrelevant, its drama is the source if the staging of an environmental work.

I have worked at very different scales. In China, for example, it was the coloring of a city; in France, among other sites, to produce a light installation in a chapel. In both cases the narrative elements drawn from cultural history, local life, the evolution of techniques and attitudes, have been the source for the ideas.

To illustrate my point, I wish to present six projects: 1 - The coloring of the city of Tanggu. Owner: planning departments of the city of Tanggu, China, 2008. 2 - "thoughtful gestures", work for the stadium in the city of Jianyin, China, 2010. 3 - "The Colour Out of Space", a work on light for the Baroque chapel of Apt in Provence, France, 2000. 4 - "The blue in flowered medow", a work on light, outdoor, in the Region Centre, France, 2002. 5 - "The colors of the spirit, work on

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light for the Parliament of Saxony-Anhalt, Magdeburg, Germany, 2003. 6 - “Signal” work on light for Carrefour, Créteil, France, 1968.

3. A color palette for a city

In 2008, the city of Tanggu, launched a study for the coloration of the city. The study was commissioned by the planning departments of the city led by Mr. Peng. It was done with the assistance of the agency Tianjin Zhong Ou Lu Investment Consultants Ltd. under the direction of Ms. LIU Yin Chen, an architect, and with the participation of Mr. Liu Wei, also an architect. The agency had requested my assistance in this operation.

From a plastic viewpoint, since the appearance of the city is fairly diverse, the objective it was to make it homogenous through an appropriate palette. Students from the Tianjin University of Science conducted surveys of existing colors (1), under the supervision of their teachers. These surveys enabled us to establish a historical palette of colors, according to geographical segments, layers of building height and their functions.

On taking the surveys made by students into account, we decided to use a scalable and open palette. It is the result of choices which were made according to functionality and pondered by more flexible factors.

The first palette is based on the function of buildings, building density, or the specificity of certain neighborhoods, like the business district Binhei. In addition to these criteria, we also considered: 1 - The geographical focus in relation to the Chinese tradition (2), but adapted (5 colors, 5 directions) 2 – Proximity to Water: River or Ocean (Yin / Yang - hot / cold), 3 - The height of buildings (softer colors for the upper parts), 4 - The type of activity of the area (recreation, industry, housing, ...), 5 - The amount and type of traffic.

In summary, this palette opens to a large number of combinations, so there are a wide variety of colorful expressions yet without affecting the overall consistency.

4. Compositions which use natural light

At a smaller scale, I worked on the properties of light. Some of these projects are based on the special nature of reflected light, essentially natural light. My artistic project is to “dematerialise” that which appears to be solid and unmoveable, for example, a stone wall, sheet steel, a partition made of concrete or various materials. Some arrangements play with the fluctuations of light according to the weather. The idea is to give the impression that the architecture has become porous and that it breathes. The characteristics of a building, its use as well as the amount of sun, determine the choice of devices.

The colours which appear in the work titled *The colours fallen from heaven* (3) are the results of reflected natural light on the substances deposited on the wooden lattes. When the lattes are lit from the inside, they are white.

To make *Reflected gesture* (4), the painted lattes when lit from the front are grey.

5. Compositions which use artificial light

One such accomplishment was to was differences in perception of spectrally opposed colors. *Azure in a flowering field* (5) is an installation in a half hectare field. Two sources of light were

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placed 2,30 metres above the ground, one was blue, the other red. The focal point on the retina is different for each one of these two colours and causes a slight vibration creating an impression of movement on the entire surface of the field.The difference of focalisation of these two colours on the retina creates a faint vibration giving the impression that the entire field is moving.

Colours of mind (6) is a work using a strange phenomenon of perception. The Saxe-Anhalt parliament in Germany had created an international competition for the realisation of a work designed to decorate the premises of Parliament situated in the city of Magdeburg. A constraint was to use "the phenomenon of coloured shadows ". Otto von Guericke who was an eminent figure in Magdeburg in the 17th century was one of the first in history to have observed this phenomenon. Here are the characteristics. If one lights up an object placed on a white surface, logic would have it that two lights, one neutral, the other coloured would create two shadows, one neutral and the other coloured. In fact, if the conditions are favourable, we see two coloured shadows appear. This characteristic enables the creation, for example, of six colours from three light sources of which only two are coloured. In certain conditions, the phenomenon also is produced with natural lighting.

Signal (7) is a large dimensional work using the properties of selective absorption of coloured surfaces. The graphics painted in two main colours on the walls of the building changes aspect according to the colours of the lighting. When the colour of the projected light is identical to that of the painted surface, the wall is light, but if the colour is complementary, the surface seems dark. Thus a more or less marked contrast will render the painted graphic elements more or less visible. Alternating the coloured lights will alternately make each graphic appear. An illusion of movement is created whenever the variations are sufficiently rapid. When the two sources simultaneously light up the painted surfaces, the wall seems to be immaterial.

6. Conclusion

Taking into account the scenographic dimension of space opens artistic creation to a wide variety of expressions.

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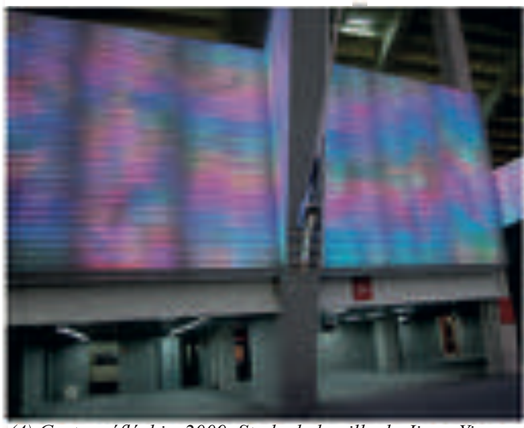
Illustrations

Tanggu, 2008, relevé des couleurs des zones de commerce à différentes hauteurs des bâtiments (Ref: NCS)

(2) Tanggu, 2008, nuanciers basiques en différentes dominantes couleur pour les zones Sud. (verre, métal, brique)

(3) Des couleurs tombées du ciel, 2000. Chapelle baroque de l'Ecole de Musique, Apt-en-Provence, France



(4) Gestes réfléchis, 2009, Stade de la ville de Jiang Yin, Chine

(5) L'azur en pré fleurit, 2002. Le Louroux, Region Centre, France

(6) Les couleurs de l'esprit, 2003. Parlement de Saxe-Anhalt, Magdeburg, Allemagne

(7) Signal, 1968, Carrefour, Créteil, France

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Lumalert: Safety signal system for cyclist

Sandra CHAVARRO
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Abstract

Inspired by the mobility problem in big cities nowadays, LUMALERT is a portable safety device that aims to improve the communication between cyclists, pedestrians and vehicle drivers on the road through a light response activated by human interaction. One of the easiest and most efficient ways for cyclist to communicate a change of direction to other drivers is through hand signals. Most countries have implemented in their traffic codes the use of hand signals as a preventive way in case that the bicycle, also considered as a vehicle, does not count with a lighting system. Although this measure works well during the day, during the night the cyclist can see himself in danger by not being able to indicate his intentions to other traffic. In order to make visible the cyclist hand signals, I have designed a device that interprets the hand movement and traduce it into a light signal that change its colour and mode of operation according to what the cyclist wants to communicate: a right turn, a left turn or stop. The role of light and colour in this project will enable the immediate perception of hand signals executed under low-light conditions in order to prevent traffic accidents.

1. Introduction

Compared to cities of northern Europe like Oslo or Amsterdam where the 30% of daily trips are made by bicycle, the city of Bogota is catalogued as being 6 times more dangerous to cyclists when it comes to traffic. According to Bogota's district department of transportation (STT), the number of cyclists killed in bike-care collisions in 2009 increased a 30% compared to 2008. In a traffic accident case there are too many factors of influence: Environment variables, type of vehicle, driver's profile, type of infrastructure and victim profile, to name a few. The fact is that during the night, when the visibility is reduced, it's when the highest number of accidents involving cyclist happen. This has been proved in several traffic studies where the 70% of accidents took place at night. What happens is that cyclists remained invisibles until the last minute when it is too late to prevent a severe injury. Riders cannot depend on external light sources to be visible, nor they can limit their personal safety equipment to reflective accessories or regular bike lights. Therefore, it's my purpose to aboard this problem from a design perspective to generate a self-preventing tool for vulnerable cyclist on the road.

2. Design referents

2.1. User and context research

Although in the last 10 years there have been built 300km of cycle-ways in Bogota, cyclists continues to travel along the main road infrastructure next to private vehicles and public transport due to the discontinuity of cycle-ways. During their daily journey, cyclists find all kind of obstacles: pedestrians crossing, taxis and buses parked in forbidden places, passengers getting in and out of their vehicles in the middle of the street. This situation forces the cyclist to change

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directions and to put himself in the left side of the road, reserved for faster moving traffic. Once he has the intention to shift sides and tries to communicate this to other traffic, he barely arrives to do it by using his own hand signalling, which during the night is practically unseen. The traffic code for Bogota establishes the use of a reflective vest, regular bike-lights and other kind of accessories for high visibility during 6pm and 6am. It also demands the permanent use of the helmet, being its lack of use sanctioned by the immobilization of the vehicle. In the end the only way of prevention used by most cyclists in Bogota is the helmet.

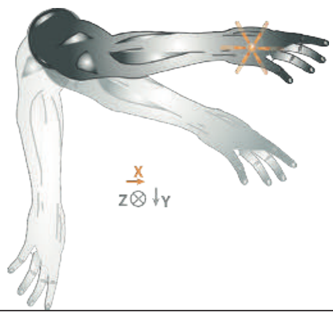
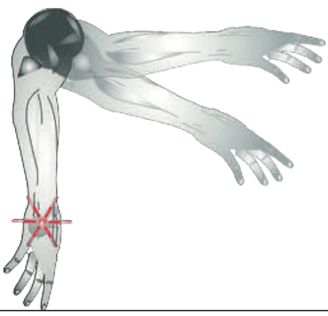
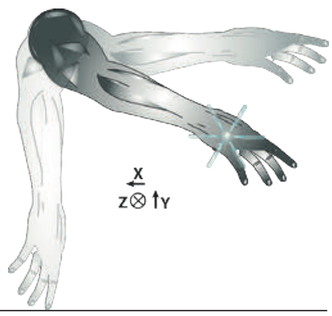
2.2. The role of light and colour in nightime safety

Lighting enables visual task performance for the human eye and determines the speed of perception. The eye's acuity it's also a key factor for visual perception since it's sensitive to object movements or static positions. Something that is commonly used when designing emergency and security lighting are titling effects that generate contrasts and increases the speed of perception of the eye, highlighting the contours of an object when the contrast between object and background is not big enough. The industry of signalling devices for traffic has gradually introduced LED light sources into their products due to its efficiency and bright illumination. The colour code standard adopted in most countries for long distance communication, such as traffic lights, has given to each colour a semiotic significance where green light allows traffic, red light denotes prohibition, yellow light prepares drivers to stop and amber light alerts the approaching to crossroads.

3. Design concept

LUMALERT is a portable safety device designed to communicate cyclist's intentions to other traffic through a color code system. The functional principle of this product relays on the different positions adopted by the arm when hand signaling. An accelerometer inserted in the system is programmed to generate 3 LED light color responses depending of the position axis (yellow=X, red=Y, white=Z).

Table 1. Position Axis.

	Yellow LED / X axis	Red LED/ Y axis	White LED/ Z axis
Position			

4. Prototyping and experimentation

The prototype made to evaluate the user's interaction with the product was composed by two main parts: 1) An electronic system that integrates three ultra-bright LEDs, one microcontroller, one lithium battery and 1 accelerometer sensor that detects movement in X, Y and Z axis; 2) A container made of waterproof textile to protect the electronic components from cyclist sweat and environmental factors.

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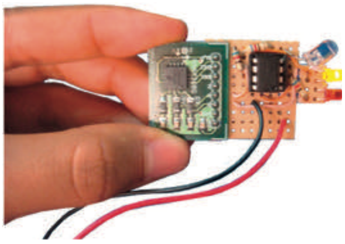
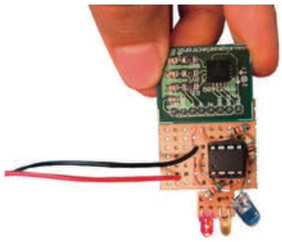
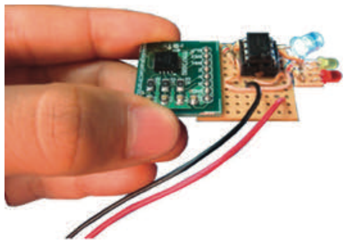
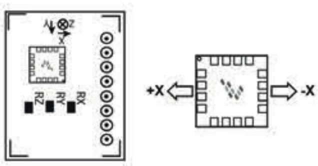
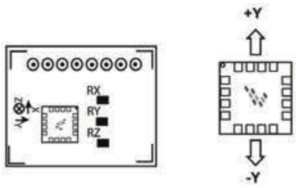
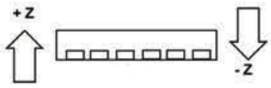
Table 2. Electronic device prototyping.

	Yellow LED / Acceleration in X axis	Red LED/ Acceleration in Y axis	White LED/ No acceleration detected in X or Y axis
Prototype			
Sensor Diagram			

Once the microcontroller was programmed and the sensor was settled to response to the three cyclist's arm positions, the circuit design was tested in Proteus and PicBasic software and printed in a board small enough to be attached to the cyclist hand. This prototype was employed to determine the best way to place the electronic device, according to the physiognomy of the hand and the ergonomic standards. The electronic device works in 3 ways: 1) When the sensor detects acceleration in X axis the yellow LED is activated and it will flash 3.0 times per second[1]; 2) When the sensor detects acceleration in Y axis the red LED is activated; 3) When there is no acceleration detected in X or Y axis, the white LED remains on.

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1 The human eye can detect a pulse of light with an interval up to 0.016 times per second.

5. Final Product

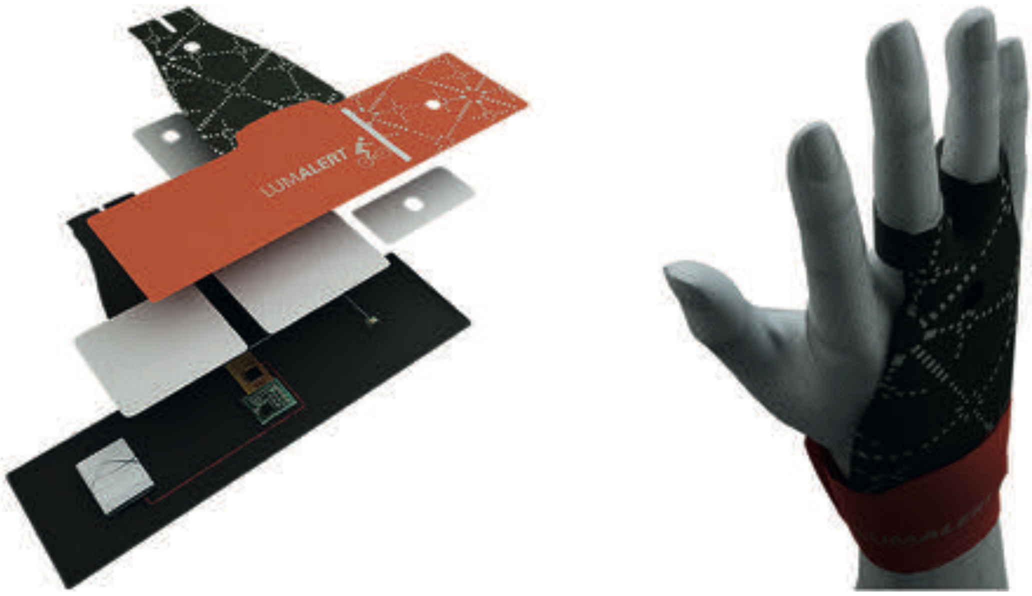

Figure 2. Final product explosion and hand fitting.

Acknowledgments

I wish to thank Professors Amparo Quijano and Christiaan Job Nieman at the University of the Andes in Bogota for guiding this project and to also thank Light Land Ltda. for their technical support.

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Capturing the gist of color information in an image

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Abstract

The amount of color information in a complex scene is extremely rich. It is of great applicational value if one can grasp the gist of color information in an image with just a few parameters. We try to summarize colors in a given image by computing the overall brightness, contrast, saturation, and four basic hues along the two opponent axes as the descriptive parameters. The variances in the values of these parameters obtained from 120 test images were compared to that of human judgments. Human judgments were collected from a free-naming and a restricted rating task. All parameters except for contrast correlated well with the rating results. Some factors, as revealed by the free-naming data, cannot be captured by the seven basic parameters, but seem to be of psychological significance. These outliers tend to be related to material properties and cannot be computed on a pixel-wise basis.

1. Introduction

An image contains thousands of pixels of assorted colors. The amount of information needed to describe the color content of an image is overwhelming. While an observer of normal color vision can easily discriminate millions of colors, the capacity of human cognition, especially the span of the short term memory, is much more limited and incapable of handling numbers of that scale. When presented with a picture, we do not trace the precise color of every pixel, we form a general impression about the color composition of an image instead. We describe the overall color composition of an image as "predominantly red and yellow", or "predominantly blue with a slight tint of green", etc.. In other words, the grain of information used for classifying our color impressions is much coarser than that for performing a color matching or color discrimination task.

Much has been learned about the "fine-grained information" used by human observers in color matching or discrimination experiments. Relatively little research attention has been directed to the issue of how we form the general color impression in a complex scene. The aim of this study is to evaluate the possible parameters that contribute to our subjective impression of colors in an image. The rationale behind the computation is drawn from the known color vision principles. The validity of these parameters was tested against human performances.

2. Methods

2.1 Test materials and parameter computation

120 photos covering a good variety of categories were selected as stimuli. The selection criterion was the richness of colors, i.e. good dynamic range in brightness, contrast, saturation, and hues. The test images were presented on a gamma corrected 21 inch CRT (EIZO Flex Scan T965) with regulated power supply. Each image subtended 22° by 16.5° visual angle at the viewing distance.

To capture the gist of the color information in an image, we computed seven parameters,

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namely, brightness, contrast, saturation, the amount of red, the amount of yellow, the amount of green, and the amount of blue, in an image (Feng and Chen, 2005; 2007). The color of each pixel of the image was converted to HSV format (Foley et al., 1990). The brightness and saturation values are the average density of V and S across the image. The contrast value was a form of Michelson contrast weighted non-linearly by the ratio of the size of bright area to that of the dark area as defined below:

$$(B_{Max} – B_{Min}) \times (1 – ABS(Area_{Bmax} – Area_{Bmin})) \text{ …....(1)}$$

where B_{Max} is the maximum value of brightness in the processed image, B_{Min} is the minimum, $Area_{Bmax}$ is the area occupied by the maximum brightness values, and $Area_{Bmin}$ is the minimum brightness area.

Each of the amount of the four basic colors was derived by centering an integration window, a rectified sinusoidal function in this case, around a given unique hue, the span of the integration window was adjusted to match to the range of hues that carries the tint of the center unique color, then all the weighted H values under this window function were integrated, as is illustrated in Figure. 1.

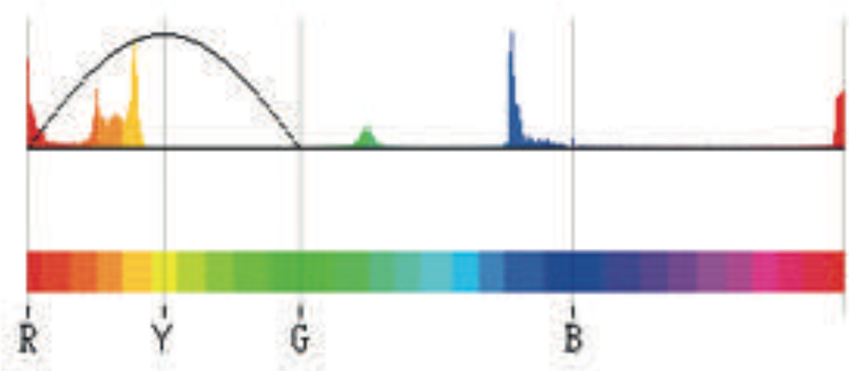

Figure 1. Opponent Y value is defined as the sum of the yellow section of HSB color histogram weighted by a halfwave-rectified sinusoidal function.

2.2 Free report and rating procedures

Ten observers were recruited to report their impressions about the general color compositions of the test photos. The flow of the experiment was controlled by Presentation® (Neurobehavioral System, Inc.). On each trial, a test image was shown on the screen until the participant finished both the free report and the rating tasks. In the free report task, the participants were encouraged to write down as many terms as possible that are appropriate for describing the general color impression of an image. They were then requested to rate the overall brightness, contrast, and the amount of the four basic colors of these images on a seven point Likert scale.

3. Results and discussion

A detailed content analysis of the free reports on the color impression reveals that the participants did describe their impressions on the dimensions of brightness, contrast, vividness, and hues. Table 1 shows the top 10 most frequently reported adjectives by the participants. Some frequently reported dimensions such as "haziness", "cleanness", and "sharpness" were not covered in the seven parameters we chose to compute. While these descriptions are more related to the spatial

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frequency contents of the test images, one must keep in mind that surface textures do contribute significantly to the color appearance of an object. Few participants decompose their hue descriptions into the exact four basic opponent colors. More often they use the dimension “cool vs. warm” instead. Some color terms such as “brownish” and “pinkish” were not of the four basic colors, either. However, to a large extent, the great majority of reported dimensions can be approximated by combinations of the seven parameters computed in this study.

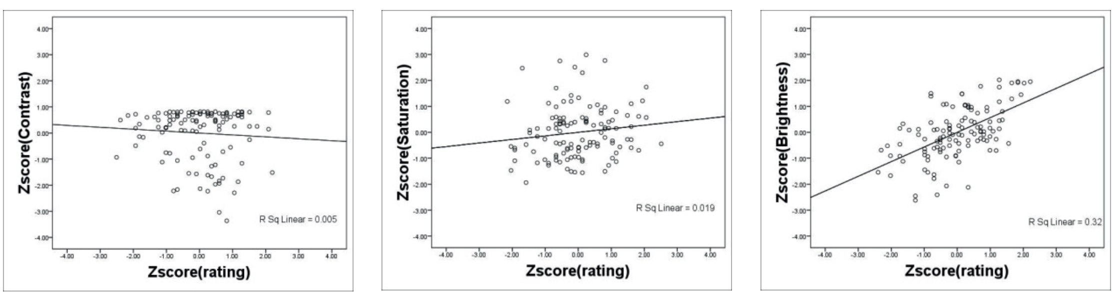
Table 1. Most frequently reported color terms in the free report task.

Frequency rank	Color terms	Relavent parameters
1	Vivid	High saturation and brightness
2	Warm	High in red and yellow
3	Bright	High brightness
4	Colorful	Even distribution of the four basic hues
5	Bluish	High in blue
6	Greenish	High in red
7	Clean	Not applicable
8	Cool	High in green and blue
9	Sharp	Not applicable
10	Brownish	High in red and/or yellow, low in brightness

The response space is open in the free report task. However, the most frequently used color terms are highly related to the seven parameters used in this study. The rating task is a constrained measure, the participants need to evaluate the color quality of an image on dimensions associated with each of the parameters.

Figure 2 shows the scatter plots plotting the values of computed parameters against human ratings. All plots show good linear relationships expect for the parameter of contrast. More efforts should be dedicated to finding a sensible and sensitive index to the subjective contrast of an image.

In summary, we proposed and tested the idea of using sparse codes to specify the subjective color impressions of complex scenes. The results show that while the seven parameters predict the rating data quite well, some dimensions revealed by the free report are not captured by the basic parameters. More higher order parameters need to be sought after to enhance the performance of the coding.



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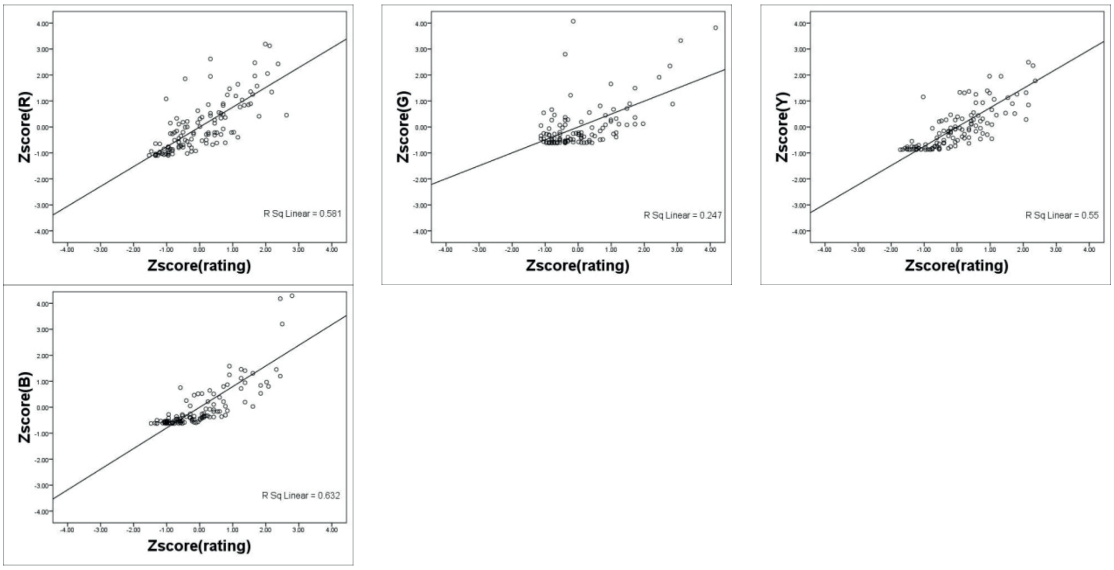

Figure 2. The relationships between parameters and their corresponding rating data.

Acknowledgments

This research was granted by National Science Council, Taiwan (NSC 97-2410-H-009-045) .

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Image-dependent colour palette applying to preferred colour correction of flat panel displays

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Abstract
Colour quality is an important issue for display manufacturers. Visual assessment and physical colour measurement methods have been widely used for evaluating colour quality of flat panel displays. In this study, image-dependent palette was constructed based on memory colours such as skin colour, green grass and blue sky. Software was provided to automatically measure colour palettes and to accurately correct colour in a short time period.

1. Introduction
Visual assessment and physical colour measurement methods have been widely used for evaluating colour quality of flat panel displays. The former is to visually compare a series of test images between a reference and a test display side by side in terms of image quality. However, this approach is time-consuming and the results cannot be directly used for quality improvement. The latter approach is to measure the predetermined colour patches shown on the test display by an instrument such as a colorimeter. Because the results from colour patches have no information on image content, it is difficult to improve image quality by adjusting individual patches on images.
To produce more pleasing colours of objects in an image is one way to improve image quality. In this study, image-dependent colour palette was designed to achieve preferred colour correction. It analyzes preferred colours of displayed images in a palette, such as skin colour, green grass and blue sky, by means of automatic colour measurement, to perform visual assessment and to correct colour at a short time period.

2. Experiment design
The experiment design in the present study consists of three tasks: to create image-dependent palette, to measure palette colours and to correct preferred colours.

2.1 To create image-dependent palette
The task is to create the image-dependent colour palette which is used to evaluate colour gamut and tonal gradation of preferred colour clusters extracted from an image. **Figure 1** illustrates the workflow for generating the preferred colour palette. A facial image is first converted into $L^*s^*n^*$ colour channels using **Equation 1**. The $L^*s^*n^*$ colour space is formed according to the principles of opponent colour (Y.C. Hsu and H.S. Chen, 2009). It is obtained by rotating the predetermined skin-colour hue angle, h_s, on a^*b^* plane, while keeping the image's lightness. The new colour values designated as (s^*, n^*), means skin colour channel and non-skin colour channel axis.

The skin-colour pixels in an image is then extracted from s^* channel with a pre-determined

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threshold. To obtain more accurate skin colours, morphological image erosion technology is used (Alasdair McAndrew, 2004). Finally, the palette colours are displayed in the border of a test image including the gamut boundary points from skin colour distributions. They are determined by segment maxima method (J. Morovic, 2008).

$$\begin{bmatrix} s^*(x,y) \\ n^*(x,y) \end{bmatrix} = \begin{bmatrix} \cos(h_s) & -\sin(h_s) \\ \sin(h_s) & \cos(h_s) \end{bmatrix} \begin{bmatrix} a^*(x,y) \\ b^*(x,y) \end{bmatrix} \quad (1)$$

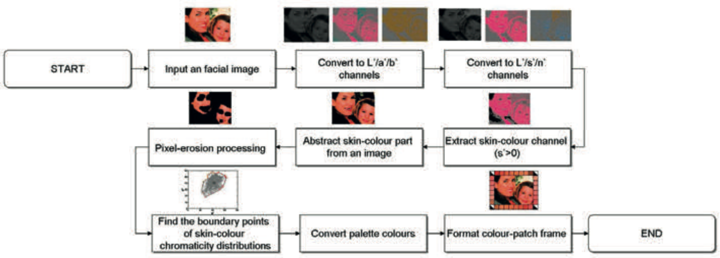

Figure. 1 The work flow of skin-colour palette formation

2.2 To measure palette colours

A Graphic User Interface (GUI) was designed to obtain the colorimetric values for each colour patch located at the border of the test image via a 2-D luminance and chromaticity analyzer (see **Figure 2**). **Figure 3** demonstrates the set-up for measuring palette colours on an LCD TV by a 2-D image analyzer (Topcon UA-1000A).

2.3 To correct preferred colours

The task is to develop an automatic colour correction method to achieve preferred colour reproduction. Firstly, a representative colour area corresponding to an object is extracted from an image using measuring colorimetric data mentioned above. Linear transformation mapping based on polynomial regression will then be applied to each preferred colour cluster on a displayed image individually to execute preferred colour correction (H.S. Chen et al., 2010).

The colour transformation based on polynomial regression between source color (***A***) and target color (***B***) is given in **Equation 2** (Howard Anton and Chris Rorres, 2000). Here, *X* represents the transformation matrix. *A* and *B* means input/output colour samples. When the least-square method is used to link colour mapping operation between ***A*** and ***B***, the least-square solution *X* must satisfy the condition of **Equation 3**. Then the least-square solution *X* could be given by **Equation 4**, where superscript *T* denotes the matrix transpose. To avoid the contours occurred in a corrected image, a matrix *M* is designed in the operation. The *M* in **Equation 5** will be calculated according to the linear interpolation of two neighbor pre-defined matrixes (*M1* and *M2*). *M1* is the matrix of exact preferred colour mapping and *M2* is the matrix of neighboring preferred colour mapping. The weighting is defined by *S1* and *S2* (see **Figure 4**). *S1* is the radius of great circle and *S2* is the radius of little circle. If input pixel is located in the intersection region of two circles, the output pixel can be calculated using *M*.

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$$AX = B \quad (2)$$

$$A\hat{X} \cong B \quad (3)$$

$$\hat{X} = \left(A^T A\right)^{-1} A^T B \quad (4)$$

$$M = \left(\frac{S_2 - S_1}{S_2}\right) \times M_1 + \left(\frac{S_1}{S_2}\right) \times M_2 \quad (5)$$

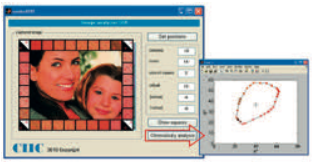


Figure. 2 GUI design

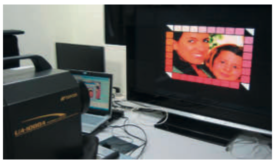


Figure. 3 The setup of measuring palette colors

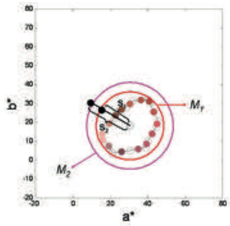


Figure. 4 The weighting of the contour smoothing

3. Results and discussions

Three kinds of preferred colour palettes produced from test images are given in **Table 1 (a)**. The first row shows test images with preferred colour palette generated from their corresponding preferred colour distributions.

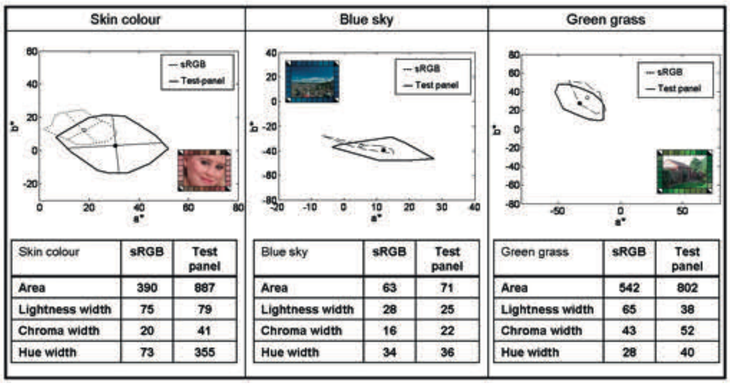
Each assigned palette colour patch surrounding an image includes a pair of the same colour triangles, which can be used to improve measuring reliability when colour measurement is performed. In addition, four pairs of black and white triangles are arranged at four corners of the screen, which can be used to evaluate the screen's luminous uniformity. The second row in **Table 1 (a)** displays the palette of preferred colours on the test image. It is easily realized that the preferred colours on the left side and their corresponding colours as shown in spots in the image on the right side. The proposed preferred colour palette design is effective for visual assessment and physical measurement.

Table 1 (b) shows the analytical results of the palette colours. The a^*-b^* gamut size of palette colours are larger than those on the reference sRGB display. The gamut area of palette colours are also analyzed in terms of CIE L^*, C_{ab}^* and h_{ab}. The chroma ranges of all 3 kinds of preferred colours on the test display are larger than those of sRGB. This implies that the test panel are more vivid than sRGB. The first column in **Table 1 (c)** displays corrected images. The last column shows the simulated results using colour difference maps. The numbers in colour bar under the bottom of the image mean the colour difference value (ΔE^*_{ab}).

Table 1. The results of image-dependes preferred colour palette

	Skin colour	Blue sky	Green grass
Original image with preferred colour palette (sRGB)			
Corresponding to image			

(a) The palette colours and the corresponding parts in the images

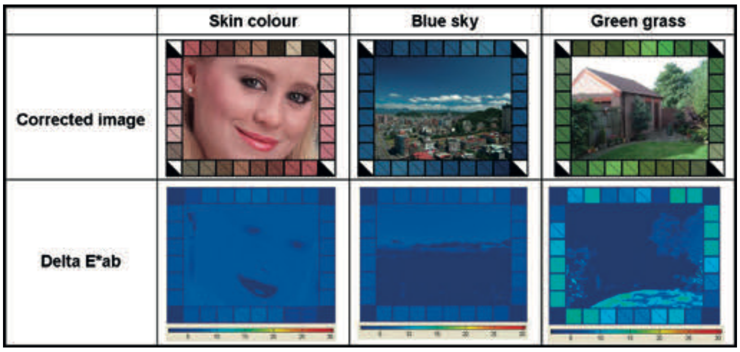


Skin colour	sRGB	Test panel
Area	390	887
Lightness width	75	79
Chroma width	20	41
Hue width	73	355

Blue sky	sRGB	Test panel
Area	63	71
Lightness width	28	25
Chroma width	16	22
Hue width	34	36

Green grass	sRGB	Test panel
Area	542	802
Lightness width	65	38
Chroma width	43	52
Hue width	28	40

(b) The analytical results of palette colours



(c) Preferred color correction

4. Conclusion

A method for producing image-dependent preferred colour palette which can be used to apply automatically to produce colour correction algorithm for individual display images was developed. It is easy for evaluating the colour distributions of preferred colour on display system for the purposes of visual assessment and colour measurement. The palette colours established can make preferred colours of an image easily adjusted and quickly measured in terms of the user's pleasing or colorimetric intentions. It is an effective tool for analyzing and improving colour quality of displays.

Acknowledgments

This research is supported by the National Science Council of the Republic of China under the grant of NSC 98-2218-E-011-003-MY2.

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A new saturation model

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Abstract

Colour appearance has been defined by CIE colorimetric system in terms of a three dimensional space with variables such as lightness, colourfulness (or chroma, chromaticness) and hue. However, scaling the dimension of colourfulness can be properly performed only by observers with a sufficient understanding of a colour appearance. Even if the observers are well-trained prior to the experiment, the visual results for scaling of colourfulness may still show poorer data consistency as compared with the other two dimensions. To address the issue, the present study was aimed to develop a new "saturation" model that better reflects novice observers' view of colour appearance. The "saturation" scale has been identified from the authors' previous unpublished study as a dimension orthogonal to both lightness and hue.

1. Methods

A psychophysical experiment for the scaling of saturation was carried out using category scaling method. A panel of 29 British observers (=14 male and 15 female, participated in the experiment). All observers had normal colour vision, with no colour science training and were naïve to colour appearance scaling.

Forty-eight 3×3 inch colour patches were used as the stimuli from which 24 randomly selected were replicated for repeatability test. All colour samples were selected from the Natural Colour System (NCS) to cover a wide range of hue, chromaticness and blackness. Observers were asked to assess each colour in terms of "saturated/unsaturated" on a six point scale. Each colour was presented in a VeriVide viewing cabinet with a grey background (X=154.05, Y=159.40, Z=188.15) illuminated by a D65 simulator, situated in a darkened room. The reference white in the viewing cabinet measured X=491.95, Y=511.35, Z=557.20. The viewing distance was about 60 cm.

2. Results

CIELUV saturation (S_{uv}) equation was first tested using the experimental data. Figure 1 shows the relation between observer response and the CIELUV saturation S_{uv}. The correlation coefficient was 0.69 between observer response and the CIELUV saturation. According to the CIE definition, the CIELUV saturation is $S_{uv} = \frac{C^*_{uv}}{L^*}$ (Colorimetry 2004). This indicates that the colour in high chroma and low lightness is highly saturated.

The present experimental data for the "saturated/unsaturated" scale were then compared with CIELAB values, including CIELAB chroma and lightness, as shown in Figure 2 (a) and (b). It was found that observer response of saturation was high in low lightness, as shown in Figure 2 (a). Figure 2 (b) shows somewhat good correlation between observer response and the CIELAB chroma, with a correlation coefficient of 0.63.

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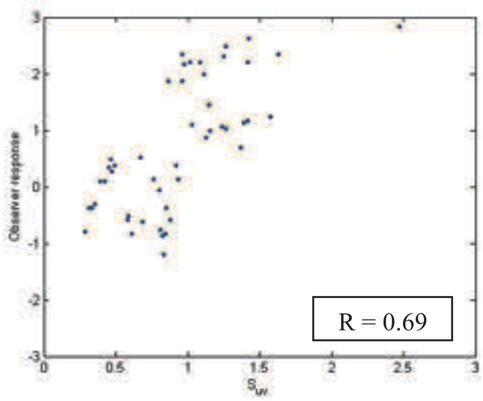
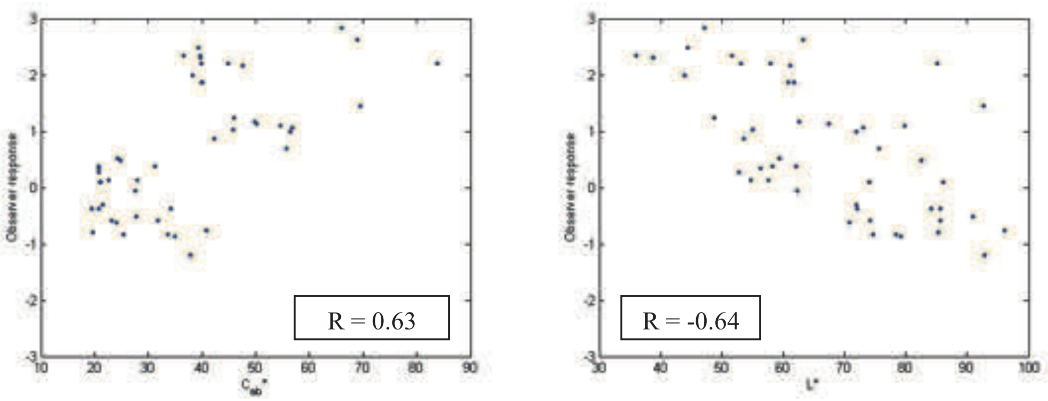


Figure 1 Relationship between "saturated/unsaturated" and CIELUV saturation (s_{uv})



(a) (b)

Figure 2 Relationship between the observer response of "saturated/unsaturated" and (a) CIELAB chroma, and (b) lightness

A new saturation model was developed using existing colour emotion modelling technique, which are normally based on a colour difference formula (Sato et al 2000, Ou 2004):

$$\Delta E = \sqrt{\{k_L(L^* - L^*_o)\}^2 + \{k_A(a^* - a^*_o)\}^2 + \{k_B(b^* - b^*_o)\}^2} + k_M \quad (1)$$

Here, L^*_o, a^*_o, b^*_o are the coordinates of the reference colour (in this case, the least saturated colour) of the CIELAB space in terms of L*, a* and b* values, k_L, k_A, k_B: Constants representing the contribution of CIELAB space in terms of L*, a* and b*, k_M: Constant for scaling.
Figure 2 (a) and (b) suggest that the least saturated colour is likely to be white, which is high in lightness and low in chroma. Thus, the reference colour in Equation (1) was set to be white (L*=100, a*=0, b*=0). All coefficients in the equation were determined using the Excel Solver tool for minimising the difference between observer response and predicted value. The equation is shown in the following:

$$\mathbf{\Delta E} = -\mathbf{2.4} + \mathbf{0.07}\sqrt{(\mathbf{L}^* - \mathbf{100})^2 + \mathbf{1.26}(\mathbf{a}^*)^2 + \mathbf{0.83}(\mathbf{b}^*)^2} \quad (2)$$

During the optimisation based on Excel Solver tool, the best solution for the reference colour was in fact not the white colour, but a yellowish white. This seems to suggest a hue effect, which was modelled by the following equation (as the best fit for the mean observer response as a function of CIELAB hue angle):

$$h_E = -0.25 + 0.2\sin(h-125.12) - 0.24\sin(2h-128.69) \quad (3)$$

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This can be illustrated by the curve shown in Figure 3.

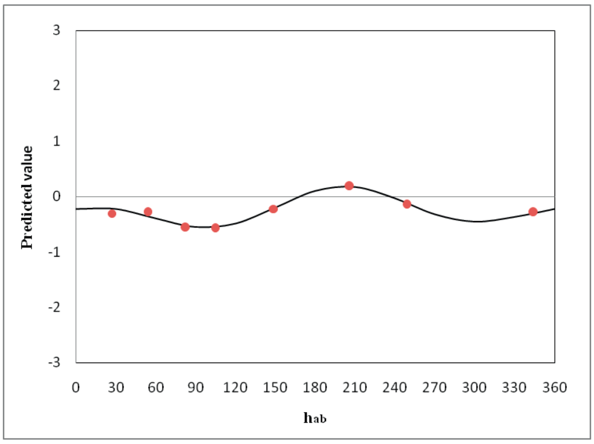

Figure 3 Relationship between the predicted value (--) and mean observer response (·) as a function of CIELAB hue angle

Equation (2) and (3) were then combined to become a saturation model considering the hue effect:

$$S_h = \Delta E + h_E$$

The relation between observer response and predicted value shows high correlation coefficient of 0.93 and a root mean square of 0.41.

This model consists of two main terms, ΔE and h_E. To see whether the two terms both have significant contribution to model prediction, each term was tested by comparing the predictive performance of the full model and that of the incomplete models in which either of the two terms were taken off. The comparison was made in terms of correlation coefficients between the observer response and the full model (S_h), between observer response and the ΔE-function, and between observer response and the hue effect (h_E) by the Z test (Lewis 1998).

In the hypothesis testing, the null hypothesis assumed two groups to be same and the alternative hypothesis assumed not to be same. In the significance level of 0.05, if the Z value is greater than 1.645, the null hypothesis is rejected, meaning that the two groups are significantly different, and thus the term (either ΔE or h_E) taken out of the model has significant contribution. As a result, the Z value was 1.20 for the incomplete model without h_E, and 7.20 for the incomplete model without ΔE. This suggests that the hue effect (h_E) has insignificant contribution, and that the ΔE function has significant contribution to the model prediction. Therefore, ΔE function alone can be regarded as the final saturation model. The coefficients in the ΔE function was optimised further by Excel Solver tool as shown in the following:

$$S = \Delta E = -2.56 + 0.06\sqrt{(L^* - 100)^2 + 1.34(a^*)^2 + 0.64(b^*)^2}$$

Figure 4 shows high correlation between observer response and the new saturation model, with a correlation coefficient of 0.90 and a root mean square (RMS) of 0.50.

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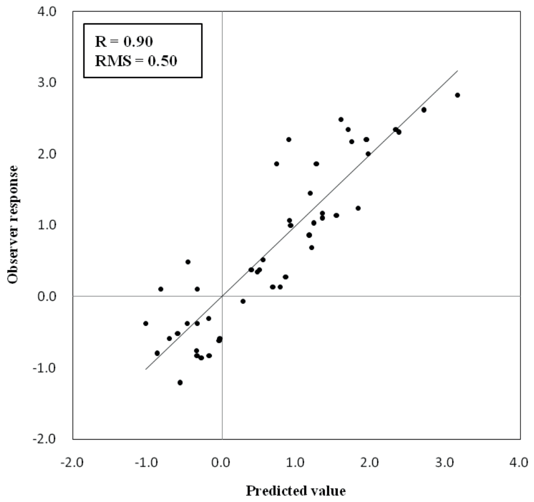

Figure 4 Correlation between observer response and the predicted saturation value

3. Conclusion

The existing CIELUV saturation was tested using the experimental data for the "saturated/ unsaturated" scale. The correlation coefficient between the observer response and CIELUV saturation was 0.69. A new saturation model was developed based on CIELAB using a modified colour difference formulae, with a high correlation coefficient of 0.90. This model may serve as an alternative to the third dimension of colour appearance that better reflects novice observers' view of colour appearance.

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Inter-agreement between typical colour measuring instruments

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Abstract
Colour measurement instrument is widely used for colour quality control for the surface colour industries such as graphic art, textile, coating. This study is aimed to evaluate the inter-instrumental agreement between some state-of-the-art colour measuring instruments including a digital camera system and four spectrophotometers. The spectrophotometers were divided into two groups (d:8^o and 45^o:0^o) according to the illumination and viewing geometry. Comparisons were made between the instruments having the same geometry. The accuracy of each instrument was investigated against the results of NPL-CERAM standard provided by the CERAM. Ten paint pairs supplied by DuPont were used to test instrumental performance using colour-difference between instruments. The results showed that the accuracy performance (using CERAM tiles as standard) was worse than the inter-instrument agreement. The measure using relative colour-difference gave the best performance. It was found that the d:8^o spectrophotometers performed better than the 45^o:0^o spectrophotometers. This is mainly due to the use of double colour analysers for the former. The camera based system was also evaluated. Although its performance was affected by the daylight lamps used with some variation, it is still effective for measuring colour-difference between a pair of samples.

1. Introduction
The performance of various state of the art colour measurement instruments was evaluated in this study including a digital camera system and four spectrophotometers. The spectrophotometers were divided into two groups according to the illumination and viewing geometry. Comparisons were made between the instruments having the same geometry. The accuracy of each instrument was also investigated against the results of NPL-CERAM standard provided by the CERAM (CERAM 2009).

The Color, Imaging, and Illumination Centre (CIIC) at the National Taiwan University of Science and Technology (NTUST) has recently been established. One laboratory is entirely devoted for appearance research. Various types of colour measuring instruments have been acquired including spectrophotometers with different geometries (d:8^o, 45^o:0^o and multi-angle). The former two geometries were most widely used and were recommended by the CIE (CIE 2004). Each surface was measured by each instrument and the spectral reflectance between 400 to 700 nm with an interval of 10 nm was reported. Table 1 provides the specification for each of the four spectrophotometers studied: denoted as A, B, C and D respectively.

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Table 1. Specification of spectrophotometers

Instrument	A	B	C	D
Geometry	d:8°	d:8°	0°:45°	45°:0°
Wavelength Resolution	10 nm	10 nm	10 nm	10 nm
Wavelength Range	360-700 nm	360-750 nm	400-700 nm	380-730 nm
Aperture size	26 mm	22 mm	7 mm	4.5 mm
Light Source	Pulsed Xenon	Pulsed Xenon	Gas-filled tungsten	Gas-filled tungsten

Since the inter-instrument agreement should be based on the same geometry, Instrument A was compared with Instrument B, and Instrument C was compared with Instrument D. The ASTM weighting table for D65 and 10° observer with a 10-nm interval from 360 to 780 nm was used for computing XYZ tristimulus values (ASTM 2008). The missing reflectance values at both ends were made equal to the values of the first and the last measured values of the spectrum, respectively. All the comparisons were reported in terms of mean CIELAB colour-difference (ΔE^*_{ab}).

An imaging system based on digital still camera was developed and applied to measure colours in terms of tristimulus values within an image (Luo et al. 2002). In comparison with spectrophotometers, the digital camera based system is not only able to convey the whole design idea via accurate images, but also to be able to measure non-uniform and curved products. The digital camera was located on the top of the illumination cabinet with a CIE illuminant D65 simulator. The illumination and viewing geometry can be considered as d:8°. A camera characterisation model is used to correlate the imaging RGB values to the output XYZ values (Hong et al. 2001).

2. Data collection

Four sets of samples were used to evaluate the inter-instrument agreement: Ceramic Colour Standard – Series II (CCSII), Ceramic Gray Scale, EBU/CAM and the paint pairs prepared by DuPont. The set of Ceramic Colour Standards – Series II (CCSII) consists of 12 tiles developed by the CERAM in collaboration with the NPL (CERAM 2009). The Ceram Gray Scale was also manufactured by CERAM and is composed of 10 glazed ceramic tiles for evaluating the photometric linearity of a spectrophotometer. The EBU/CAM surface colour samples are composed of 21 paint colours including skin, foliage colour and several primaries (EBU 1983). These colours were mounted on a piece of hard cardboard to keep them flat during measurement (EBU 1983). The 10 paint pairs with 20 samples were prepared by DuPont to illustrate the differences of colour differences calculated between CIELAB and CIEDE2000 (Wang et al. 2008). This set was used to test the variation of colour difference of a pair of samples in the unit of relative colour difference ($\Delta E^*_{relative}$) which is defined by equation (2):

$$\Delta E^*_{relative} = \sqrt{\left(\Delta L^*_1 - \Delta L^*_2\right)^2 + \left(\Delta C^*_{\mathrm{ab},1} - \Delta C^*_{\mathrm{ab},2}\right)^2 + \left(\Delta H_{\mathrm{ab},1} - \Delta H_{\mathrm{ab},2}\right)^2} \quad (1)$$

where ΔL^*_1, $\Delta C^*_{ab,1}$, $\Delta H_{ab,1}$ are the lightness, chroma, hue difference respectively using one instrument; and ΔL^*_2, $\Delta C^*_{ab,2}$, $\Delta H_{ab,2}$ are measured using the other instrument; the $\Delta E^*_{relative}$ represents the relative colour-difference. There are 63 samples in total, and the colour distribution in CIELAB a^*b^* and $L^*C^*_{ab}$ planes are plotted in Figure 1.

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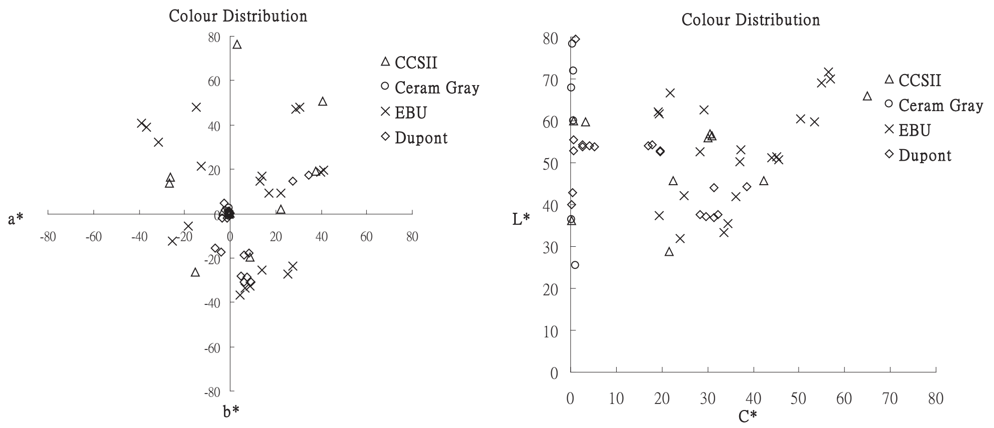

Figure 1: Colour distribution of 63 samples

3. Results and discussion

3.1 Accuracy and inter-instrument agreement

The 12 CCSII tiles were first used to examine the accuracy of each instrument. The performance in terms of mean CIELAB colour difference is summarised in Table 1. The results showed that the d:8° instruments agreed better than 45°:0° instruments. In general, maximum ΔE^*_{ab} is about twice of the mean values. The camera system performed the worst among the instruments because it applies a fluorescent daylight simulator which has quite different spectral power distribution and somewhat different colour temperature from the CIE D65 illuminant. Also, there was certain degree of variation for the lamp used in the camera system.

Table 2: Summary of the instrument accuracy results

Instrument	A	B	C	D	Camera
Mean(ΔEab*)	0.59	0.75	0.46	1.01	2.17
Max(ΔEab*)	1.11 (red)	1.95 (red)	0.90 (bright yellow)	3.09 (orange)	3.67 (deep blue)

The inter-instrument comparisons were performed between Instrument A and Instrument B and between the camera system and Instrument A because each pair had the same geometry d:8°. The results in Table 3 showed that the two d:8° spectrophotometers agreed well with each other (about 0.5 unit), followed by the two 45°:0° spectrophotometers (0.8 units) and camera vs Instrument A with a discrepancy about 1.74 units. As mentioned earlier, this is caused by the light source in the illumination box.

Table 3: Summary of the inter-instrument agreement results

	CCSII	Ceram Gray	EBU	DuPont	All
A vs B	0.50	0.33	0.56	0.44	0.47
C vs D	0.95	0.26	1.12	0.59	0.78
Camera vs A	2.20	1.48	2.01	1.31	1.74

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Table 4 shows the mean of relative colour-difference ($\Delta E^*_{relative}$ (Eq.1)) between different pairs of instruments. The result between Instrument A and Instrument B was 0.08 $\Delta E^*_{relative}$. That is to say, the colour-differences of these 10 pairs measured either by Instrument A or Instrument B provide quite similar result and all instruments had good agreement. Considering the camera system, the mean relative $\Delta E^*_{relative}$ was 0.51. Namely, although the agreement between the camera system and Instrument A was quite large (1.74 ΔE_{ab}^*), the difference was largely reduced to about 0.5 units, which is acceptable in many applications.

Table 4: The relative colour difference

Inter-instrument	**A vs B**	**C vs D**	**Camera vs A**
$\Delta E^*_{relative}$	0.08	0.11	0.51

4. Conclusion

Four sets of samples were used to test the performance of five state-of-the-art instruments for measuring surface colours: two d:8^o spectrophotometers, two 45^o:0^o spectrophotometers and a camera based system. Four groups of test-samples were accumulated to evaluate the instrumental performance including two ceramic and two paint sets. The camera based system was also tested.

The results showed that the instrumental accuracy performance (using CERAM tiles as standard) was worse than the inter-instrument agreement. The inter-instrument of relative difference, which measures the variation of colour difference pairs, was quite acceptable. Overall, the d:8^o spectrophotometers performed better than the 45^o:0^o spectrophotometers. This is mainly the use of double colour analysers for the former. The camera based system is considered to be a colorimeter. Although it used a daylight simulator with some variation, it is still effective for measuring colour difference between a pair of samples.

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A cross-cultural study of the relationships between colours and products

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Abstract

The purpose of this study is to investigate the salient impact of the colour attribute for both high- and low-involvement products. According to our literature review, little attention has been devoted to both low- and high-involvement products from a cross-cultural perspective. In order to gain a better and deeper understanding of how colour and product types may affect consumer perceptions in different cultural contexts, three apparel products that include socks, t-shirts and eveningwear (women's dresses/men's suits) were deliberately chosen for this study. A self-administered questionnaire was employed to collect demographic data, to measure and understand consumer colour perceptions in Canada (Western society) and India (Eastern society). Young female subjects were solicited and a total of 132 and 88 useable questionnaires were collected from Canada and India respectively. According to the findings of consumers' perception of colour, Canadian respondents were relatively more concerned about their personal experience and self-contentment than the Indian counterparts. In addition, it is evident that the colour cue played a relatively less significant role as compared to fit or comfort and style. Thus, it is reasonable to suggest that colour cue becomes less important when other product cues are available.

1. Introduction

Colour often plays a significant role in the acceptance or rejection of an object. According to a number of research studies, colour is considered to be the most visible and appealing design element (Bevlin 1997; Myers 1989; Rasband 2001). Colour cue provides immediate information to a viewer about the objects prior to touching, feeling and interacting. In other words, the sense of vision helps viewers or consumers to form impressions as well as to make judgments about quality and function. If a viewer experiences aesthetic pleasure from an object, he/she is more likely to further explore, investigate or even purchase it. Therefore, colour is a powerful tool for evoking sensory pleasure, influencing viewer perception and behavior, creating awareness and resonance, and conveying social and cultural meaning (Aslam 2006; De Klerk and Lubbe 2006).

2. Literature review

2.1 Colour references

However, the desirability of colour may change according to its contextual application (circumstantial appropriateness), product type (high-/low-involvement product, functional/ symbolic product), object style (classic/modern, formal/casual) and culture (Western/Eastern). Colour preferences and perceptions are often learned from prior experience through various socialization agents such as parents, peers and the media as well. It is evident that individuals develop preferred colour choices for certain objects through associative learning (e.g., the old

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adage “pink is for girls, blue is for boys”). In other words, certain colours are more acceptable and/or appropriate for specific objects (e.g., product type) (Chae *et al.* 2006; Holmes and Buchanan 1984; Mundell 1993), demographics (Picariello *et al.* 1990; Sweeney and Soutar 1993) and social situations (DeLong *et al.* 2002). In a similar vein, colour preferences and meanings may vary across cultures, and some colours may be more universally accepted than others (Hupka *et al.* 1997). For example, white is symbolic of purity and black with mourning in the West, whereas white is associated with mourning in Japan and black signifies dullness and stupidity in Indian culture (Creusen and Schoormans 2005; Kreitler and Kreitler 1972). In addition, colours may carry multiple meanings and are therefore not stagnant. The meanings of colour (associative, contextual and symbolic) have evolved and have been redefined over the course of human history.

2.2 Consumer involvement

Involvement has been defined as an individual’s perceived relevance of an object based on needs, aspirations, values and interests (Zaichkowsky 1985). High-involvement objects are often viewed and perceived as important – they carry greater significance and more meaning to the individual (Bloch and Richins 1983; Lastovicka and Gardner 1979; Traylor 1981). A large body of literature (Clarke and Belk 1978) clearly suggests that consumers tend to spend more time and effort on the processes of information search, selection and evaluation of high-involvement products than low-involvement products. They are not only more emotionally attached to these products, but they also devote a substantial amount of time, thought, feeling and behavioural response when they search or interact with them. Thus, it is important to investigate the salient effects of the colour attribute in regards to aesthetic stimulations and responses to both high- and low-involvement products.

2.3 Colour and product

According to several research studies, colour plays a less significant role in the evaluation and selection of high-involvement products over low-involvement ones (Grossman and Wisenblit 1999; Lee and Barnes 1990; Martindale and Moore 1988; Middlestadt 1990). People seldom base on a single cue such as colour to judge the quality of a high-involvement product. In other words, multiple descriptive, inferential or information cues are often used to assess a high-involvement product more often than a low-involvement product. For example, other than colour attribute, consumers may use price to infer quality, brand name to display social status, and fabric to indicate the psychological and physiological comfort when they search for a high-involvement product such as a jacket or coat.

With this perspective, it is reasonable to suggest that colour may play a more significant role on consumer perception for low-involvement products rather than high-involvement products. However, little attention has been devoted to both low- and high-involvement products from a cross-cultural perspective. In order to gain a better and deeper understanding of how colour and product types may affect consumer perceptions in different cultural contexts, three apparel products that include socks, t-shirts and eveningwear (women’s dresses/men’s suits) were deliberately chosen for this study.

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3. Research method and questions

There are several reasons why socks, t-shirts and eveningwear (dresses/suits) were chosen for the present study. First, these products are very different in terms of their level of involvement. If a bi-polar continuum scale is employed to illustrate the involvement intensity of these products, socks will be classified as low-involvement, t-shirts as 'in-between' or mid-involvement, and evening dresses/suits would be considered as high-involvement. Secondly, colour will often play an essential and influential role in product evaluation and selection. And finally, most consumers are familiar with these products regardless of their cultural background.

A self-administered questionnaire was designed and developed to collect demographic data, to measure and understand consumer colour perceptions in different cultural contexts, and most importantly, to investigate the salient impact of the colour attribute for both high- and low-involvement products. In order to gain a deeper understanding, open-ended questions were adopted for this study to allow respondents to describe and express their experiences and viewpoints in their own words.

With this context in mind, participants from Canada (Western society) and India (Eastern society) were selected and the following research questions were raised to guide and direct the present study:

- What role does the colour attribute play in the evaluation of both low- and high-involvement products?
- To what extent do colour preferences affect individual's perceptions, attitudes and behaviours towards both low- and high-involvement products?
- Are there any colour preference differences and/or similarities existing between Canadian and Chinese consumers?
- Do any distinctive/universal colours exist for our chosen low- and high-involvement products? Why?

4. Results and discussion

Young female subjects were solicited and a total of 132 and 88 useable questionnaires were collected from Canada and India respectively. The respondents ranged from 18 to 25 years old, and the mean age of Canadian sample was 19.86 and Indian sample was 19.36.

In order to understand the salient effect of colour, the cue utilization theory was used to examine the significance of colour among a wide array of product cues. According to the results, Canadian respondents rated fit as the most important evaluative cue for both t-shirts and evening dresses followed by style and colour while Indian respondents rated fit as the most important cue for both items as well followed by comfort, style and colour. In terms of socks, Canadian respondents rated comfort as the most important cue followed by price and fabric and durability, and Indian counterparts rated fit as the most important cue followed by comfort, fabric and colour. It is obvious that fit play a more significant role in the evaluation of t-shirt and evening dress/suit than many other attributes.

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Table 1. The significance of product cues

	Canada			India		
Order of Significance	T-shirt	Evening Dress/Suit	Socks	T-shirt	Evening Dress/Suit	Socks
1 (most significant cue)	Fit	Fit	Comfort	Fit	Fit	Fit
2	Style	Style	Price	Comfort	Comfort	Comfort
3	**Colour**	**Colour**	Fabric	Style	Style	Fabric
4	Comfort	Fabric	Durability	**Colour**	**Colour**	**Colour**
5	Fabric	Price	Fit	Fabric	Fabric	Durability
6	Price	Comfort	**Colour**	Durability	Brand	Style
7	Coordination	Durability	Style	Brand	Durability	Price
8	Durability	Brand	Coordination	Price	Price	Brand
9	Brand	Coordination	COO	Coordination	Coordination	Coordination
10 (least significant cue)	COO	COO	Brand	COO	COO	COO

In the present study, the colour cue played a relatively less significant role as compared to fit or comfort and style. It is reasonable to suggest that colour cue becomes less important when other product cues are available. Although colour did not consider as the most influential cue, it was rated relatively high as compare to many other cues such as durability, price, wardrobe coordination, brand name and country of origin. To summarize, colour cue didn't play a significant role on evaluating the low- and high-involvement products in both countries, and the results also didn't show any significant differences between Canadian and Indian respondents. This finding is clearly inconsistent with Lee and Barnes (1990) and Martindale and Moore (1988).

Table 2. Consumers' perceptions of colour

Consumers' Perceptions of Colour	Canada (%)		India (%)	
	Agree	Disagree	Agree	Disagree
I am uncomfortable when the colour of my clothes are different from others	24.4	75.8	30.7	68.2
I buy the same colour of clothing as what others are wearing	6.8	92.4	8	92
I would not buy certain colours if my good friends told me they did not like them	10.6	98.4	35.2	64.8
I enjoy wearing unusual colour of clothing	78	22	60.2	37.5
I use colour to differentiate from others	61.4	38.6	54.5	44.3
I wear certain colour that make me feel distinctive	83.3	16.7	65.9	33
I buy certain colour to draw the other's attention	59.1	40.9	42	56.8
I wear certain colour to appeal to the other gender is important to me	37.9	60.6	46.6	51.1
I buy colour to keep up to date on fashion	55.3	43.2	69.3	29.5
The current fashion colour trend is important to me	55.3	43.2	68.2	30.7
I buy certain colour to express who I am	87.9	10.6	68.2	29.5
I tend to buy clothing in my favourite colour	76.5	22	84.1	14.8
I don't care whether people like the colour of my clothes or not	80.3	18.2	69.3	29.5
I buy certain colour to make me feel good	92.4	6.1	84.1	13.6
I choose colour to evoke thoughts of happiness	63.6	34.8	68.2	29.5
I buy certain colour because it makes me look more mature	49.2	49.2	35.2	63.6
I buy certain colour because it makes me look more younger	17.4	81.1	38.6	60.2
I spend time to find colour that look best on me	84.1	14.4	64.8	34.1
I spend time to find colour that coordinate well with my wardrobe	70.5	27.3	48.9	48.9

According to the findings of consumers' perception of colour (as shown in Table 2), Canadian respondents were relatively more concerned about their personal experience and self-contentment than the Indian counterparts. For examples, there was a higher percentage of Canadian agreed on the following statements than Indian counterparts: "I wear certain colour that make me feel distinctive" (83.3% vs. 65.9%), "I buy certain colour to express who I am" (87.9% vs. 68.2%), "I

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don't care whether people like the colour of my clothes or not" (80.3% vs. 69.3%), "I buy certain colour to make me feel good" (92.4% vs. 84.1%), and "I spend time to find colour that look best on me" (84.1% vs. 64.8%). This finding is in line with Hofstede's (1984) study, Eastern society (India) is high in collectivism, whereas Western society (Canada) is high in individualism. Another study of denim jeans consumption conducted by Rahman *et al.* (2010; pp. 303) found that Canadian consumers were more concerned with their individual self rather than the social self. Moreover, the colour cue clearly played a more significant role on wardrobe coordination for the Canadian respondents than the Indian respondents (70.5% vs. 48.9%).

In terms of colour preference among various apparel products, the results are very similar except wedding dress and t-shirt. Overall, Indian respondents tended to choose more bright colours for clothing than the Canadian counterparts. For example, there are more Canadian respondents chose black and white for the tops (e.g., t-shirt and tank top), whereas Indian respondents preferred blue, pink and red for t-shirt, tank top and even hoodie top other than the black. Due to the socio-cultural differences, it is obvious that some colours are more appropriate for certain occasions/cultural contexts such as the colour of wedding dress.

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Colour and light in urban planning: Policy, palettes and the sense of place, mood and movement

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Abstract

Since the 1970s the impact of *light-texture-colour* on colour collections and colour concepts for urban planning have undergone important changes. Historically three major stages can be distinguished: 1) During the 1970s and 1980s research on *light-texture-colour* focused on qualities of light – both of daylight and related to seasonal changes – and their interaction with space-defining elements of colour appearances, e.g., aspects of mineral formations, vegetation, water and sky; 2) during the 1990s newly introduced metallic opalescent materials generated a fluctuating appearance of architectural façades whereby light interacts with coloured surfaces; and 3) to date new materials with optical properties and so-called 'effect pigments', e.g., pearl and iridescent qualities, which not only increase effects of light but also create a broad palette of different colours. The full effects can only be perceived by the viewer in motion. In this sense movement has become an essential element structuring the chromatic perception of the built environment.

1. Colour concepts for urban planning

Atelier Cler defines and develops chromatic studies as a special method and procedure in understanding and approaching *light-texture-colour* in urban space, industrial and rural environments. This paper deals with some significant findings and tools associated with creating sense of place, mood and movement including aspects of light, texture and colour related to colour concepts for urban planning.

2. Qualities of light

This paper aims at discussing the role of natural light in conceiving colour palettes for urban planning and how light and the textures of materials have an impact on the perception of colour appearance in space and the built environment. It is important to note that the notion of *light-texture-colour* has considerably evolved over time. Since the 1970s Atelier Cler has been realising colour concepts for valleys, villages, industrial parks, newly developing areas, etc. that are in harmony with the natural surrounds. Atelier Cler's approach aims at emphasising a dynamic equilibrium of the features of existing and newly introduced colours.

Chromatic studies include exploring colours of the mineral and vegetal features of the site and its surrounds, as well as others arising through the properties of water, sky and natural light, e.g., how colour appearance changes under the varying conditions of daytime, nighttime and different seasons. Also considered is how different scales of such elements influence the perception of colour appearance, as well as considering how colour is affected by changes in distance or proximity. (Cler, 2007, 2008) Other important factors are geographical: climate, geology, vegetation and human-made elements of a specific topographical area affect the appearance and perception of colours. Cultural articulation and differences are also addressed, a complex field since any local colour culture is usually embedded in a wider cultural context. In any case the

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meaning and significance of colour can be described as preserving the collective memory of a site. What develops over time is a chromatic identity that lends the urban space a distinctive meaning and mood. However, this overall chromatic appearance is not stable and permanent, but fragile and subject to the emergence of new colour developments through the appropriation, use and adaptation of colours from within and outside of the specific context. (Cler, 2005a)

During the 1970s and 1980s research on *light-texture-colour* focused on qualities of light – both of daylight and related to seasonal changes – and their interrelationship with space-defining elements of colour appearances, e.g., aspects of mineral formations, vegetation, water and sky. As demonstrated in the following case study of Estaque in the French Mediterranean region, chromatic studies explore, collect together and synthesize space-defining elements of colour appearance. (Fig. 1)

distant *closer* *close*

View from the site to the sea | *View from the sea to the coast* | *View from the sea to the port* | *View from the sea to the site* | *View from the site to the sea* | *Colour ranges of façades* | *Colour ranges of superstructures*

Fig. 1 Chromatic Study for the Autonomous Port of Marseille, Dry Dock 10, Estaque, Marseille, France, 1981-1982. ©Atelier Cler, Paris

Based on analyses and syntheses of such colour features, the colour ranges or palettes of chromatic studies result in an overall *Colour Chart* that includes a variety of interrelated tools: *Colour Card, Palette*, *Chromatic Orientation Scheme* and *Chromatic Reference Plan*. These tools are operationally essential for both short-term and long-term applications. (Cler, 2005b) They summarize the diversity of natural, traditional and new materials being employed. They also reflect colour features resulting from human activities – industrial, cultural, historical, social and political – as well as the latest desires of inhabitants even the potential expectations of future users. (Cler, 2008) Basically the Atelier Cler's approach emphasises a harmonious balance that combines indigenous and 'foreign' colours. The appropriate application of the Atelier Cler's method or procedure, however, is not to provide colour recipes, but to ensure awareness and the possibility to choose colour harmonies. The pre-organised colour chart provides a palette whereby individuals have the final decision and responsibility collectively.

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3. Metallic materials with light effects

During the 1990s newly introduced metallic opalescent materials generated a fluctuating appearance of architectural façades whereby light articulates coloured surfaces. In 2000 the Atelier Cler completed the colour collection *Aludesign métalprofil* (Fig. 3) for Haironville (today Arcelor) in Belgium. The aluminium cladding – much lighter than steel – should ideally call to mind and underscore qualities of lightness and the effects of light. To this end the palette has been conceived on the basis of luminous colours that differ from those used for steel cladding.

Fig. 2 Natural light on a stormy day at sea. France Cler. ©Atelier Cler, Paris

Fig. 3 Metallic surface of building materials for façades enhance the changing effects of light, 2000.

Sensitive to changing natural light (Fig. 2), building façades vary their appearance in accordance with light, seasonal and weather conditions.

4. Colour variegation perceptible through movement

To date new materials with optical properties, so-called 'effect pigments', e.g., pearl-lustre and iridescent qualities not only increase the effects of the light of sparkle or silky sheen but also produce a broad palette of different colours. The full effects of iridescent colours can only be perceived by the viewer in motion. In this sense movement has become an essential element structuring the chromatic perception of the built environment.

The colour modulations of these specific materials acquire a visual depth and chromatic complexity only with the movement of the viewer. This not only affects the intensity of the colour – lightness or darkness – but also the hue. A same colour sample, e.g., *Apple perla*, has the ability to change its appearance variegating from a light apple green to a dark olive colour with at least three intermediate nuances. (Fig. 4) Other samples change from an intense violet to a light bluish grey or from a sparkling orange brown to a yellowish white. The sample *Mica perla* demonstrates three additional modulations in appearance. Amplified or reduced, enlightened or intensified, exalted or submerged in a harmonic chromatic atmosphere, ephemeral colours become tangible fostering rich re-definitions of colour and light interactions and also defining a new colour vocabulary, a new trend and approach to achieve new kinds of urban atmospheres and spatial interpretations.

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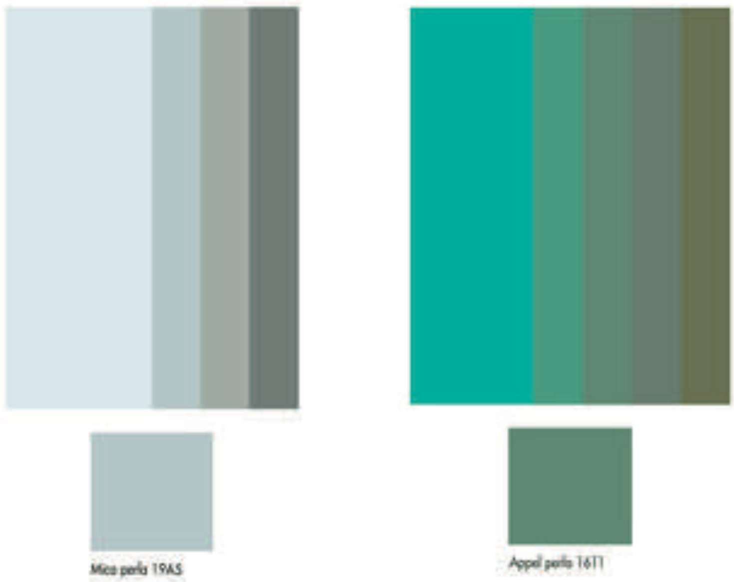

Fig. 4 Visualisation of the ephemeral aspect of the changing chromatic appearance of building materials through movement. ©Atelier Cler, Paris

These kinds of materials have been proposed by the Atelier Cler for an industrial park project in Civrieux being realised in 2010-2011.

5. Preliminary conclusive remarks

Technological development will continue to have an impact on building materials and also on colour appearance. In the future will architectural façades become skin-like claddings sensible to light and temperature with related variegating colours? Will materials be 'interactive', flexible, poly-sensorial and responsive to the human eye, touch and sound? Will everybody be able to produce their own individual and exclusive atmosphere, harmonious to individual needs and desires?

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A promenade through Buenos Aires – colour and art changing the imagined city

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Abstract

In the popular imaginary, Buenos Aires (with the exception of *La Boca*) is a city of grey. But recent intervention projects are infusing its neighbourhoods with new colour. A walk through these neighbourhoods – informed both by a thorough study of the relevant literature and by interviews conducted with project actors, local residents and professionals (e.g., architects, designers, artists) – yields insights into the interventions' intentions, processes and results. The interventions' use of colour and art appears to be accepted as a legitimate means of building the public space, as an embodiment of a public and participatory process, and as an expression of the local citizenry. Professionals and residents, alike, place high importance on the public and participatory nature of the intervention process. As for outcomes, the studied interventions seem to succeed more in producing exceptions to the city image than they do in actually changing it. Professionals are generally more skeptical than actors on this point, but perhaps through interventions such as the ones described herein, the citizens of future Buenos Aires will re-imagine their self-identities as the dwellers not of a city grey, but of one more vibrant of colour.

1. Introduction

Though Buenos Aires is always changing, with new ambiances emerging freely in the absence of regulation, Guerra (2005), the imaginary of a grey city persists, Lacarrieu and Albuquerque (2007). Against this monotone image, *Caminito* (*La Boca's* most famous street), with its postcard-bright, saturated colours, provides an obvious exception. But even *La Boca*, as we now know it, owes much to an intervention: Quinquela Martin (a famous Argentine painter local to the neighbourhood), in expanding upon local colour tradition, extended his work from canvas to streets, brought his palette to façades, and proposed the use of consistent criteria regarding the use of colour on *Caminito* and the surrounding area, Rabuini and Mattiello (2008).

The touchstone of *La Boca* shows itself in present day interventions.[1] Like their predecessor, the new interventions bring mostly saturated colours (but now to parts of the city normally considered drab), introduce their changes onto a pre-existing architecture, and arise through non-governmental organization. A look at these interventions raises the following questions: Are the interventions perceived as being legitimate? How well do they accomplish their goals? What do they bring to the city? Between the different approaches that they take, what are the relative pros and cons? Do project actors and experts share the same understanding of those interventions? Finally, do they really change the appreciation of colour and light in the city?

1 Recent neighbourhood colour change trends effected by non-organized private citizens, such as in Palermo Viejo and non-touristic La Boca, lie beyond the scope of this paper. Both neighbourhoods were studied in 2009 by field and impression survey by this author (in the case of La Boca, in collaboration with E. Rabuini).

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2. Methodology and case studies

Answers to the above questions were sought through the following methods: (1) field observation; (2) conduct of interviews with project actors (artists, association members and participating residents), professionals/experts (e.g., architects, artists, designers) and neighbourhood residents; and (3) a thorough study of the existing literature on the subject. The case studies are presented below, structured as they could actually be experienced during a promenade through the city.

We start early in the morning, passing by *La Vereda*, a Civil Association working mainly with local children from homeless families near *Plaza Once*. Their project *Pintar el Once* (2006) brought together children, teachers and artists to repaint the neighbourhood, resulting in a work of energetic primary and secondary colours extending over three façades (two commercial buildings and the association's facade) on the same city block. A volunteer artist, inspired by the work of Torres García, incorporated the children's drawings for the façades into the final composition. By extending Hundertwasser's *Window' right*, Restany (2002), the intervention enabled the children to claim their neighbourhood as a space self-constructed.

By the time the sun is overhead, we reach the commercial and touristic area of *Abasto* where amidst the bustle we find two other projects. The first is *El Abasto y el Fileteado Porteño* (2004), through which competing *fileteadores*[2] painted – in warm background colours contrasted with bright decorative drawings – six one-story façades (some from the early 20th century in simil-piedra[3]) around the Carlos Gardel Museum. This project, created by neighbours in association with the Museum, aimed to cultivate a particular image (and to rebirth a local cultural identity) connecting *tango* with *fileteado*. The second is *Partituras Musicales* (2002), an artistic intervention by Marino Santa-Maria, comprising eight versions of a large-scale, Warhol-like pop portrait of the iconic *tango* singer Carlos Gardel. The eight versions, which vary in colour, not form, adorn the gables and gates of various area buildings. Owners granted use of their buildings, and, upon request of the local residents, the artist made some adjustments to his original idea before finalizing the project.

Later in the day, we see the play of light on the mosaics of *Calle Lanin* (2001-11), another artwork by Marino Santa-Maria. Here, more than forty family houses (mainly non-descript one-story buildings) see their previously anonymous, grey façades transformed into a light and colourful open-air museum. Here, again, neighbours allowed use of their façades, chose their preferences from among Marino's abstract paintings and negotiated adjustments to colours, allowing the artist's work to express everyone's right to Art.

To close out our tour, again in *Barracas* we see how the design participation project *Barracas Pinta Bien* (2010) has transformed a calm residential area for the better. Civil Association Más Color, which works in all of Argentina, organized workshops to train project participant (local residents) about public space responsibilities, colour and how to paint, and then the residents painted the façades of their own buildings, in accordance with a pale, soothing palette proposed by the association. The idea that everyone should have a beautiful place to live, enacted, means that the once-dirty, common, one-story houses (which had gone unpainted for over twenty years) are now covered by soft colour.

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2 Fileteador is an artisan/painter of fileteado, a popular pictorial art form born in early 1920s Buenos Aires. Its decorative character results in part from the use of straight and curved lines mixed with flowers, scrolls, ribbons with Argentine colours, dragons and natural elements (five-petaled flowers, acanthus leaves).

3 Traditional technique for wall textured finish/surface, imitating the appearance of stone.

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3. Results

Interviews of project actors and local residents were conducted in 2010, during project meetings and social gatherings and at pre-arranged meetings. Interviews of professionals remain ongoing; the results expressed here form a subset of the final data to be studied for a doctoral dissertation.

3.1 Interviews of project actors and local residents

The project actors and the local residents see the above interventions as opportunities to improve the public space. In all places visited, the majority of the answers reveal satisfaction with the strong before-and-after improvements: places initially ugly and forgotten became brighter, cleaner, more beautiful, happier. Paint, art, colour upgraded the neighbourhoods' status, from faceless anonymity to local points of reference. This holds especially true in the case of *Calle Lanin*, now "a place in the map" and something of a tourist attraction, even though fame or commercial success was never a primary goal of any of the projects' (except Abasto's) participants. For the most part, residents enjoy their improved image, but want to avoid commercial "invasions" that now occur in *La Boca*.

The improvements went beyond aesthetics, as the interventions presented opportunities to meet neighbours and form new social ties. In many cases, completion of painting did not end the project – local and participant residents still meet for occasional street parties (*La Vereda*, *Calle Lanin*), or even daily (*Calle Lanin*, and *Barracas Pinta Bien*). Comparing processes, the feelings of appropriation, belonging and membership seem strongest in projects that required the most public participation (*Barracas Pinta Bien* and *Pintar el Once*).

3.2 Interviews of professionals

The professionals' answers generally corroborate the local residents' and project actors' opinions about changes and benefits brought by the interventions, albeit with more restrained confidence and cautious optimism. Three main ideas emerge from the interviews so far: (1) public participation in such projects is highly important, as it provides legitimacy and helps express the citizens' will; (2) the interventions are too few to change the general public's image of Buenos Aires but, even so, (3) they generate singularities within that city image. The interventions, in all their complexity, can be seen as popular expressions, ways of inhabiting space, generators of meaning in meaningless spaces, and ways to give new life to architecture.

Thus far, one professional has taken an overall negative position on the intervention projects, stressing their lack of transcendence and opining that such interventions are ill-suited to the more classical Italian influenced architecture from the early 20th century.

4. Conclusions

The colour interventions result in painted houses and murals and, yet, they accomplish so much more. They evoke local memories, produce meanings and landmarks, change local perceptions and bring new, identity-making images to popular neighbourhoods. Residents involved in participatory interventions – collaborating with artists, designers and project leaders – lay claim to their rights and needs, such as the right to have a home (*Pintar el Once*), the right to beauty (*Barracas Pinta Bien* and *Calle Lanin*), the democracy of art (*Calle Lanin*) Lacarrieu (2008). Beyond that, their participation lends legitimacy to the interventions to which they contribute; all interviewed saw resident involvement as an essential value, as did Holm (2006) with reference to

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design and architecture. Moreover, the coming together to paint intuitively produces a happening; it promotes the encounter, a desirable value among contemporary artists Bourriau (2006) and Traquino (2010). It is a durable social effect, even after completion of painting, as places for parties and events are created, and contacts between neighbours, established.

True, most of the colour interventions remain neighbourhood- and not city-scale. Still, they are substantial. They convert "grey" areas into *loci* of identity, belonging and artistic expression, and sow seeds of future changes, not only in the real image of the city, but also in the imagined one – a contribution to the intangible heritage, Canclini (2007). Reminiscing project actors and residents describe their neighbourhoods as, vibrant beautiful, special, explaining that "to paint is not something for the eyes but for the soul." From the sounds of it, their perception of colour and light has already begun to change.

Acknowledgments

I would like to express my gratitude to my advisers, Professors Maria João Durão and José Luis Caivano. I would like also to thank the Fundação Ciência e Tecnologia – Portugal, for supporting my PhD grant, enabling me to carry out the research presented herein.

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Some inputs for colour design education: An empirical study correlating variables gender, area of interest and colour blindness

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Abstract

The purpose of this paper is to present an empirical study done so as to test how some known colour design studies relate to Model Sens-Org-Int, in order to detect from these studies which ones may be generalized to human beings with normal eyesight. Sens-Org-Int Model was devised by the present author, published and awarded in IVLA's (International Visual Literacy Association) 2007 *Book of Selected Readings.* The model differentiates the three processes that occur in human perception: sensory impressions (Sens), organizing processes (Org) and interpretive processes (Int) of visual perception. Analysis of these questionnaires comparing the subjects' categories offers inputs for the main conclusion, that the processes tested and their visual communicational possibilities are independent of gender or professional area. Thus, the colour design studies tested may be considered as Sens and Org processes of perception, and thus, tend to be generalized to all human beings with normal eyesight. Therefore, colour educators may consider these inputs when attempting to teach objective colour design principles.

1. Introduction

Theories about perception tend to emphasize the role of either sensory data or knowledge in the process. Some theorists have adopted a *data-driven* or *bottom-up* stance, or synthetic approach, according to which perception is direct: visual data are immediately structured in the optical array prior to any selectivity on the part of the perceiver proposed by Hering (1850), Gestalt theories, and Gibson (1979). Others adopt a constructivist, top-down or analytical approach emphasizing the importance of prior knowledge and hypotheses, argued by Berkeley (1709), Helmholtz (1925), and Bruce, Green & Georgeson (2003).

Sens-Org-Int Model was devised in an attempt to differentiate which principles or laws of design and art are common to all human beings with normal eyesight from the concepts that are not common to everyone. Those that are not common therefore are learned or otherwise acquired. Therefore, this model unites the synthetic and the analytical approaches to psychology as well as physiological inputs from the visual neurosciences (Chalupa & Werner 2004; Kaiser & Boynton, 1996; Knoblauch & Shevell 2004; Pinna & Spillman 2001; Shimojo, Kamitani & Nishida 2001; Spillman & Levine 1971; Zeki 2000) on how the brain works, and relates them to classical art and design principles.

The starting point of this research was a bibliographical review of colour design studies, so as to map them in terms of Sens, Org, and Int variables. Since the main objective here was to detect colour studies that tend to be valid for all human beings with normal eyesight, emphasis was given to Sens and Org variables. Sources for this bibliographical review included Albers (1974), Chevreul (1854/1987). Itten (1979), Beck (1972), Birren (1978, 1986), Evans (1948), Gerritsen (1976), Graves (1951), Hickethier (1973), Kuppers (1975), Pedrosa (1995); Sausmarez (1974) and Wong (1997).

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The empirical study was conducted using a questionnaire with eighteen questions elaborated from the bibliographical study. This questionnaire was applied to 300 subjects, classified into different categories: age, gender, and professional area. Altogether, the subjects tested were undergraduate students in Fine Arts, Design, Business Management, International Relations, Communications, Product, Mechanical and Electronic Engineering. From the 300 subjects tested, 57% were male and 42% female.

Among all the courses that the students attended, three clusters were formed, grouping subjects in terms of area of interest. Thus, using Gardner's (1993) theory of multiple intelligences, the groups were: Visuals, Humanities, and Quantitative. Visuals consisted of the courses, Fine Arts and Design, with a total of 82 subjects. Humanities consisted of Communications, Business Management and International Relations, having altogether 95 subjects. Quantitative consisted of Product, Mechanical, and Electronic Engineering with 97 subjects.

2. Pilot test

Before actually submitting the questionnaire to the subjects, a pilot test was conducted in order to validate the questionnaire. During this test, some observations were found, which were critical for the final result. It was noted, during this phase, that the greatest obstacle was indeed the choice of terms used in the questions. Some terms such as, balance and tonal value, which for the author seemed common sense, proved not to be. Thus, the terms were revised many times until the questions were indeed clear for everyone.

Another point noted, was the interference of previous knowledge. This appeared, for example, in questions where there was a light background and the subjects had to answer which element would advance in this background. It occurred that some people would say something like, "I remember when I was in primary school, I learned that always, the lighter color comes forward." When this happened, not only would the subject not answer based on his objective perception, but also, was basing in his previous knowledge, or putting it in better terms, previous lack of knowledge!

Also, crucial for the efficiency of the questionnaire, was the elimination of signic value. In other words, all questions would have to work solely in terms of objective perception and meanings like the tonal values of a landscape or of a cube had to be eliminated.

Last but not least, the questionnaire had to undergo a series of color printing tests. Because the questionnaire is more concerned with color contrasts, a slight difference in tonal value, for example, would cause an opposite answer by the subjects.

3. Analysis and results

The rate of responses was very high, since the students enjoyed answering the questionnaire. Now, were the answers actually good for the research? Since the goal of the questionnaire was to see if each color concept studied was indeed an Org variable, a high rate of a "correct" response in each question was desired. And in fact they were. Six questions had a rate ranging from 97% to 100%; four questions, ranging from 83% to 96%, five questions ranging from 72% to 82% and three questions, ranging from 61% to 71%. These rates were high indeed, but not enough for me to take conclusions. A statistical test was sought to confirm this. The formula for Observed Value (Vobs) was used. If the value of Vobs was greater than 1.64, that would mean that there is a tendency. As noted, all questions demonstrated a tendency, which could lead to the conclusion

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that indeed, all color concepts used in the questionnaire, tended to be Org variables. All of the statistical analyses were tabulated with software Minitab.

Some more interesting conclusions were also evident from the analysis. The Visuals cluster showed a rate of responses a little bit above average. Since all questions were solely Org oriented, this tendency would not be due to the fact that they have learned a color concept before. Indeed, I applied the questionnaire to some of my students before they learned the color concepts that I teach. A hypothesis for this, would be that students in Design and Arts, indeed have more sensitivity to visual elements.

Another interesting observation, was that women rated slightly above average, while men slightly below. The same hypothesis here applies: women tend to be more sensitive to visual stimuli.

Considering colour blindness variable, it was noted that several people are color-blind, but are not aware that they are. This could be seen when confronting one of the presentation questions: "Are you color-blind?", to which they would answer "yes" or "no", with another question, number 1, which is the Ishihara Test for color-blindness. Whilst 98.5% of subjects answered "no" (that they weren't color-blind) only 91.1% in fact answered the test correctly, meaning they weren't color-blind. The statistics observed validate numbers found in the literature: According to the *Report on Defective Colour Vision* compiled by the Colour Group of the Physical Society (1946) statistics show that 8% of the male population suffer from marked color-blindness while the proportion of color-blind women is much smaller. Of the total population, between 4% and 5% possess more or less seriously abnormal color vision (Clulow, 1972; Kaiser & Boynton, 1996; Fix, 2007).

Crossing sex variable with color blindness variable, it was noted there are more women than men who aren't aware that they are color-blind. This could be seen when 100% of women answered NO, they weren't color-blind, but in fact only 89.9% of women answered Ishihara's Test correctly.

And very curiously, students in Design and Arts, are the ones least aware of their color-blindness. Since 100% answered "no", they weren't color blind, while only 83.9% of them answered Ishihara's Test correctly.

Analysis of these questionnaires comparing the subjects' categories offers inputs for the main conclusion, that the processes tested and their visual communicational possibilities are independent of gender or professional area. Thus, the colour design studies tested may be considered as Sens and Org processes of perception, and thus, tend to be generalized to all human beings with normal eyesight. Further research may validate this conclusion, extending variables cross culturally, and also considering variables such as social class, among others. Therefore, colour educators may consider these inputs when attempting to teach objective colour design principles.

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A holistic view of colour – a bridge between physics and metaphysics

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Abstract

My work is centred around the alchemy of colours: as a paint manufacturer, paint is the base material I produce, the 'prima materia'; as a painter, colour is my artistic medium. I am in daily dialogue with the material properties of colour, as well as their aesthetic aspects but even more their symbolic dimension and relationship which art is ultimately concerned with. My artistic experiences accompanied by intercultural studies on the meaning and function of colours are the basis of my work. Thus I do not represent a specific academic position, but rather, I am inspired by a unified vision. In my presentation I'd like to give an insight into the metaphysical level of colour along the Sirius colour system. And to assert that matter is imbued with light as well as that light reveals itself through matter.

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As physics, metaphysics is concerned with the laws of nature and the cosmos. But metaphysics has split off from the scientific approach, which separates, categorizes and emphasizes matter over mind (and spirit). Its concern, however, about the nature of light has moved modern physics very close to metaphysics which is, in many cases, actually even one step ahead. What metaphysics beholds, is the power of belief in the wonder of creation, without the need either to prove it nor to subject it to a mechanistic caesura. It is of central importance for our present time to connect the material sciences and metaphysics, to facilitate a new holistic view, and the so desperately needed new consciousness. Embracing the original law of creation: that everything around us is part of one great and interconnected whole.

> *"Science without religion is lame. Religion without science is blind." (Einstein 1941)*

What Eastern civilizations have known for thousands of years is today confirmed by our Western science: that everything is energy! We are surrounded by a bioelectrical field through which an information exchange takes place: with the speed of light, information is absorbed and released. Constantly we are in communication and interaction with everything. Quantum physics has revealed us the heart of matter, which is energy and information. And those subatomic particles have only meaning in their relation to everything else, but not isolated in themselves.

> *"The universe is no longer seen as a machine made up of a multitude of objects but rather as a harmonic 'organic' whole, whose parts are only defined through their interactions." (Capra 1986)*

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Dimensions of colour

Light is the mother of colours. From the unity of light the colours unfold in their diversity. This so-called visible spectrum is a small one compared to the entire spectrum of rays[1]. Each colour frequency has specific information – therefore colours are waves of energy transmitting information. Colours form a system of human orientation. Through colour we interact with nature. Colours generate a vibrational field that permeates and alters each living organism.

The effect colour has on our physical as well as our mental and spiritual bodies is most powerfully experienced in the face of a Northern Light; hence we become ultimately and humbly aware that we are part of something bigger: deep in our hearts we sense the elemental forces. For the Sami (Lapps), the indigenous people of northern Scandinavia, the Northern Lights are the bridge to the other world. They form an integral part of their mythology and world view which is, like most indigenous peoples', a pantheistic one where everything is alive. For them the dancing colours on the dark winter sky are transmitting information and messages from another sphere. Over these frequencies they *re-connect* to their ancestors, to their cosmic roots – to the divine[2].

Cell communication is based on light

Biophotonic researchers have been able to show that every living cell emits minimal but measurable light quants, so-called biophotons (electromagnetic vibrations). In the 1970s Fritz-Albert Popp discovered the source of this biophotonic radiation to be found in the DNA. This radiation coordinates all biochemical processes in the cells and also transmits information between cells. Moreover it was shown that it is mainly the DNA which is sending and receiving the biophoton radiation.

> *"Based on the measurements of these electromagnetic fields, the so-called biophysics has developed a 'field model' of living organisms. Accordingly plants, animals and humans do not only consist of solid matter, but also of different types of fields that connect these particles with each other and in which the physical body is embedded. This completes the leap from material thinking to subtle thinking: recognizing light as language of life which controls and coordinates everything and builds the bridge to subtle energy levels." (Niggli)*

That the cell communication is based on light thus implies the human being is a light system which can be regulated through colour. Each specific colour frequency affects us, whether we are conscious of it or not. It influences all dimensions of the body: the physical, the mental, the emotional and the spiritual dimension. Together they form the bridge over which all life is connected to the cosmic stellar light. Astrophysicists tell us today all the matter we know – stars, planets, people is made of the same kind of material. Here, the law of resonance is at work which is an energy exchange between two or more energy systems. The interaction between us and the environment and fellow human beings is based on the principle of resonance.

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1 The visible spectrum ranges from wavelength violet-blue (approx. 400 nm) to red-magenta (approximately 700 nm).

2 Religio means reconnection which is the origin of the word religion.

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Although the effect of colour has been recognized in ancient times,[3] the function of colour as a mentor for the spiritual growth of humankind is in its comprehensive meaning yet hardly recognized. Colours, like sound, are originally frequencies of the universe. This is why orders and harmonies derived from them are so significant for us: Besides mathematics, music and mythology, colour orders and harmonies have long served humanity to systemize the phenomena. Thus a multitude of colour systems and theories have arisen to date in both the scientific and the artistic communities. They evolved from the interaction of the time and its prevailing consciousness/awareness.

That we are not comprised solely of matter is today a largely accepted fact. As quantum physics confirmed, the existence of matter is by virtue of a force, behind which there must be a field, a consciousness, a mind. We have a mind to be aware of creation; to the knowing of which we arrive at by means of analogies – whether we take the path of science or that of the humanities. The *subtle thinking* mentioned above (facilitating new concepts of *fields* in physics) which I call intuitive or poetic thinking, has been always very familiar to artists.

The Sirius Primary System

Having been privileged to be able to paint with wonderful paints from early on, I have always been intrigued by the mixing and blending of colours. There lies the foundation of my search for a harmonious and holistic colour system. But the limitation of systems based upon the intermixing of the traditional three primary colours taught from primary to art school everywhere always bothered me because it leads to very limited and imprecise results. What is explained in theory, doesn't work in practice; an empirically noticeably discrepancy. "Why can't there be a simple and clear colour mixing system which transcends these limitations and which bridges the concerns of art and science?"

I wondered.

In 1995, I started to research and develop an expanded and holistic colour system based on five primary colours. Due to their purity and balanced frequencies they allow a precise mixing of an unlimited range of harmonious and differentiated nuances. The new paint material I produced I named *Sirius Primary System*[4]. Sirius, the brightest star in the night sky, bears an energetic as well as a mystical relationship to our nearby earthly cosmos. As an important orientation, it has been anchored in the cultural traditions of people since the beginning of time. And today's science found out that our solar system and Sirius (which is itself an entire solar system) are intimately connected by the force of gravity!

On a physical-material level, on the base of purest pigments and binders, the Sirius Primary System is a perfectly working mixing system. Mixed in equal parts, the five primary colours, magenta, red, yellow, cyan and ultramarine, produce a vibrant neutral black. An additional Sirius white rounds off the system. The Sirius colours produce luminous, clear and lively colours, maintaining their chroma in unlimited ranges of mixtures: from secondary, tertiary colours to earth and pastel tones.

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3 The old Egyptians painted 'healing rooms' for patients in specific colours. The rooms were assigned to different chakras and specific planetary constellations.

4 The Sirius Primary system received a European patent as *Five-colour theory* in 2001.

Such a multitude of subtle and differentiated nuances promote a highly subtle and differentiated perception. The frequencies of the five primary colours, precisely aligned with one another, enhance individual colour receptivity (light receptivity). Colour perception and colour awareness are a function of consciousness, and these mutually impact one another. By resonance, through working with the Sirius Primary colours, we tune in and align to the original unity. The Sirius Primary System demonstrates that every material colour inherits the metaphysical dimension of its cosmic origin; spirit manifesting in matter.

The symbol I used for the Sirius colours is the pentagram; a symbol rich with connotations of man and cosmos. In ancient times it was associated with the star Sirius, as well as with *the quintessence*[5]: stellar energy embodied within our earthly matter. Symbols are powerful and are bridges to the forces of the creation. Symbol, from Greek means *to connect*. A symbol expresses a whole constellation of meanings by a selected form.

Researching and working with the Sirius Primary System, I arrived at many analogies and correspondences which reveal the inherent forces in the colours. For example assigning the five primary colours to the five primary elements: fire, earth, water, air and ether, which I then associated with the five fundamental forces of nature[6]. These five fundamental types of exchange sustain the universe and in physics are described as interactions. Visualized in colours, their motion and interaction I found expressed themselves best in the alchemical symbol of the caduceus[7]. Reminiscent of the DNA, the double helix or the two intertwining serpents symbolize the polarities through the balance of which the neutral element emerges: a neutral yellow balanced with a warm red and ultramarine on one side and a cool magenta and cyan on the other. The serpent is the first symbol for the arrangements of the elemental forces – and the coloured serpent, the rainbow serpent, is the first model for the arrangement of the Sirius primary colours as an expression of the elemental forces**.** Encompassing the unifying principle, the Sirius Primary System provides a system for human orientation.

The Sirius colours have deeply shaped my art work. "Her paintings situate locations on a path. An inner path involving levels: mythic, psychological, spiritual. Through her paintings we traverse atmospheres. … To name Diethelms language, we must say it's necessary to even pass through her concrete use of colour and form. When we have sensed her eloquence here, we move on – depth after depth. Connected to, but simultaneously beyond the structures of analysis, we emerge past all the linear interpretations. Another reality reveals itself: we arrive to discover origins and changes – the Great Spirit of nature." (Benazzi-Pilosian)

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5 Also known as 'fifth element' or 'fifth force' it has been described by ancient mystics, such as Pythagoras, and is a major concern of modern physics.
6 Gravity, electromagnetism, the strong nuclear force and the weak nuclear force, and the fifth force.
7 The ancient Egypt. Symbol of Thoth and later of the Greek Hermes. It was a symbol for healing.

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Image retrieval by impression word based on feeling prediction from color combination

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Abstract

This paper presents a new image retrieval method by impression words. The proposed method relates four feeling values to each image in database. These feelings are pleasantness, contrast, floridness, and warmth. The method also relates impression words and the feeling values. The usage of impression word would be a little different between users. Therefore, the relationship between impression word and feeling values is determined for each user by questionnaires. Feeling values of images are determined by following steps. First, three representing colors are detected from each image in database by the image division and the color clustering using k-mean algorithm. Then, feeling values are calculated from three-color combinations by feelings prediction formulas. In the image retrieval, images that have feeling values close to feeling values of impression keyword are retrieved from database. We examined image retrieval tests for evaluating the proposed method. The results show the feasibility of the proposed method.

1. Introduction

This paper presents a new image retrieval method by impression words, which are related to color feelings of images. It is difficult to find images that have required feelings, such as, a pleasant scenery image, a calm scenery image. For such image retrieval, we must add an appropriate impression word to each image as a keyword. If we add impression words to all of the images in database manually one by one, it will be time-consuming and, moreover, the end results will depend strongly on the person's skill who adds the keyword. To solve these problems, we propose the method to relate images to impression words automatically based on the feeling prediction from color pixel information of images.

There are many researches on content-based image retrieval as described in Liua et al. (2007). Color feature is one of the most widely used features in image retrieval methods, and color gives feelings to person. If impression words and color features are related, it is easy to realize image retrieval by impression keyword. Nayatani and Sakai (2009a, 2009b) proposed feelings prediction formulas from color combinations. This method calculates feelings from color combination as values of pleasantness, contrast, floridness and warmth. These formulas are available to relate impression word to color features. Note that, however, the usage of impression word would be a little different between users. Therefore, the relationship between impression word and feeling values should be determined for each user by questionnaires.

The proposed method gives four feeling values to each image in database by the feelings prediction formulas. Images are retrieved by feeling value matching of images and an impression keyword.

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2. Image retrieval based on feeling prediction

In the proposed method, images that have feeling values close to feeling values of impression keyword are retrieved from database. The feeling values of images are calculated from the color combination representing images. Determination of the relationship between impression word and feeling values is done by questionnaires for each user.

2.1 Determination of the relationship between image and feeling values

Three colors are detected from an image as the color combination representing the image. The representing color detection procedure is done by following steps. First, image is divided to 16 areas (four rows and four columns) equally. Images have several compositions, such as right and left, top and bottom, and inside and outside. The division conforms to these several compositions. Then, the representing RGB color of each area is detected by color histogram analysis. The analysis detects frequent appeared color. The detected 16 colors are clustered to three colors by using the k-mean algorithm (MacQueen 1967). The k-mean algorithm is a method for the classification of data. In this algorithm, initial center of each cluster is chosen firstly. We set three initial centers as colors that are nearest to red, green and blue respectively. Next, each color data is allocated to cluster whose center is the closest to the color. Then, the center of each cluster is replaced with the average color in the cluster. The procedures of the color data allocation and the center replacement are repeated until all cluster centers are converged. The representing colors are defined as the colors that are closest to each cluster center. Our algorithm avoids including identical colors in these three colors. These representing RGB colors are converted to Munsell hue, value, and chroma (HVC) values.

Feeling values for the image are calculated from these HVC colors by equations in Ref.2 (Nayatani and Sakai 2009a). Feeling values are pleasantness (Eq.(1,2) in Ref.2), contrast (Eq.(3,4) in Ref.2), floridness (Eq.(5,6) in Ref.2), and warmth (Eq.(7,8) in Ref.2). We introduce only the formula for pleasantness feeling value in this paper. The feeling value of pleasantness for two-color combinations, $x_p^{(2)}$, is predicted by Eq.(1).

$$x_p^{(2)} = b_0 + \sum_{n=1}^{1} b_n \cdot x_n \, , \qquad (1)$$

where the coefficients $b_{0,}$ b_n and variables x_n are shown in Table II in Ref.2. The variables x_n consist of $Z_{1,i}$, $Z_{2,i}$, and $Z_{3,i}$, that are transformed values of Munsell notation of a component color (i=A,B) of two-color combination. The transformation equations are given in the following equations.

$$Z_{1,\,i} = C_i \bullet \cos\theta_i \, , Z_{2,\,i} = C_i \bullet \sin\theta_i \, , Z_{3,\,i} = 8.33\ V_i \quad \text{for} \quad i=A,B \qquad (2)$$

where q_i, V_i, and C_i are the Munsell hue, value, and chroma; the subscripts A and B correspond to two component colors of a two-color combination. Note that Munsell Hue q_i is in angle unit; q_i = 0 [deg.] for 10RP, 18 [deg.] for 5R, 90 [deg.] for 5Y, and so on. Then, the feeling value of pleasantness for three-color combinations, $x_p^{(3)}$,is calculated from three feeling values of two-color combinations. Eq.(3) is the formula for three-colors combination, where colors are A, B and C.

$$x_p^{(3)} = x_{p,AB}^{(2)} + x_{p,BC}^{(2)} + x_{p,CA}^{(2)} \qquad (3)$$

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The range of feeling values is normalized from 3 (very pleasant) to -3 (very unpleasant).

2.2 Determination of the relationship between impression word and feeling values

Determination of the relationship between impression word and feeling values for each user is done by questionnaires. In questionnaires, many images were displayed one by one on a monitor. Then, users selected several impression words for each displayed image from 38 Japanese impression words. These words are 19 pairs of positive and negative adjective words for freshness, depth, refinement, pleasantness, calmness, hardness, weight, clearness, unification, gorgeousness, strength, brightness, beautifulness, transparency, flippancy, prosperousness, delicacy, vividness and balance.

The feeling values of the impression are defined as average feeling values calculated from images that are selected to the impression. Images whose feeling values are quite different from other images in selected images are excluded in the averaging procedure.

2.3 Matching of feeling values

In image retrieval, the similarity of four feeling values between image and impression is evaluated. The subtraction of feeling values between an image and an impression is calculated for each feeling. When absolute values of the subtractions are smaller than thresholds, it is determined that the image relates to the impression word. The thresholds are adjusted for the number of retrieved images.

3. Experiments

We examined image retrieval tests for evaluating the proposed method. Images in our database were collected from the Corel image database. The Corel images are often used for evaluations of image retrieval methods (H. Müller, et.al, 2002). We choose image categories of nature photos, architectures and textures. Then, we selected 300 images from these categories. 100 images were used for questionnaires to determine the relationship between impression word and feeling values, and other 200 images were used for image retrieval tests. We investigated feelings of images in database by questionnaire for 10 Japanese university students.

Image retrieval tests by all impression words were done for all subjects. We set the number of retrieved images to nine. The results of image retrieval were mostly appropriate for feelings of subjects. For example, Figure 1 shows images selected as "beautiful" in questionnaire by a subject, and Figure 2 shows images retrieved by impression keyword "beautiful" for the subject. The subject evaluated the appropriateness of these images. As the result, the number of appropriate images was six. All subjects evaluated retrieved images for all keywords in the same manner. The average number of appropriate images in nine retrieved images over all subjects was 5.8. The proposed method uses feeling values calculated from color combination. Therefore, the colors in the retrieved images are often different from the colors in selected images in the questionnaire. Figure 3 shows the retrieved images by impression keyword "beautiful" for another subject. We considered the difference of feeling for color between individuals. Therefore, the retrieved images for this person as shown in Figure 3 are different from the retrieved images shown in Figure 1.

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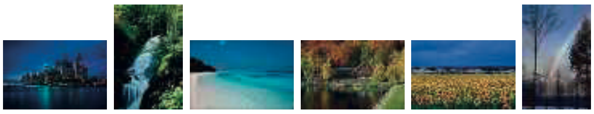

Figure 1. Images selected as "beautiful" images by a subject in questionnaires to determine the relationship between impression word and feeling values.

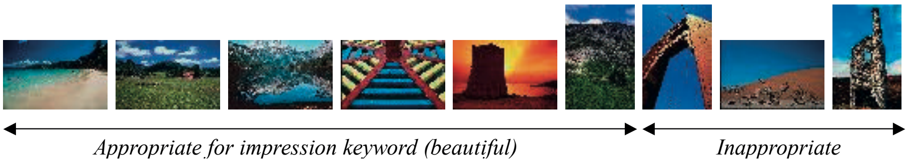

Figure 2. Images retrieved from test database by impression keyword "beautiful" for the subject. The number of appropriate images in the evaluation by the subject was six.

Figure 3. Result of image retrieval by impression keyword "beautiful" for another subject. The number of appropriate images in the evaluation by this subject was eight.

4. Conclusions

This paper proposed the image retrieval method by impression words. The proposed method relates four feeling values to each image in database. The feelings are pleasantness, contrast, floridness, and warmth. The feelings are predicted from three color combinations in the image by feeling prediction formulas. The color combination is detected from the image by color image processing. The method also relates impression word and the feeling values by questionnaires. The usage of impression word would be a little different between users. Therefore, the relationship between impression word and feeling values is determined for each user by questionnaires. The experimental results suggest the feasibility of the proposed method. The average number of appropriate images in nine retrieved images over all subjects was 5.8. We have plans to collect more experimental data for more reliable results and quantitative evaluations.

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Using 2D image composition to model and evaluate soldier camouflage in the visible wavelengths

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Abstract

The development and evaluation of camouflage systems is usually very time-consuming. Any evaluation that could be done using simulation prior to a field deployment would significantly shorten the development cycle. One could for example use simulation to evaluate the effectiveness of a new concept soldier camouflage pattern within a specific environment without having to print and manufacture sample uniforms. We present a 2D image composition simulator to do exactly this. If one assumes a diffuse material bidirectional reflectance distribution function then the target to be camouflaged may be used as a diffuse light probe that adequately captures the direct and diffuse scene lighting. The simulator results are visually very close to the photographs of reference uniforms. The remaining discrepancies between the simulation results and the validation references do however show that the material BRDF is not perfectly diffuse and that the point spread functions of the camera and fabric printing process still need to be taken into account.

1. Introduction

The development of camouflage systems can become quite expensive if one has to do pairwise comparisons or probability of detection evaluations of many concept camouflage patterns using only field exercises. The majority of evaluation strategies are based on the Law of Comparative Judgement, sliding scale methods, probability of detection [Peak 2006] methods and the Analytical Hierarchy Process [Baumbach 2008]. If one does not make use of simulation then all of these evaluation strategies involve the set up of multiple field scenarios in the environment under consideration, with manufactured camouflage systems and groups of observers to evaluate each system in each scenario.

Any evaluations that could be done using simulation prior to a field deployment would therefore significantly shorten the development cycle. We present a camouflage simulator based on a 2D image composition approach to do exactly this for the design of soldier camouflage in a bushveld environment. The simulator digitally paints a concept camouflage pattern onto a target in a 2D background scene.

2. The simulation method

The simulation method includes a background measurement process, a background and digital camouflage pattern calibration process and a 2D image composition process.

2.1 The background measurement process

It is important to note that the background scene must already contain the target to be digitally camouflaged as shown in Figure 1. To ease the calibration of the measurement process the target to be camouflaged must be of a grey colour with a known CIELAB lightness (L*) value and a standard colour reference should be included in the background photo. In order to minimise

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compression errors and approximations it is preferable to use a camera that can output images in a raw format (such as Nikon's .NEF format).

If one assumes a diffuse material Bidirectional Reflectance Distribution Function (BRDF) and isotropic scene lighting (identical upwelling and downwelling scene illumination) then the grey target adequately captures the direct and diffuse scene lighting. In other words, one could use the colour and lightness of the target to modulate the applied digital camouflage pattern without the need to consider the scene and local target geometry.

2.2 The background and digital camouflage calibration process

The colour reference should be located near the target and we use a standard Macbeth ColorChecker. In this version of the simulator we use the colour reference only to white balance the raw (.NEF) background image and it is of course important to use a reference grey in the colour reference which is not overexposed. We make use of the open source image editor Gimp, which has a UFRaw plugin that allows one to white balance on a colour sample from the raw image. Once the background is white balanced the target to be camouflaged is also assumed to be grey i.e. to have a* and b* values of zero.

To calibrate the concept camouflage pattern the CIELAB values of each colour used in the pattern are measured from test prints or colour references. We do the measurements under the standard illuminant C using a Konica Minolta CECF-9 Color Reader. The digital pattern is then re-coloured with the measured CIELAB colours. We use Photoshop to convert the CIELAB camouflage pattern to the Red, Green and Blue (RGB) colour space (under the D50 standard daylight illuminant) for use by the 2D image composition process.

2.3 The 2D image composition process

A simulator, using the MATLAB scripting language, has been developed to automate the 2D image composition process. Once the background is white balanced the target is assumed to be grey and may be used to modulate the camouflage colour to be applied to the target without the need for further colour calibrations or corrections.

A simple heuristic is used to automatically isolate the grey uniform from the background scene. The heuristic makes use of the assumption that colours in the bushveld environment is more green and red than blue. Note that the heuristic therefore fails for background images that also contain sky, but if the user selects a target bounding box then this limitation could be overcome.

The grey uniform's pixel brightness is used to modulate the RGB colour of the concept camouflage according to :

$$RGB = \mu \frac{100}{L^{*}_{Uniform}} RGB_{Camou} ,$$

where RGB_{Camou} is the colour of the digital camouflage pattern and μ is the pixel brightness in [0.0 ,1.0] of the grey coloured target to be camouflaged. Although the image composition process is a simple 2D overlay of the concept camouflage pattern on the target, the shading information provided by the grey uniform creates the illusion of 3D camouflage.

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3. Results

Figure 1 shows the CamouSim GUI and Figure 2 shows an example simulation scenario and concept pattern. Figure 3 shows a side by side comparison of the concept patterns and reference uniform prints.

In the middle pane of Figure 3 the virtual camouflage on the left matches the reference image on the right well on the shoulders, but not so well on the soldier's back. Also, in the rightmost pane of Figure 3 the virtual camouflage pattern on the left-hand soldier is much sharper than the reference pattern on the right-hand soldier. This is because we have not taken the material BRDF and the Point Spread Functions (PSFs) of the camera and camouflage printing process into account.

4. Conclusion

We have shown that colour matched results can be achieved when designing the camouflaged patterns in the measured CIELAB colours using the target as a light probe.

From the results and from recent BRDF measurements it is clear that the material does not have a diffuse BRDF. There is in fact a much larger Fresnel reflection component than we originally considered. It is also clear that we still need to take the PSFs of the camera and fabric printing process into account when applying the concept pattern to the grey target.

Acknowledgments

We would like to thank the South African National Defence Force (SANDF) and the Armaments Corporation of South African (Armscor) for funding this work.

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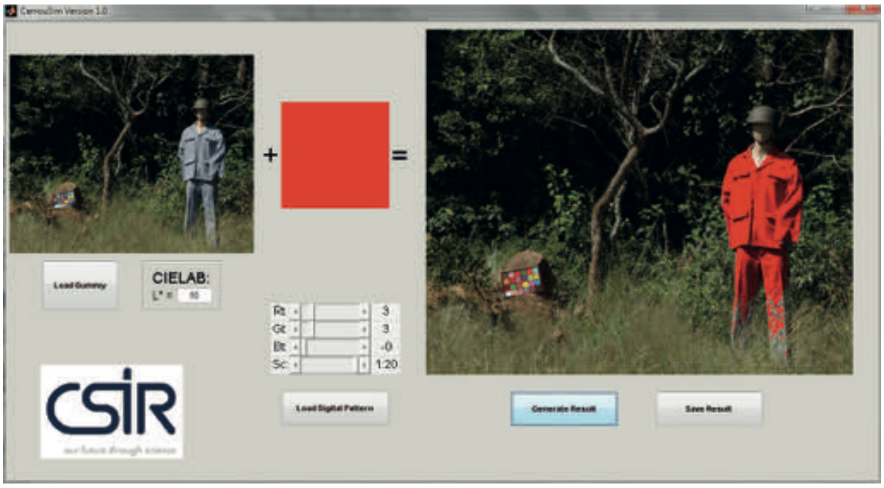

Figure 1. CamouSim GUI with red camouflage pattern to demonstrate the image composition.

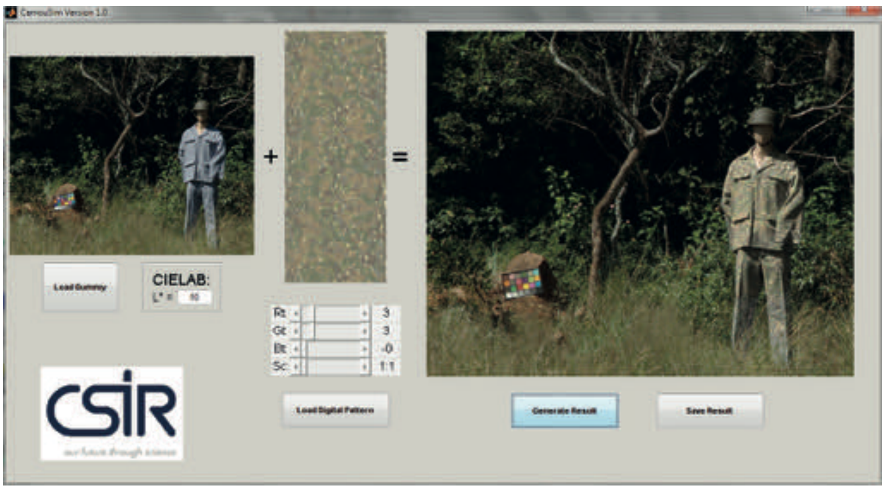

Figure 2. Demonstration of CamouSim with an example concept pattern.

Figure 3. CamouSim results. (Left: Input image with validation reference; Middle&Right: Virtual camouflage on left compared to validation reference on right.)

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Towards an automated method of objective gingival inflammation assessment on colored digital still images

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Abstract

Obtaining methods for objective quantification of gingival inflammation is a challenging task, ever since. A major reason for this is the fact, that most commonly accepted methods rely on visual parameters of gingival health state, which need to be quantified subjectively by an expert in the field of dentistry. In this article, we present a novel method for image acquisition of colored oral cavity digital still images that can be used for an automated and objective gingival inflammation assessment in routine clinical procedures. Further, we present our initial work and results towards obtaining an automated digital image processing streamline to assess gingival health. Amongst the applied image analysis techniques are several segmentation approaches for teeth region segmentation from digital still images, including a *K-means*, a *nearest-neighbour* and a *Self Organizing Map* approach.

1. Introduction

Gingival health state assessment is a research field with a long history in the area of dentistry. Early methods assessed and classified gingival health subjectively as good, medium or poor. Later methods used indices that quantified several clinical signs such as the location of inflammation, the area of affected gingivae or gingival encroachment over tooth surface. However, the limitation of most indices is the subjectivity of the observer. [Smith et al. (2007), Tatakis and Trombelli (2004), Ciancio (1986)]

In the past two decades, some research has been conducted towards obtaining objective methods of gingival health state assessment involving techniques of image analysis in several forms [Smith et al. (2007), Ellis et al. (2008), Denissen, Kuijkens and Đozic (2007)]. Ellis et al. used photographic images to assess gingival overgrowth [Ellis et al. (2008)]. Denissen et al. used digital photographic images to measure color characteristics of healthy gingivae [Denissen, Kuijkens and Đozic (2007)] and Smith et al. used digital photographic images to quantify gingival inflammation [Smith et al. (2007)]. The goal of our work is to establish robust methods for automated quantification of objective gingival health state assessment. By this token, our work aims on establishing a novel method for image acquisition of colored oral cavity digital still images and on developing robust and reliable methods for automated quantification of objective gingival health state assessment. In the following we will outline our research approach and state of the art, based on an initial field test of image acquisition and preliminary experiments on image analysis techniques.

2. Characteristic parameters of gingival inflammation

Our work focuses on gingival inflammation process assessment, a subdivision of gingival health state assessment. We therefore aim at quantifying parameters that indicate inflammation of

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gingival tissue. Such parameters can be redness [Smith et al. (2007), Meitner et al. (1979), American Academy of Periodontology (2000), Ciancio (1986)], edema [American Academy of Periodontology (2000)], encroachment over teeth [Smith et al. (2007)], calculus [American Academy of Periodontology (2000)] or bleeding upon probing [Meitner et al. (1979), American Academy of Periodontology (2000), Ciancio (1986)]. Most of those parameters can be quantified by visual inspection, which qualifies them for a photographic image based analysis in an objective manner. Redness can be quantified by determining the location of certain colored regions of gingivae in a three dimensional color space. Edema and gingival encroachment over teeth are closely related, whereas edema of gingivae usually implies an encroachment over teeth areas. One method for quantifying this parameter is to determine the visible size of teeth or the location of the gingival margin. Calculus can be quantified by its size within visible teeth areas. Bleeding upon probing is a method where a probe tip is placed 1-2mm into the gingival sulcus and moved along the gingival surface for 2-3mm. The presence of blood on the tip indicates gingival inflammation [Meitner et al. (1979)]. However, bleeding upon probing cannot, of course, be quantified from photographic image data of oral cavity images.

We aim at utilizing redness and gingival encroachment as parameters for our studies. Smith et al. have shown that these parameters are reliable and valid for the purpose of gingival inflammation assessment, based on digital images [Smith et al. (2007)]. Their work is also based on photographic digital still images, but utilizes a commercial software tools for image analysis that requires the user to have in-depth knowledge of that software tool and experience in utilizing software tools for image segmentation. In addition, this method implies a certain degree of subjectivity due to manual segmentation steps.

3. Image acquisition setup and image pre-processing

We have established a method for image acquisition that requires only standard photographic equipment (single lens reflex camera, camera tripod, circular polarization filters) and can be accomplished in non-laboratory environments to maintain applicability of use at dental practices. Figure 1(a) illustrates the basic scene setup and Figure 1(b) illustrates the image acquisition process. We use polarization filters during image capture to reduce specular reflections in the acquired images. This approach, together with drying of the oral cavity prior to image acquisition with a blast of air has shown to provide good results in term of specular reflection reduction. A sample of an image acquired with this method is illustrated in Figure 1(c).

As we intend to use image analysis methods that are based on spatial and color properties of photographic image data, it has to be ensured that these properties remain unaltered within successive image capturing for the same subject over time. The capability to compare images of a subject over time is of utmost importance, as health state assessment of the medical condition of gingivae requires recurring monitoring of individual subjects over a certain period of time, from a week to often several months or a year. Amongst others, one central factor that can alter the color properties given by the camera response values along successive image acquisition is a change in illumination over time. Even if the same light source and a fixed distance between camera and subject within the same environment for capturing are used, unavoidable changes in illumination will remain. These changes can be due to varying ambient light within the scene or changes of the spectral properties of the light source over time.

One approach to maintain color properties amongst acquired images as constant as possible,

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given the conditions of clinical practices, is to pre-process images by performing white balancing according to a gray reference patch included in the image scene and a white patch algorithm. The white patch algorithm independently scales individual channels (R,G,B) of the image by the maximum pixel value found in each channel [Cardei and Funt (1999)], in our case for the region in the image that includes the reference patch. We use this approach in combination with an unsupervised threshold based segmentation to detect the location of the patch in order to automate white balance of each individual image (see Figure 1(c)).

A second step of pre-processing is to crop the images. The region of interest that is cropped from the images is defined to include the visible part of the upper and lower incisors and canine teeth, as an initial frame. An example of a resulting image after all pre-processing steps is shown in Figure 1(d).

Using the experimental set-up for image acquisition and the pre-processing steps described above, we obtained an initial image database with 90 images from oral cavities of 27 subjects with healthy gingivae in an initial first field test. A set of 36 images has been acquired at two different days for 18 subjects. Our purpose was to render this database public in the near future, as we have noticed a lack of publicly available oral cavity images of healthy subjects by now.

4. Analysis of oral cavity images

As stated earlier, we intend to quantify redness and gingival encroachment as parameters for gingival inflammation assessment. We used images from our database to apply various image analysis techniques. A first step in this process is to obtain a robust segmentation of significant regions within the images. For redness analysis, significant regions are defined as pixels in the image with certain color properties. Encroachment analysis relies on tooth segmentation, as tooth size is used as the parameter that quantifies encroachment. Because both types of analysis rely on segmenting teeth regions from non-teeth regions, we began by addressing this issue.

Initial experiments with several segmentation methods have confirmed the complexity of segmentation based on colored oral cavity images: A main challenge is that color properties of both, teeth and gingivae can vary widely if compared among several subjects and amongst different gingival health states [Denissen, Kuijkens and Đozic (2007), Schwabacher and Goodkind (1990), Heydecke, Schnitzer and Türp (2005)]. Furthermore, for images of certain subjects, color clusters from teeth and non-teeth areas existing within an individual image turn out to be non-separable when illustrated in RGB color space. We have used three different segmentation algorithms and two color spaces for our set of preliminary experiments. The algorithms for segmentation that we have applied are nearest neighbor or NN [MathWorks (2010a)], K-means [MathWorks (2010b)] and Self Organizing Map or SOM [Vesanto (1999)]. Segmentation quality has been computed as the percentage of pixels of teeth classified wrongly as non-teeth (discrepancy empirical quality measure), compared to manual segmented ground truth of individual images. The results for different algorithms and color spaces are displayed in Table 1.

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Table 1. Segmentation error (percentage of pixels that have been classified wrongly) from segmenting teeth from non-teeth areas of oral cavity images

Algorithm / Color space	Mean value	Standard deviation	95 percentile
NN → CIE-L*a*b*	12.33	7.76	26.71
NN → CIE-L*a*b*, using only a* and b* components	13.13	8.36	26.28
SOM → RGB	9.94	3.29	16.23
SOM → CIE-L*a*b*	5.09	0.94	6.66
K-means → RGB	23.84	22.56	82.60
K-means → CIE-L*a*b*	18.40	19.36	71.67

Using *CIE-L*a*b** color space has shown to improve segmentation results. We found that the selection of color space seems to be strongly related to the performance of segmentation and therefore should be investigated further. The algorithm performing best segmentation quality is SOM.

5. Summary

To sum up, by now accomplished research provides a fully developed method for digital still image acquisition of oral cavity images, based on standard photographic equipment. The so acquired images are white balanced to allow comparison of color features amongst several images of the same subject. This qualifies our method to be utilized for long-term studies on individual subjects health states.

The conducted research on color image analysis for gingival inflammation assessment that has been based on our initial data acquisition has brought about several important questions for future work. One of these questions motivates further research on the selection of a suitable color space to enhance segmentation performance of gingival regions within oral cavity color images.

Hence, the above outlined results constitute the motivation for further investigations we intend to accomplish on this promising topic. Such work includes tooth area evaluation, gingival area segmentation for redness evaluation and overall optimization of segmentation techniques used.

(a) basic scene setup (b) image acquisition (c) white balanced image (d) cropped image

Figure 1. Experimental setup and image acquisition

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Colour change in printing inks caused by light exposure

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Abstract
It is well know that every material modifies both structural and colour proprieties in irreversible way if it is exposed to light for much time: this event is called photo-damage. Unfortunately, the temporal evolution and the characteristic factors of the fading processes or the reactions on the materials at the light exposure have not still totally comprehended.

The Photometric Laboratory of the University of Padova made some accelerating aging tests, choosing samples of printing coloured inks used actually for artistic prints or photographs [1] [2] . The experiment aims to identify a procedure which measures the properties to change own colours of a material and its responsivity at the photo-damage. These data allow also to define the ideal spectrum of the source which should be used to light an art work without damage. The presented paper describes the method used in the Laboratory to fade the inks samples, measuring their colour changes occurred during the test, and presents the first results obtained from the collected data.

1. The accelerated-aging test of the ink
The photo-damage process is reproduced by continuous radiant exposure of the coloured printing ink samples in the laboratory. They are put inside an accelerated aging chamber under a wide-spectrum light source. The printing inks are chosen as samples for the aging test, because they guarantee to obtain samples with homogeneous and uniform surfaces that are repeatable in the time and equals to each other. Moreover, their relative spectral responsivity $s(\lambda)_{dm,rel}$ has not still analysed. The colours of the samples, whose original reflection spectral coefficients are shown in Figure 1, correspond to the subtractive primary colours – cyan, magenta and yellow – that are mixed in the same quantities to obtain the secondary ones – blue, green and red. In this way, possible relationships between hue couples behaviours could be researched and verified at the end of the experiment.

The accelerated aging chamber is a box with white and diffusing walls (Figure 2) in order to uniform the irradiance on the samples' surfaces. Its sizes are 80 x 65 x 92 cm and it is totally closed and isolated from external light or other climate factors and the inside clime is controlled: in this way the solicitations on the samples are constant. A high-power metal halide lamp is mounted in the centre of the box cover. Its wide spectrum spans from about 200 nm to 1000 nm as shown in Figure 3, other electric, spectral and photometric characteristics of the lighting source are reported in [3] . The maximum incident radiant power on the samples is about 587 Wm^{-2}, subdivided in UVC (1.52 Wm^{-2}), UVB (6.5 Wm^{-2}), UVA (25.4 Wm^{-2}), Visible and IR radiation (553.4 Wm^{-2}).

The experiment program is articulated in three main steps in order to investigate as many aspects as possible of the colours fading:

1. exposition to a radiation with a complete spectrum, containing every wavelengths;
2. exposition to several intensity of incident radiance (75%, 50%, 25% of the radiant power at

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point above), putting the samples at several distance to light source to verify the Reciprocity Principle. The results are compared with the ones described in [4] ;

3. exposition to monochromatic irradiation selected by 7 interference filters which spectral transmission are shown in Figure 4, to calculate the relative spectral responsivity of the inks. The test is analogous at [5] and [6] and the results are compared with them.

Stages *a)* and *b)* are protracted until the colour of every sample disappeared completely. Each one is repeated twice in order to assure and confirm the obtained measures. The successive elaborations are made using the average of the measured data for every sample. Step *c)*, instead, has been still in progress, because the monochromatic filters reduced too much the incident radiant power on the samples so the test is longer. However, the measured data are elaborated and analysed until now.

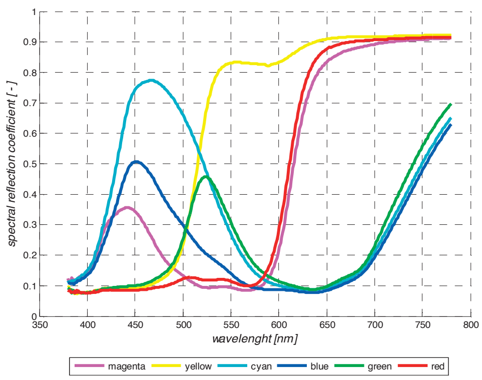

Figure 1 - Spectral reflection coefficient of the coloured printing inks chosen as sample

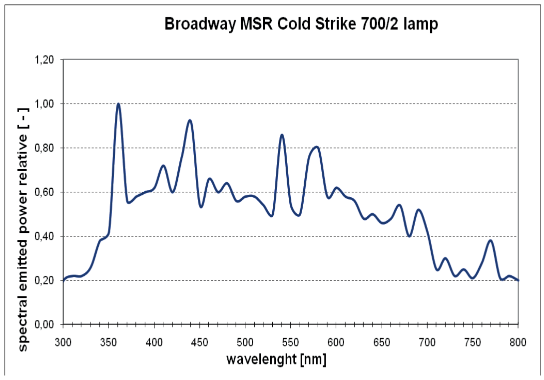

Figure 3 - Emitted radiant power spectrum of the source

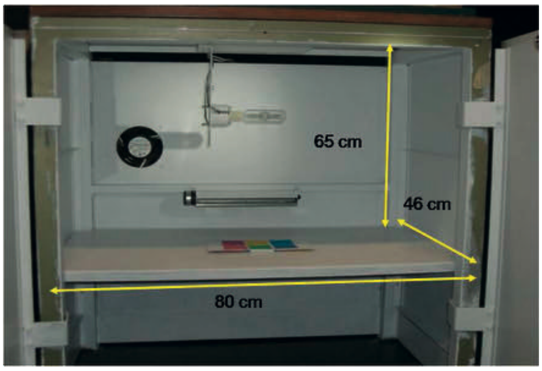

Figure 2 - The accelerating aging box

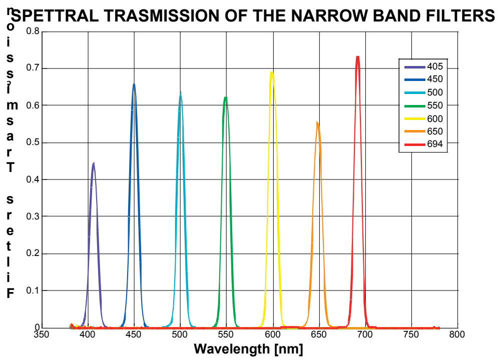

Figure 4 - Spectral transmission of the narrow band filters

During each accelerated aging test, the spectral reflection coefficient of every ink samples is monitored periodically by a Minolta CS1000 spectroradiometer in measuring geometry 0/45°. In Figure 5 the behaviour of the spectral reflection coefficients for every samples during the first step of the experiment is shown. It is possible to note how the coefficients flatten their diagrams and they increase their average values until to unit value. Even if the interval of time between two successive measurements is the same, the amounts by which the graphs increase are very large at the beginning of the fading process and then they become more closed. So this effect demonstrates that the fading process starts very fast and then it continues more slowly until to reach a regime value.

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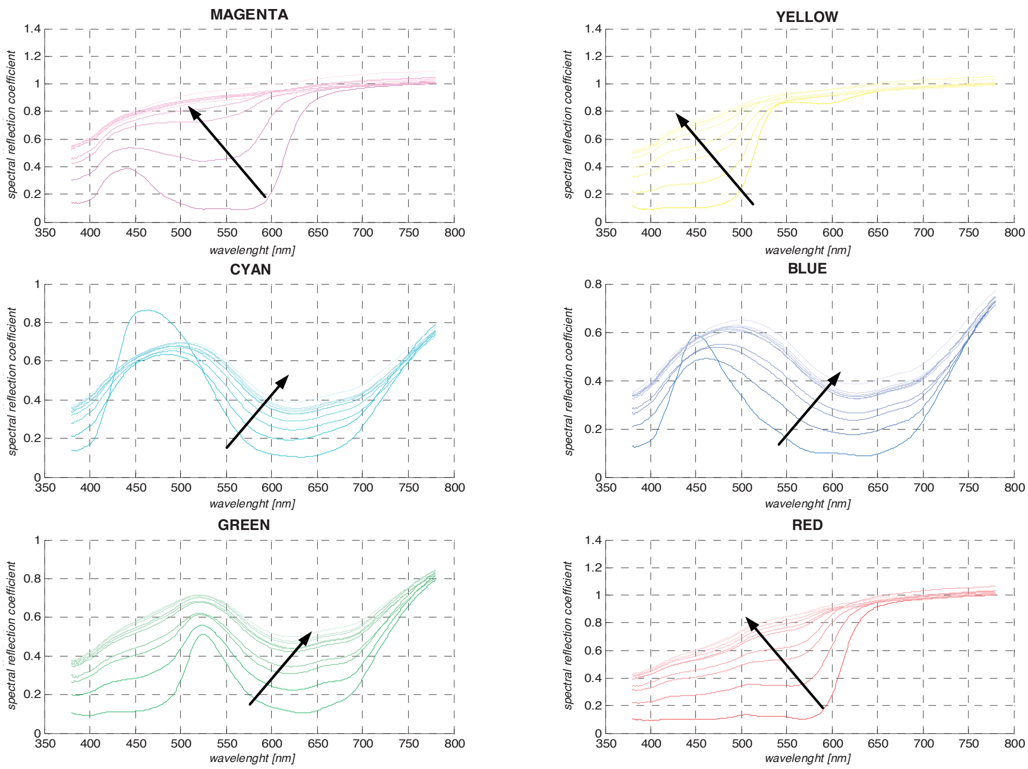

Figure 5 - Evolution of the spectral reflection coefficients of each colour ink

In a second moment, every spectrum is converted in the correspondent trichromatic coordinates L^*, a^*, b^* of the three-dimensional colour space CIELAB using CIE Standard Illuminant D65 as reference illuminant. In Figure 6, the three planes of the colour space CIELAB with the chromatic points of every sample during first and second steps of the experiment are reported. For each step of aging test, they result grouped in base of their own colour sample: this means that every hue has an own specific behaviour. The points of yellow and red samples are aligned almost in parallel with b* or a* axis, respectively (Figure 6c), and their luminosity grows constantly (Figure 6a-b). Then, only a desaturation effect happens in these samples and their colours appear lighter than the original. On the contrary, in the blue, cyan and green samples in addition to desaturation, also a hue change happens, in fact their points are not fitted by straight lines through the axis origin, as shown in Figure 6c. In the same figure, it is possible to note two distinct achromatic points as regime values for the six groups of colours: one for the cool hues, another one for the hot ones. Analogous conclusions are possible analysing the trichromatic coordinates L x y of the CIE 1931 colour space in the chromaticity diagram, as shown in Figure 7.

2. The colour shift of the inks

The colour changes ΔE are calculated as Euclidean displacement between couples of tern $L^*a^*b^*$ corresponding to the same point of the sample, according the next equation:

$$\Delta E = \sqrt{(L_1^* - L_0^*)^2 + (a_1^* - a_0^*)^2 + (b_1^* - b_0^*)^2}$$

where L^*_1, a^*_1, b^*_1 and L^*_0, a^*_0, b^*_0 are the trichromatic coordinates the spectral reflection coefficient of the same point of the sample measured in two different moment of the aging. This difference

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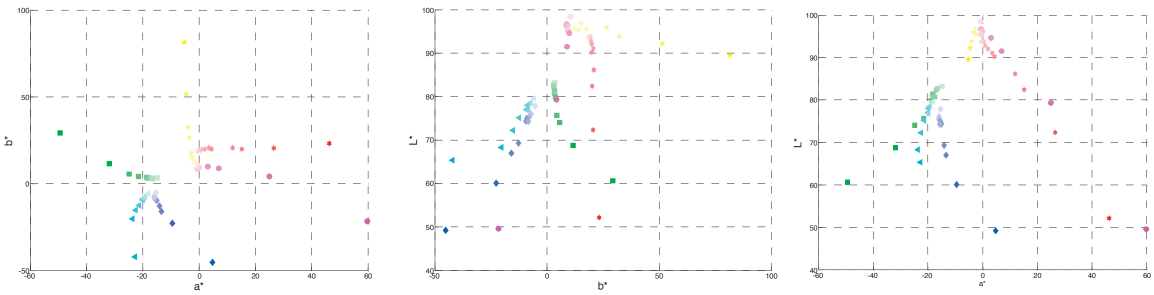
ΔE represents the colour change caused by light-exposition. Figure 8 shows the variation of the distance ΔE as a function of the radiant exposure H, i.e. of the product of incident radiant power and exposure time which corresponds to the total radiant energy received on the samples. Also this result demonstrates that the fading process starts fast and then it continues more slowly until a regime value is reached. In first approximation, as described in literature [7] , the inks behaviour can be represented by exponential function of the form:

$$\Delta E = K^*(1 - exp\ (H/\tau))$$

where ΔE is the colour distance in CIELAB colour space, H is the radiant exposure, K and τ are parameters indicate respectively total perceptible variation submitted by the coloured ink and how quickly it changes.



(a) a*b* plane – L* constant *(b)* L*b* plane – a* constant *(c)* L*a* plane – b* constant

Figure 6 - Evolution of the trichromatic points of each sample in the CIELAB colour space (the points colours correspond at the colour of the samples)

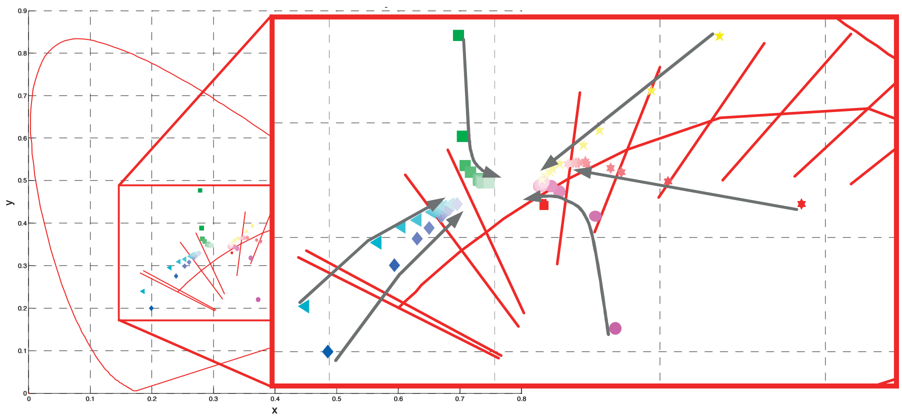


Figure 7 - Evolution of the trichromatic points of each sample in the CIE 1931 colour space (the points colours correspond at the colour of the samples)

The magenta sample changes more and faster than the other ones, the green one is faster than blue one, but it submits a smaller final deviation. For every coloured ink, the parameters K and τ have specific values, so it means that the original hue of samples influences the fading process. These values are quite close each other, except for the lowest value of the incident radiant power, when the parameters K and τ reduced their values, until more than 10% for some coloured inks. It could mean that the reciprocity principle could be not always true and some threshold phenomenon could happen when low value of incident radiant power are used, in contrast with the literature.

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3. The relative spectral responsivity

The colour shift *ΔE* against the radiant exposure *H* graphs for each sample are calculated for every step of the experiment. At the end, from the one obtained in the last step *(c)* with monochromatic filters, the relative spectral responsivity *s(λ)dm,rel* of each coloured inks are estimated. This propriety indicates which wavelengths are more dangerous for the fading of the ink and so it should be avoided to light it. The calculation procedure follows the one described in [5] : the relationship between the wavelength of the irradiation and damage is determined by interpolation of the colour change after an exposure of 25.000 Wh/m^2. In our case, the procedure is repeated with several values of exposure *H* in the *ΔE – H* graphs besides the unique one used by Saunders (Figure 9). In this way, it is possible to note that the relative spectral responsivity $s(\lambda)_{dm,rel}$ of a coloured ink varies with the considered value of exposure *H*. In particular, two behaviours are distinguishable which depend on the considered phase of the fading process where the value of exposure *H* is chosen. If this value correspond to the initial linear slope, then the inks have the highest value of relative spectral responsivity $s(\lambda)_{dm,rel}$ for the lowest wavelengths (the blue zone of the spectrum). Instead, if the value of considered exposure *H* is over the knee in the *ΔE – H* graph of the examined coloured ink, then each ink shows an own trend of its relative spectral responsivity $s(\lambda)_{dm,rel}$.

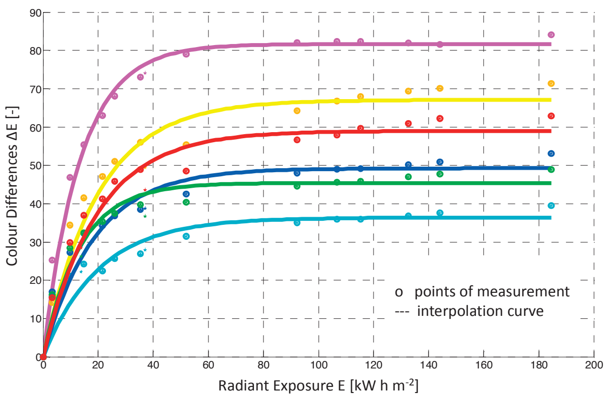

Figure 8 - Plot of colour changes ΔE against exposure H for ink samples during the stage a) of the experiment

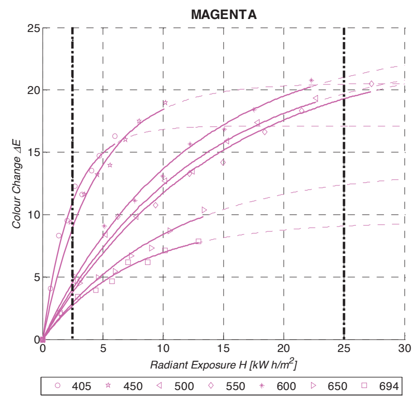

Figure 9 - Plot of colour changes ΔE against exposure H of magenta ink for every monochromatic filters. The vertical lines indicat two values of exposure H where the relative spectral responsivity $s(\lambda)_{dm,rel}$ *of the ink is calculated.*

In Figure 10 the relative spectral responsivity $s(\lambda)_{dm,rel}$ of the magenta and green inks are compared. The spectral responsivity $s(\lambda)_{dm,rel}$ at the lowest values of radiant exposure *H* are very similar between each others, as solid line with stars shows. For the other higher values of radiant exposure *H*, both inks have different graphs for everyone of them, as dotted line (*H* = 25.000 Wh/m^2) and dashed line (*H* = 250.000 Wh/m^2) noted. In this case, the maximum value of the relative spectral responsivity $s(\lambda)_{dm,rel}$ happens at 600 nm for the magenta ink; instead for green ink, they occur at 450 nm. Moreover, none correlation appears between the spectral reflectance or absorbance of coloured inks and their relative spectral responsivity $s(\lambda)_{dm,rel}$.

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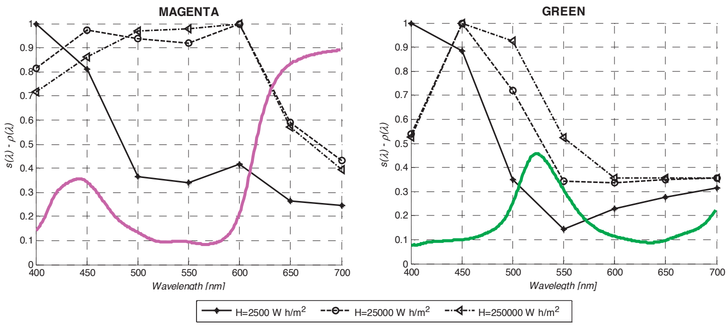

Figure 10 - Spectral reflectance (coloured solid line) and relative spectral responsivity $s(\lambda)_{dm,rel}$ (solid and broken black lines) calculated at several values of exposure H for magenta and green inks samples

4. Conclusion

In the Photometric Laboratory of the Padova University some coloured ink samples are put under accelerating aging test in order to investigate their process of fading. During the test, the spectral reflection coefficients of the samples are constantly monitored under several lighting conditions in terms of intensity and spectral components of the incident radiation. The colour differences ΔE of the samples between two successive measurements versus the radiant exposure H is analysed. The fading process can be represented by exponential function, where the coefficients K and τ are specific for every sample. From these $\Delta E - H$ graphs, the relative spectral responsivity $s(\lambda)_{dm,rel}$ of each colours inks is calculated.

The research doesn't confirm the reciprocity principle as described in literature, so the coefficients K and τ seem are depended from the value of radiant exposure H. Also the relative spectral responsivity depends from the value of radiant exposure H where it is calculated. For these reasons, further accelerated aging tests and counter-checks could be necessary to clarify the phenomenon. For this issue, a new accelerating aging chamber with LED sources which facilitate the luminous intensity control is under construction.

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Colour and light in the media architecture envelope: Kinetic and luminous effects on building façade

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Abstract

In the contemporary architectural project, the realization of media facades is growing up. In the collective imagination these systems refer only to an architectural skin made by electronic tools: large bright screens, video walls and architectural projection systems, very different from each other, but still always of luminous and informative type.

The media façade can change its image and, at the same time, its form, not only perceptually with the aid of digital artificial instruments or with the actual usual coloured coatings, but also with a "simple" movement of its components. These are panels and mechanisms more or less dependent on each other and with the building, poly or monochromatic, transparent or opaque, metallic or plastic, etc. Their movement can be created with purely kinetic systems (automatisms), hydraulic systems or pneumatic ones.

The aim of this contribution is to investigate how technologies and systems currently in use for the construction of mechanical façades (for kinetic, pneumatic and hydraulic systems) influence the perception of colour and light on the contemporary architectural surfaces and their interaction with the surrounding urban space. In this analysis we will include natural and artificial parameters and systems.

1. Introduction

The contemporary urban space seems to become a place to experiment all the technologies and materials suitable to communicate, through the used colours and the applied light systems. The planners put a lot of attention to the details that help bring to life the architecture with materials and technology able to cause reactions, interactions and interferences. The result of this evolution is expressed in architectural surfaces that have become important vehicles of colour and sound messages, where "colours are the way the surfaces appear. (...) Walls, screens and paper surfaces, plastic, aluminium, glass, fabric etc. have become important media" (Flusser V., pp.3-4.).

Dorfles argues (Dorfles G., pp.57-59) that the senses of modern man are undermined by the bombing of imaginative billboards and commercial television so that the contemporary environment is saturated with colour and light, 24 hours per day. It's also true as he says that the colour is vehicle of messages and codes.

We know that before the invention of writing, man communication was enabled through symbols and images: the numeric writing system was developed by passing through the stages of the pictogram, the ideogram, and then only as a last step we have moved to the phonogram (signs that represent sounds, such as the musical notation on the staff). In human history the transmission of knowledge by images was perfected by the frescoes, the mosaics, the carpets and the stained glass windows of the cathedrals. As the interior of a Gothic nave was illuminated by the colours of its stained glass windows, today, lights and colours produced by large-size display are reflected in urban development and in the surrounding landscape, creating what Virilio called the "Electronic Gothic of the Mediabuildings" (Virilio P., pp.7-8). In our age characterized by the information, the

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image has an even more important role because it seems to be the cheaper and faster media. The image is striking and instantly perceived by anyone, it is a means of information more effective than any other (narrative, music, etc...) Does it mean that we are going back to a primitive culture?

2. The perception of architectural surfaces

Until a few years ago and still today, in many suburbs or small towns, the perception of architecture is realized through a more or less skilful use of colours and decorations. The planners use traditional materials such as paints, colour marble, plaster, or more advanced materials such as films or polychromatic panels paste painted (glass or plastic).

In the contemporary architectural project, the media facades are growing up in number. In the collective imagination these systems refer only to an architectural skin made by electronic tools: large bright screens, video walls and architectural projection systems, very different from each other, but still always of luminous and informative type. So we think almost exclusively to a massive use of light to adjust the visibility and the perceptiveness of the architecture. To do this, the planners use the more advanced materials and systems that induce a sense of dynamism to the vision. Recently they use fibre optics, OLED and Neuroled. These are technologies that interact in an almost intrusive way on the perception of contemporary architecture through an innovative use of colour and light. Bernard Tschumi, noting that "most of the architecture has become a surface, an applied decoration, exterior appearance, paper architecture (or "billboard building", using the famous expression of Venturi)", asked himself: what distinguishes today's architecture from the design of billboards? (Tschumi B., p.186).

In reality a media facade can change its image and, at the same time, its form not only perceptually with the aid of digital artificial instruments or with the now usual coloured coatings, but also with a "simple" movement of its components. These are panels and mechanisms more or less dependent on each other and with the building, poly or monochromatic, transparent or opaque, metallic or plastic etc. Their movement can be created with purely kinetic systems (automatisms), hydraulic systems or pneumatic. An example of this technical solution is "Daisy World" experimental project by Thomas Nicolai, which uses a pneumatic mechanical system for handling coloured rubber components (or similar material) in the form of a daisy. In other cases they may be components whose movement is generated from natural sources such as wind or sunlight, as in the works of Ned Kahn.

3. The kinetic media-façade

The Kinetic media façade is classified inside the group of mechanical media façades. Those one are realized with kinetic, pneumatic and hydraulic system. Which kind of role has the Kinesis inside this specific topic of media façade?

In this research topic the meaning "kinetic façade" was taken from the Greek "κίνησις" (Kinesis): movement, action, motion. The best cultural references date back to the history of Futurist Art.

The Futurist utopia was represented by the city eternally dynamic. For Sant'Elia, the most representative Futurist architect, the architectural space is related to time, in a systemic project of the technical science of the machine.

The technological innovation in the contemporary architecture was realizing many

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experiments and applications using new materials and building systems. They are essentially linked to the mechanical sector.

For example, in the Peugeot Building project (Sacripanti, M. 1967, Milan) we may see the design of a dynamic facade system, like as a brise-soleil, and a media system. The building skin was a cladding system realized with metallic mobile panels.

In other more recent projects the claddings may be realized in different materials: glass or plastic panels that can move with kinetic or hydraulic system. These system envelopes are "kinetic cladding" or "kinetic façade", where the dynamicity was realized linking together mechanical component with sensor system that pick up the wind speed or the air temperature, or the solar radiation, and so on. An emblematic example is the IMA project, by Jean Nouvel in Paris.

Another type of mechanical system cladding may be the pneumatic system. This one is different from the Kinetic system, because of the use of different materials and components, they have another envelope design and they use some kind of gas (air or nitrogen). As an example we may remember the geodesic domes of Eden Project by Nicholas Grimshaw.

Than, the media envelope realized with hydraulic system are similar to the kinetic cladding. The hydraulic technology applied to the media façade is constructed with an hydraulic cylinder and a mechanical actuator that imparts a linear force to the system. In this way, the generated force gives movement to the system components of the façade.

A research, conducted by the author in the *Colour and Light in Architecture* Research Unit at University Iuav of Venice, showed that the realized media facades and the facades in developing phase may be classified according to the systems used to achieve them. The identified categories are: luminous facades, mechanical facades, liquid facades, facade's projections. Because of the vastness of the topic and of the current research, in this paper we will delimitate the investigation field only to the mechanical media facades. The aim of this paper is to understand how technologies and systems currently in use for the construction of mechanical facades (for kinetic, pneumatic and hydraulic systems) influence the perception of colour and light on the contemporary architectural surfaces and their interaction with the surrounding urban space. In this analysis we have included natural and artificial parameters and systems.

The envelopes tested were made either on existing buildings or on new construction. The research was conducted through a careful analysis of the state of the art, a literature survey and a cataloguing of case-history (about 100 realizations/projects). Each project was analyzed by classifying the architectural envelope in envelope-typologies (applied and integrated), identifying the types of interfaces (direct, indirect, separated), technologies and materials used to make it happen. The result of this contribution is to investigate three fundamentals topics:

1. the type of technologies and building systems currently in use for the construction of mechanical facades (kinetic, pneumatic and hydraulic systems);
2. how those media-system could influence the perception of colour and light on the contemporary architectural surfaces;
3. their interaction with the surrounding urban space.

In this analysis have been included natural and artificial parameters and systems. From this research we may argue that the kinetic envelopes mainly interface them with the building in separate or indirect way. It means that they aren't an enclosure component. They are mostly applied to an envelope located below them and with whom they interface. Thus they become a second skin with screening or communicative function. Their dynamism can be handled by electronic or electromechanical systems. In some recent testing their movement is caused by natural elements

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like air, wind, solar and so on. It may be noted that their development leaves open many possibilities that some investigators are conducting on prototype projects, especially connected to the sustainability of architectures.

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Safety Yellow: Studies on the spatial effect of colour demonstrated on the example of Ulmbergtunnel in Zurich

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Abstract

Safety Yellow is an attempt to explore the rules of spatial perception and the relationship between spatial form and human behaviour, in a psychologic or physiological sense. The focus is on the relationship between colour, light and spatial form. The Ulmbergtunnel is a two hundred and sixty metres long passage for pedestrians and cyclists between two districts. For both it is an insecure place as they share an only three and a half metres wide track for both directions (Figure 2). Can the introduction of colour change the perception of the tunnel in such a way that the connecting passage way, currently a non space, becomes an independent space with its own character that offers passers-by better orientation and thus a subjective feeling of security? The intervention enhances the tunnel, transforming it from a non-space connecting localities into an independent locality with its own characteristics. The dramaturgy of the colour created by the sequence of increasingly light tones turns the unpleasant tunnel into a positive experience for the passers-by who are attracted by the light. The pedestrians and cyclists participate in an experience which renders their perceptual capacity anew (Figure 1).

1. Orientation

Due to its inhospitality the passage constitutes an unacceptable space especially for pedestrians: It is difficult to appraise distances or to locate the own position. The monotony of the space enhances the impression of the tunnel so that the isolation from the outside world turns into a negative experience. Can colour manipulate the space so that the lacking relationship with the outside world is compensated?

Studies on the spatial effect of colour analyse the relationship between colour, light and spatial form. Which surfaces define the spaces and how do they influence their perception (Figure 3)? How do tunnel and colour space relate to each other (Figure 4)? How can colour establish safety and clarity and at the same time oppose monotony?

The dominant topic of the tunnel as a transitory space is chosen as the central theme for the new colour design. It emphasizes the singularity of the tunnel space as a passage way and directs the attention of the passersby towards the movement itself.

My colour intervention starts off with the existing medial strip which separates pedestrians from cyclists. The attention is drawn to the yellow highlight, the yellow medial strip, which increases slightly.

When reaching the bend, the most precarious area, the medial strip is significantly modulated: The line widens to become a long stretched surface. The attention of the pedestrians and cyclists is drawn in time towards the neuralgic zone.

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Figure 1. Tunnel Crossing.

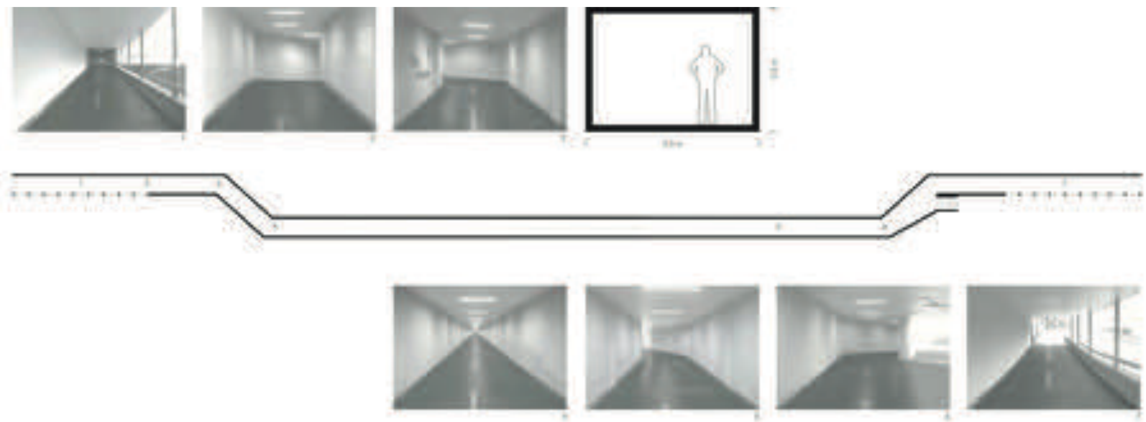

Figure 2. Ulmbergtunnel, Length: 260 metres, Width: 3.5 metres.

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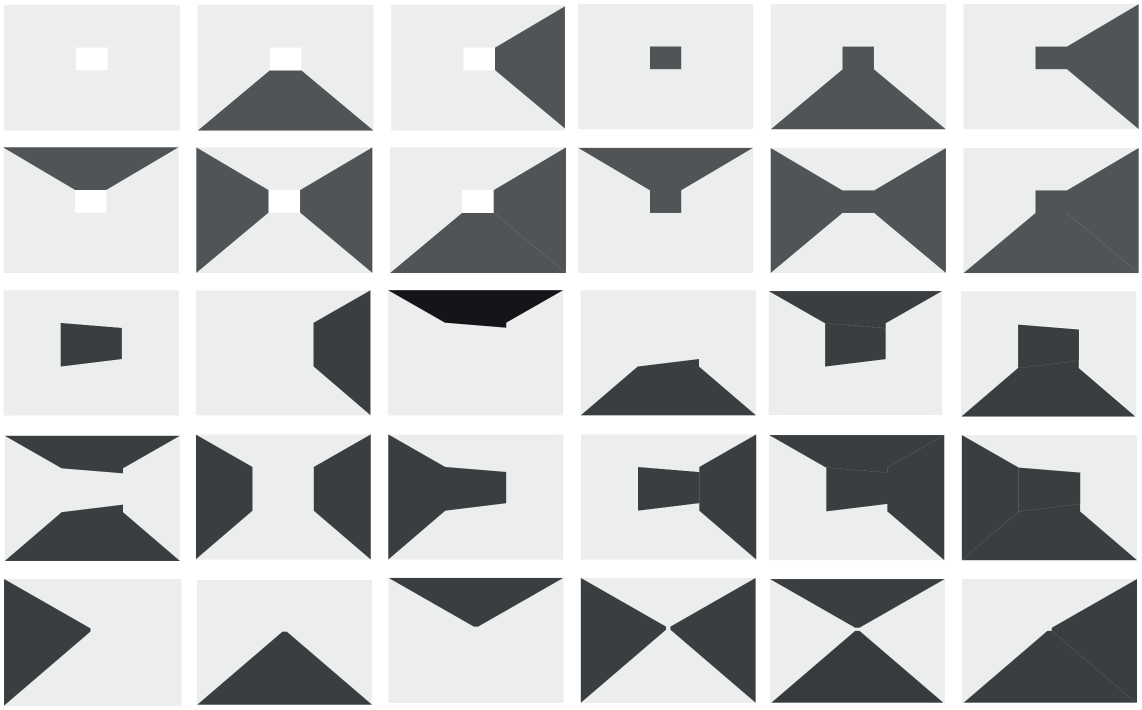

Figure 3. Studies on the spatial elements: Entrance, Exit, Bend and Straight Tunnel Passage.

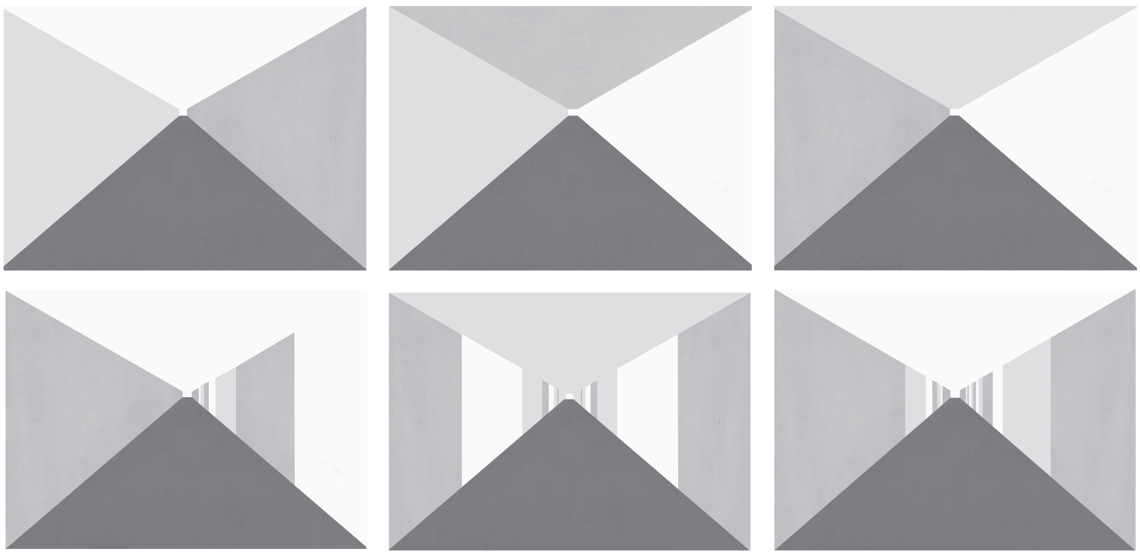

Figure 4. Studies on the spatial effect of colour: Straight Tunnel Passage.

Figure 5. Changing of monochrome surfaces when exposed to different kind of illuminations.

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One enters the long straight passage, the surface moves from the ground onto the wall. This slowly, continuously expanding wall surface directs us through the currently straight tunnel corridor. It directs our attention to the centre of the tunnel which then becomes the focus. Like this our perception of the tunnel is split into two halves.

Reaching that center, the yellow colour surfaces start to completely define the space. They appear like a plastic form, marking a "space in the space" in the middle of the tunnel. Mirror-inverted to the first half, in the second half, the impression of the plastic form is first reduced to a yellow surface and finally to the medial strip.

Tunnel and colour space are related to each other. Our perception differs in figure and ground. The real tunnel space coated in neutral grey composes the background and is not perceived. In contrast, the new yellow colour space comes to the foreground. The intervention introduces a rhythm to the transition of the tunnel. The accentuated movement and the focus onto the center of the tunnel facilitate a better orientation in the underground. The feeling of insecurity disappears.

2. Light

> *The beholding of the light is itself a more excellent and a fairer thing than all the uses of it. (Bacon 1620)*

Light and shadow construct spatiality. Apart from exit and entrance, there are no openings in the underground tunnel which would allow for daylight to penetrate. How to achieve the impression of natural light, creating the illusion that the underground space opens itself to the outside world (Figure 5)? In which context does the colour yellow show its substance or its lightness?

The illusion of light and shadow produced by colour effects the construction of spatiality. At the same time the underground space gets an illusionary opening to the outside world. In its center the three tones of yellow, based on the safety yellow of the medial strip, begin to react to each other. Light and shadow surfaces arise. We get the feeling to transit through a plastic form. The white coated ceiling enforces this effect by creating an impression of daylight in the center of the tunnel and an association of an opening towards the outside world. The tones of yellow recall daylight spots, in contrast to the dark asphalt floor which seems to be in the shade. The most deeply located place becomes the most light-coloured. The center of the tunnel is transformed into a luminous source, effecting the association of a light-flooded space. The dramaturgy of the colour created by the sequence of increasingly light tones turns the unpleasant tunnel into a positive experience for the passersby who are attracted by the light.

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The difference of color preference between color patches and products

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Abstract

The aims of this study are (1) to compare the order of color preference between color patches and color mugs and (2) to see the difference between the most preferred color and the chosen mug. To fulfill these purposes, this study conducted two experiments. The observers were required to arrange color patches and color mugs in order of color preference. After finishing the order task, each observer was allowed to take away one of the mugs as his/her gift. The results showed the preference order for color patches and color mugs was consistent. However, it was found that half of the observers took away the color mug differed from their most preferred color. The results showed the observers considered the color-shape appropriateness and wanted to have a unique color appeared on their own mug.

1. Introduction

Many studies [1-14] conducted the experiments to see the color preference. As the literature indicated, the brown and black colors were most disliked colors. But the preferred colors varied. For example, light green and blue colors proposed by Lee and Luo[1], yellow and blue colors by Liou *et al.*[3], white, pink and red colors by Liu and Lee[4] and white, red, blue and pink colors by Chen *et al.*[5]. However, in these studies, the color samples used were color patches. This made the results of color preference impractical. For product designers, they need to understand how the colors appear on the product appearance rather than on color patch. Hence, the current study intended to see the difference of color preference between color patches and color product. In this study the color mugs were used.

2. Experimental plan

To understand the color preference, two experiments were conducted. Fifty observers were invited to take part in Experiment I, including 26 males and 24 females with an average age of 22.6 years old. Thirty-one observers were participated in Experiment II, including 14 males and 17 females with an average age of 22.0 years old.

The observers were required to arrange 11 color patches and 9 color mugs in order of their color preference in Experiment I and II, respectively. After finishing Experiment II, the observers were allowed to take away one of the mugs as their gift. At the meantime, the researchers will chat with the observers to ask them why.

The 11 color patches used in Experiment I covered 11 basic color terms [15], including red, orange, yellow, green, blue, brown, purple, pink, white, black, and gray colors. Each color was produced according to their boundaries in CIELab space [16-18], and applied onto 8 cm × 8 cm square shape, as shown in Figure 1 (a). The 9 color mugs used in Experiment II included red, orange, yellow, green, blue, brown, pink, white, and black colors. These colors were measured by

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a GretagMacbeth® Eye-One. The CIELAB values were calculated under CIE D65 and 1964 standard colorimetric observers, as shown in Table 1.

These experimental samples were presented on an office desk near to windows. The samples were illuminated under the indirect daylight. During the experiments, the illuminance levels ranged between 1030 and 4622 lux and the color temperature ranged between 5147 and 6499K.

Table 1: The CIELAB values for the color samples

	color patches					color mugs				
	L*	a*	b*	C*	hue angle	L*	a*	b*	C*	hue angle
Red(R)	33	53	41	67	38	37	53	38	65	35
Orange(O)	57	40	71	82	60	53	48	54	72	48
Yellow(Y)	71	19	95	97	79	76	6	62	62	84
Green(G)	34	-29	28	40	137	70	-14	57	59	104
Blue(Bl)	37	-16	-32	36	243	11	2	-18	18	275
Brown(Br)	33	14	10	17	36	14	16	16	23	44
Pink(Pk)	67	22	7	23	18	68	20	13	24	32
White(W)	93	-2	-1	2	212	83	-1	5	5	100
Black(Bk)	16	0	-1	1	260	4	1	1	1	60
Purple(P)	31	12	-33	35	289					
Gray(Gy)	61	-2	3	4	116					

(a) *(b)*

Figure 1: The color patches and mugs used in the experiment.

3. Results

The order data obtained from experiments were converted into scores. The scores for each color were averaged to be the mean results. To see how well the individual observer's data agree with the mean results, RMS (root mean square) was used. For perfect agreement, RMS value equals to zero. The results showed the RMS values ranged between 2.23 and 3.86 in Experiment I, 1.92 and 2.86 in Experiment II.

In comparison with the previous studies [3-6, 19], the RMS values here seem higher. But considering the method of collecting data, the method used here can be seen as 11-step and 9-step categorical judgment. It is reasonable to have higher RMS here. This reflected that each observer's judgments agree with the mean results.

In order to compare the order of color preference between color patches and color mugs, the mean results were used to rank colors in order of color preference. The results are illustrated in Figure 2. It can be seen that the order of color preference was consistent between color patches and color mugs. The correlation coefficient is 0.77.

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The preferred colors for both patch and mug were white, black, red and yellow colors. The most dislike color was brown color. Green color was found to have biggest change in order of preference.

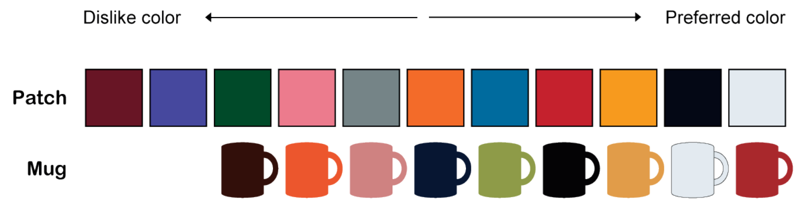

Figure 2: The color preference order for color patch and mug.

After finishing the experiment, the observers were allowed to take away one of the mugs. We expected the mug chosen would be the most preferred color. However, the results were surprisingly different. In thirty observers, only 14 observers took away the most preferred color mug. The rest 17 observers took away different color mug.

We reviewed these 17 observers' reasons and classified similar reasons together. The frequencies of each reason are summarized in Table 2. Note that some observers provided several reasons.

In Table 2, it can be seen that most observers considered the color-shape appropriateness. Some observers wanted to have unique color appeared on their own mug. A little observer picked the color because the drinks and usage place.

Table 2: The frequencies of the reason why not pick the mug with most preferred color.

The reason why not pick the mug with most preferred color	frequency
The observers picked the color that is suitable for the mug	10
The observers picked the color that is rare to be seen in daily life	8
The observers picked the color that is drink-related.	2
The observers consider the usage place	2

4. Conclusion

This study conducted two experiments to see the color preference order on color patches and color mugs. The results showed that (1) the preference order on color patches and color mugs was consistent and (2) half of the observers want to own the color mug that is differed from their most preferred color. The reason for not choosing the mug with most preferred color can be concluded that (1) the observers considered the color-shape appropriateness and (2) the observers wanted to own the color mug differed from others.

Acknowledgments

This study is funded by the National Science Council in the Taiwan. The project number is NSC 97-2221-E-036-034.

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The use of fundamental color stimulus and artificial neural network to enhance the performance of Color Profile Management Systems

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Abstract
The core of ICC profile is a look up table (LUT) which maps a regular grid of device- independent colors and converts it into the color space of the printer. There are various methods to estimate such values. In the present investigation use is made of an artificial neural network by the aid of the fundamental color stimulus. The result shows that their combination queally enhances the prediction.

1. Introduction
A popular standard color management system for controlling color reproduction is the ICC color profile [1,2,3]. ICC color profiles defined RGB printers are based on look up table (LUT) in which the input data is RGB and the output data is Lab or vice versa. In a profile making process, certain RGB values encompassing a large gamut are printed and then their respective reflectances are measured by a spectrophotometer which are subsequently converted to certain color coordinates such as the CIELAB1976 coordinates. Then the rest of the LAB values are predicted by various techniques [4,5,6,7,8,9,10,11,12,13,14,15,16,17]. The conversion and prediction technique in profile making softwares are very important and making better predictions are considered those techniques to be better techniques.

In the present investigation attempts were used for the first time to make use of fundamental color stimuli (Rfcs) in an artificial neural network in order to enhance the performance of the conversion/prediction techniques.

1.1. LUT neural network based on R_{fcs}
An artificial neural network is utilized when a complex non-linear relationship between exists between input and an output as is the case for color profiles. However, in a LUT method based on a linear technique for instance the cube [18], the relationship between inputs and outputs is linearly calculated for 8 nearest neighbor therefore the errors are not only large due to assumptions of linearity but also the errors will never be smaller than the differences between such neighbors.

To overcome such a problem in a LUT color profile prediction, use is made of artificial neural network to nullify the linearity assumption aided by utilizing fundamental color stimulus(R_{fcs}) to minimize errors in the predictions. Fundamental color stimulus (R_{fcs}) was defined by Cohen and Kapoff [19,20] based on Wyszecki's hypothesis [19,20]. In the present investigation RGBs are converted to R_{fcs} by the use of matrix Q as defined by Cohen and Kapoff and used as inputs for an artificial neural network. The outputs for such a neural network were R_{fcs} derived from measured reflectances of printed color patches.

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In this way a trained artificial neural network can predict much improved results (i.e. lower color differences between actual and predicted values).

2. Experimental

An hp D7560 printer was used for printing throughout the experimentation of color patches i.e. -125 samples and 1000 samples were used. In the first series (i.e. 125 samples) each dimension of RGB color space was divided into 5 values and in the second series (i.e. 1000 samples), here were divided into 10 values. R versus B, B versus G or G versus R are plotted in 2 dimensions are shown in figure 1.

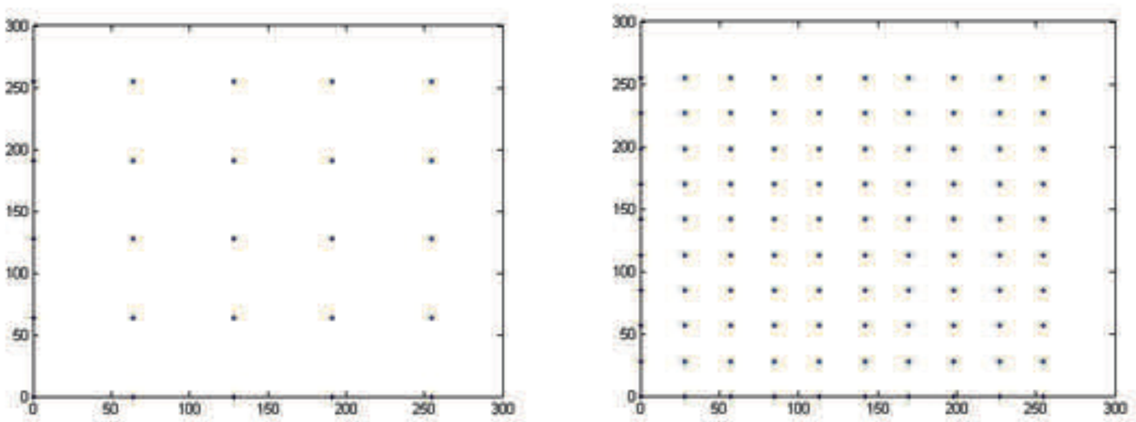

Figure 1. two dimensional plots of alternate color coordinates (i.e. R/G, B/G and G/R) for (left figure) 125 samples and (right figure) 1000 samples

For testing and comparing techniques, 1000 random color patches in the RGB space were printed.

3. Result and discussion

In this article, three methods –LUT (based on cube, LUTC), artificial neural network based on Rfcs ($ANNR_{fcs}$) and LUT- neural network based on Rfcs ($LUT_{ANNRfcs}$) were compared. Results for two series of samples are shown in table 1.

According to "specification ICC.1:2004-10" [1], computations are based on a specific observation (CIE Standard 1931 Colorimetric Observer – often known colloquially as 2 degree observer), relative to a specific illuminant (D50), and measured with a specified measurement geometry (0/45 or 45/0) that eye-one instrument is used.

Table 1. comparison of three prediction techniques i.e. (LUTC, ANNRfcs, LUTANNRfcs) for 125 samples trained

Method	**DE2000 (Mean)**	**DE2000 (Max)**	**DE2000 (Median)**
LUT (cube)	2.13	8.54	1.92
Neural Network based on Rfcs	2.79	9.79	2.61
LUT- Neural Network based on Rfcs	1.78	6.96	1.50

Table 2. comparison of three prediction techniques i.e. (LUTC, ANNRfcs, LUTANNRfcs) for 1000 samples trained

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Method	DE2000 (Mean)	DE2000 (Max)	DE2000 (Median)
LUT (cube)	0.79	3.52	0.67
Neural Network based on Rfcs	1.78	8.32	1.62
LUT- Neural Network based on Rfcs	0.70	2.86	0.59

As is seen, the results for LUT- neural network based on Rfcs shows great improvements.

4. Conclusion

The experiments show that using LUTANNRfcs is better. For LUTANNRfcs mean of DE for 125 samples is 1.7793 while for LUTC, it is 2.13 means the answer is about 16% better. For 1000 samples for LUTANNRfcs , meaning of DE is 0.6965 and for LUTC is 0.7884 that means the outcome is about 12% better. It is shown that for less trained samples results are more better than other methods.

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The effect of background lightness on perceptual color difference

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Abstract

One of the parameters which influence the perceptual color difference is background however the circumstance and the kind of its effects have not been well identified yet.

In the present study, the effect of background lightness on perceptual color difference was evaluated using a white, a middle gray and a black background. A set of printed color samples were prepared in 4 color centers closed to red, yellow, green and blue. 16 observer including 8 women and 8 men carried out the visual assessment with common gray scale method. All the pairs were assessed against the first background and then the experiments were repeated against the second background and so on.

The results show that, background lightness obviously influences the perceptual color differences. Furthermore, this effect depends on the color center of the samples. All the samples show their lowest color difference on the black background. The visual color difference of blue and red pairs is averagely decreased by decreasing the background lightness. They show the maximum color difference values against the white background. For the green samples, the color difference against the gray background is higher than the white one. The yellow pairs behave almost between red and green.

1. Introduction

During decades it is usually of interest to know parameters which have an effect on visual color difference. The CIE Technical committee 1-28 on Parameters Affecting Color Difference Evaluation (1993) has introduced a set of 6 parameters which influences the perceptual color difference. These parameters include sample's size, separation between sample pairs, luminance, magnitude of color difference, sample's texture and background color. Although it has been well known that these factors can affect the color difference evaluations, the circumstance and the kind of these effects have not been well identified yet. Guan & Luo (1999a) investigated the change of color differences via four viewing parameters: lightness of background, sample separation, luminance, and magnitude of color difference. They reported that the viewing parameters investigated had slight effect on the perceived color difference. The largest discrepancy was found between the gray and white backgrounds. The same pair of samples shows averagely a 30% larger color difference against a white background than against a gray background. Xin & al. (2001) studied five types of parametric effects including background colors in assessing color difference. It was shown that much larger parametric effects of 42% and 26% were associated, respectively, with green sample pairs assessed on the green background and blue samples pairs assessed on the blue background. The color of background in these two cases was very close to the color center of the assessed pairs, which may indicate the crispening effect. Gaun & luo (1999b) carried out another experiment using three different backgrounds i.e., white, mid-gray, and black. They showed that the largest effect was only 14% between the white and gray background conditions.

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Cui & al. (2001) investigated the effect of changes in viewing parameters on perceived color differences using Cathode Ray Tube (CRT) color samples. The effect of background was investigated using a set of backgrounds i.e. mid-gray, white, black, gray, red, yellow, green, and blue. It was found that a sample pair viewed against a white background shows a larger perceived color difference than when viewed against other colored backgrounds, with the exception when the background color is close to that of the samples. However, this effect is small; it is consistent for all color centers.

In the present study, the effect of background lightness on perceptual color difference is evaluated applying a white, a middle gray and a black background.

2. Experiments

In the present study the effect of background lightness on perceptual color difference were evaluated. To this end, three backgrounds including a white, a middle gray and a black card were chosen. Samples were prepared in 4 color centers closed to red, yellow, green and blue using a Hp Photosmart Pro B8850 photo printer. Four specimens were produced for each color centers. The spectral reflectances of the printed colors were measured using a GretagMacneth Eye-One spectrophotometer in the range between 380nm and 730nm. Figure 1 shows the spectral reflectance of the four color groups. Table 1 indicates the corresponding CIELAB values of the samples under D65 illuminant and 1964 CIE standard observer.

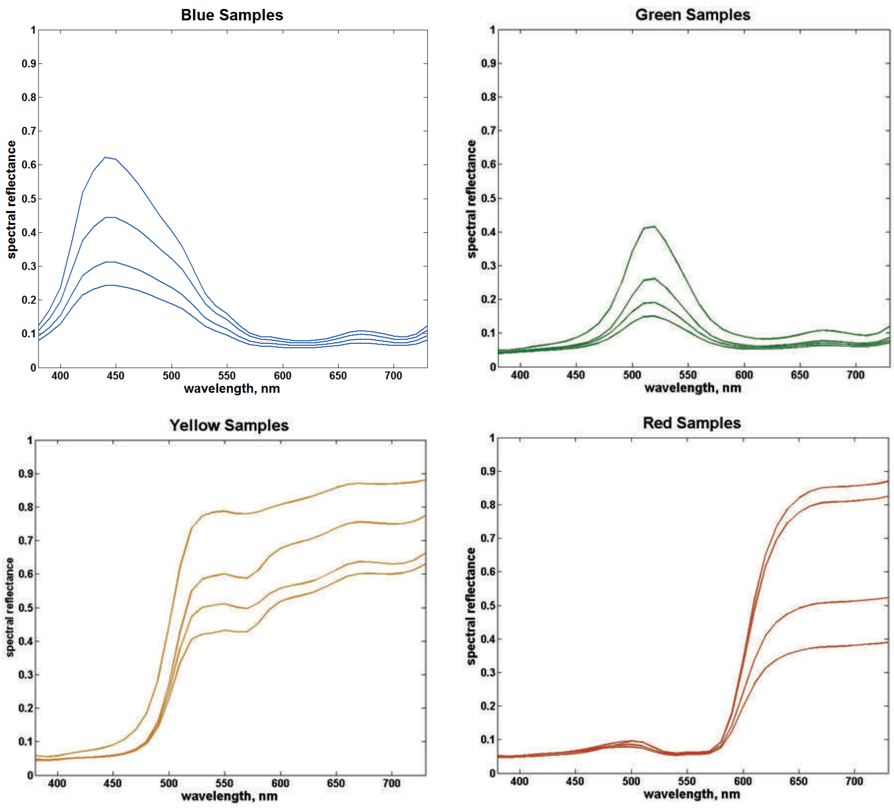

Figure 1: the spectral reflectance of the four samples in each color group

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Table 1: CIELAB values of the samples under D65 illuminant and 1964 CIE standard observer

b*	a*	L*	sample
-46.46	-5.36	52.56	**Blue1**
-37.23	-8.15	48.49	**Blue2**
-30.26	-7.50	43.25	**Blue3**
-26.25	-6.83	39.65	**Blue4**
24.35	-48.51	53.78	**Green1**
18.41	-37.68	44.40	**Green2**
13.63	-29.19	40.09	**Green3**
11.03	-24.08	36.76	**Green4**
77.47	-6.20	86.88	**Yellow1**
76.35	0.42	78.20	**Yellow2**
68.65	-1.28	73.18	**Yellow3**
63.65	2.07	69.48	**Yellow4**
29.63	49.49	47.28	**Red1**
25.54	48.00	46.60	**Red2**
17.58	37.27	41.42	**Red3**
13.26	31.08	38.47	**Red4**

Four sample pairs including 1-2, 2-3, 3-4, 2-4 were selected for color difference assessments. The visual assessment was conducted using a VeriVide light cabinet with an approximately 0/45 illuminating/viewing geometry under the D65 simulator. 16 observer consisted of 8 women and 8 men carried out the visual assessment with common gray scale method according to ISO A02 standard. For each background, all the pairs were evaluated continuously. In the other way, all the samples were assessed against the first background and then the experiments were repeated against the second background and so on. Each observer was asked to estimate the magnitude of the perceived color difference in a test pair in terms of the gray numbers 1-9. The observers were permitted to use mid-number by a step value of 0.25. For instance, if a test pair had a color difference between the pairs of gray2/standard and gray3/standard, and it was closer to the first pair, then the result should be reported as 2.25. The gray scale rating for each pair was converted into the corresponding visual color differences based on CIEDE2000 (1:1:1) formula (Luo & al. 2001) using curve fitting method.

3. Results and discussion

Figure 2 shows the obtained perceptual color differences for each sample on three backgrounds. In addition, Figure 3 indicates the mean of color difference for 4 pairs in each color centers on three backgrounds. As illustrated, background lightness obviously influences the perceptual color differences. In addition, this effect depends on the color center of the samples. All the samples show their lowest color difference when viewed against the black background. It can be seen that, the perceived color difference of blue and red pairs is averagely decreased by decreasing the background lightness. They show the maximum color difference values against the white background. For the green samples, the color difference on the gray background is larger than the white one. The yellow pairs behave almost between red and green.

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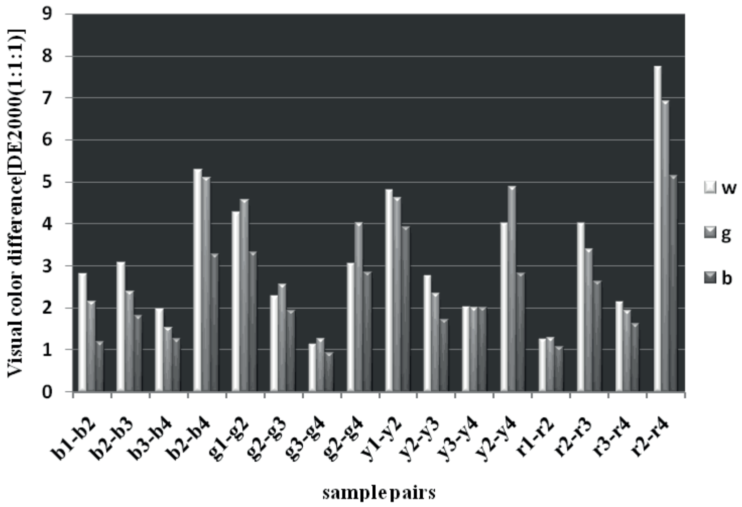

Figure 2: The bar line of the perceptual color difference for each pair.

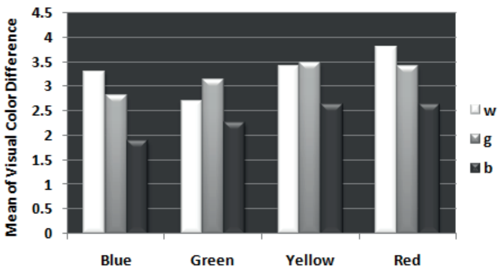

Figure 3: The bar line of the mean of perceptual color difference for each color center.

4. Conclusion

In this research the effect of background lightness on perceptual color difference were evaluated for three backgrounds: white, middle gray and black. The results show that, background lightness obviously influences the visual color differences and this effect depends on the color center of the samples. All the samples show their lowest color difference against the black background. The perceived color difference of blue and red pairs is averagely decreased by decreasing the background lightness. For the green samples, the color difference on the gray background is larger than the white one.

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Color as a light source and the receiver's participation

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Abstract

In the field of New Technologies of Communication (NTC) some artworks stand out because of their characteristic way of handling materialized color by light sources. Such light sources are poetically articulated by the artist, and they can enhance the dialogue between artwork and receiver. The aim of this article which resulted from academic research is to present how the light-sourced color manipulated by the artist using NTC technological devices can promote an environment of synergy and exchange of information with the receiver. Once the concepts of color, light and open work are set, some artworks are analyzed in order to identify the several ways color from a light source can be manipulated by the artist, considering its active and fundamental role in the dialogue between receiver and artwork. Based on certain concepts, it is expected to be possible to apprehend how the artist used color poetically as a light source in interactive installations produced by NTC in order to seduce the receiver into an exchange relationship with the artwork.

1. Corpus of the research

In order to achieve the goal of this article, it was necessary to know the historical panorama that laid the foundation for the appearance of the light-sourced color; to do so, the first part of the article aims at recovering the main scientific contributions to the study of the light-derived color, and the intention was to highlight how such contributions are at the basis of the digital artistic experiments. Those contributions, presented in chronological order, brought to light the relevance of the studies of the following scientists: Isaac Newton (1642-1727), Johann Wolfgang von Goethe (1749-1832), Thomas Young (1773-1829), Hermann L. F. von Helmholtz (1821-1894) and James Clerk Maxwell (1831-1879). A tendency to direct the study of color towards its application as a light form was perceived from the investigation of such theories, and those theories, which are considered landmarks in the history of the chromatic study nowadays, came to influence artists and artistic movements. The artists influenced by those studies and discoveries that caused a change in the way color was understood and seen would "experiment" by themselves, and they would give a new sense to color through their poetics, on the basis of the current scientific state of the art. In the scientific community, color as a light source started to be seen as a physical characteristic whose relationship with man is fundamentally important. In the field of New Technologies of Communication (NTC), the existence of some experiments which are possible through the manipulation of the materialized color by light sources is obvious. So, they can favor the synesthetic dialogue between artwork and receiver when they are poetically articulated.

The second part of the article presents information which includes the study of color as a phenomenon, considering that its physical, physiological, psychological and cultural aspects are essential for understanding the specific study of color. The importance of perceiving color not only as a physical element, but also in its subjective character was emphasized. The accomplished survey of the several aspects culminates in the introduction of color as a light

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source, and it emphasizes its properties and characteristics, which makes it understandable the gradual passage of the use of the color of the object to the color as a light source, in the context of art. The understanding and the gradual use of color through its sense aimed at reaching the receiver and making him/her an active participant of the artwork. Throughout history, artists have used the knowledge they got about composing discoveries and harmony of colors from scientists, and they have transported such knowledge to the artwork through painting. The repertoire built up in the field of the chromatic theories supported the artists who started to use color more and more intentionally and in a calculated way. Little by little, such knowledge influenced the occurrence of artistic movements that tightened the ties between the scientific and the artistic field thanks to the fact that they were open to this kind of information. The artists started to use color more and more so as to capture the observer´s attention, and this observer is going to take an active role in the artwork. Besides, the color materialized by the light in the artists´ hands would take a role of meaning greatly dependent on the participant. Its articulation as both instrument and artistic device was only possible thanks to the progressively close relationship between science and art, which resulted in technological discoveries that amplified the poetical expressiveness along the time.

The third part of the article deals with capturing the spectator´s attention in the passage from the classical to the non-classical art: it shows how the spectator moves from the role of spectator to that of *interator*, that is, the role of a transforming agent of the artwork itself, because of the possibility of being incorporated in the reception not as a person who merely enjoys the artwork, but as a transforming agent himself. For that reason, we looked into the concept of "open work" (Eco, 2003) to make clear the role the receiver has played in the passage from participation to interaction (Popper, 1988). We found out how the panorama of the spectator´s participation, which has been more and more active, reassures the concept of "open work" that, in this case, has been increased by the multiplicity of interpretations and by the ambiguity of meanings which are favored by the mediation of the color as a light source. Different kinds of opening and of levels of participation from the receiver were investigated (Tavares, 2000), and the impact caused by the use of different techniques and technologies in the context of the artistic creation was taken into account. This being the case, and considering the mechanical, electronic and digital point of view, as well as the point of view of craftsmanship, it was emphasized how the interaction of the artwork through the use of color could gradually develop, and color assumed the main role as a mediator between artwork and receiver. The use of new electronic technologies established different possibilities for the public to participate in art. The artist has in hand a variety of new technologies to work with light. These procedures of generating images allow different potentialities of expression. In the present digital experimenting, art, science and technology mix more and more as a mechanism to make it possible for the receiver to insert himself as a way to reach metalanguage, to show creativity and to guarantee the transgressing use of the means. The use of color as a light source and its process of production are invariably linked to the relationship between science and technology, and it is impossible to separate them. Therefore, the poetical way of operating the digital means reveals the transition from the use of the color of the object to the color as a light source. The artist proceeds to define the color from a light source as an element mediating the process, and he/she uses it as a link in the communication between artwork and receiver.

In the fourth part of this article, using the concepts discussed, it was possible to clearly and precisely examine three pieces of artwork that were produced on the basis of NTC and that have used color as a light source in order to insert the receiver in an instantaneous participation. In this part, from the context of the pieces of artwork studied, we intended to identify the different ways

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color from a light source can be manipulated by the artist, considering the role of color as essential and active in the dialogue between receiver and artwork. Using the concepts referred to, the investigation of the pieces of artwork taken on from the study of the dialectics between casual versus controlled, individual versus collective, projected versus emitted, aesthetic information versus semantic information, material versus abstract, and the interviews of the artists who made each one of the pieces of artwork, it was possible to understand how they used color poetically as a light source in interactive installations produced by the NTC in order to seduce the receiver to an exchange relationship with the artwork. The pieces of artwork studied are the following ones: *Colour by Numbers* (2006-2007) by Erik Krikortz, Loove Broms and Milo Láven; *Forest of Light* (2009) by Christina Mejbom and Line Langballe and *D-Tower* (2004-2011) by Q. S. Serafijn and Lars Spuybroek. Throughout this fourth part and focusing the pieces of artwork studied, we noticed different ways by which light-sourced color was used poetically by the artists so as to establish a dialogue with the receiver, whose participation was then favored, and who was seduced by the use of the senses. In such cases, the receiver updates the artwork through a feedback process, and he/she incorporates new meanings to it. We could verify that the conditions given to the *interator* to modify the structure of the artwork depend on the level of openness that piece of art proposes, and that openness is directly conditioned by the technological mechanism associated with the poetic proposal (Tavares, 2000). A reactive piece of artwork is characterized by limitation in the reorganization of its data, in opposition to a really interactive piece of artwork, which guarantees the receiver´s action over its structure, by means of different reorganizations from the articulation of its variables (Tavares, 2000). However, the artists´ poetic proposals try to reverse this technological limitation by promoting the receiver a sensitive experience relative to the artwork. The selected pieces of artwork differ from each other in relation to the levels of participation and in the ways they present themselves. However, they get closer to each other due to their poetic quality, because they try to capture the receiver and to lead him/her to produce meanings through the use of light-sourced color, as they make their latent and sensitive effects rise. When it is poetically worked, the exploration of the construction of senses, meanings and significances through light-sourced color presents itself as a very rich and ever increasing practice in the artistic experimenting with digital media. Due to the fact that it is a basic language which develops in association with personal and cultural meanings, its effects on man tend to be unique and sensitive. From the pieces of artwork studied, we realized the importance of the artist´s poetic ideas to reverse the limitations imposed by technology; such ideas allow him to promote the production of senses. When the artist does so, he/she both facilitates and creates specific strategies that make the receiver recover the artist´s poetic ideas when this receiver accomplishes the dialogue with the artwork (Tavares, 2000).

2. Final considerations

From what was presented in this article, we conclude the light source was a new datum introduced little by little in art. Its use is associated with the impetus of change resulting from the artists´ interest in adopting the most recent scientific discoveries. Such a trend, that is usual among artists from the digital era, is historically based on the studies that paved the way for scientific and technological development. The technological devices resulting from that development were followed closely by the artists, who tried to adapt them as they arose, so as to satisfy their poetical proposals at the moment their artwork was produced. Color as a light source was one of the elements used by the artists, it showed up through artificial means, and it went along with new

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ways to be articulated and manipulated, together with the technological progress, which makes it a stressing characteristic in the artwork produced by NTC.

It has to be stressed that the color from a light source, in opposition to the color-pigment, assumes a much bigger intensity, thus involving the receiver more effectively. In the poetic proposals that were studied, we found out the importance of the information provided by the color as an element that facilitates the dialogue with the receiver. From the point of view of interaction, these pieces of artwork facilitated the dialogue with the receiver and favored the production of a unique and sensitive experience. We could, therefore, realize the importance of the use of color as a way to insert the receiver once we consider the presence of the information provided by the color as something that makes that poetic proposal dynamic and real. Finally, we found out that depending on the artist´s poetic proposal, it is possible to involve the receiver making him/her act together with the artwork in a playful and unattached way. In this sense color helps this total of involvement guaranteeing – if it is used according to its physical, physiological and cultural characteristics – the effects of the strategically built poetic ideas. Therefore, color ends up by defining the sense of the artwork, thus affecting the participants sensitively, even if they are not prone to a reactive dialogue.

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Multispectral imaging system with multiplexed LED illumination for spectral and color measurements

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Abstract

This paper shows the characterization of a multispectral system that uses a cluster of light-emitting diodes (LEDs) as illumination source to perform reflectance measures. The system has two modules. The first module covers the range of wavelengths from 350 to 950nm and the second one from 950 to 1650nm. The spectral emission and temporal behavior of the LEDs are experimentally measured. Furthermore, the spatial non-uniformity of the illumination field together with the imaging sensors is evaluated and corrected. The performance of the system for the reconstruction of spectral reflectances is analyzed by simulating ideal conditions and realistic ones adding noise. The results show that a rather good performance of the setup is expected. However, they also reveal a difference in the performances of the two modules, being that of the second one poorer due to the fact that it has a lower number of LEDs with a wider spectral emission covering the near-infrared range.

1. Introduction

Multispectral imaging is a field with a wide range of applications because of its capacity of offering spectral information with high spatial resolution; it extends over industrial problems as well as biological ones passing by arts, pharmaceutical and many others, Sheth et al. (2009); Vilaseca et al. (2008) . A multispectral system can be implemented in different ways and recently the development and accessibility to LED technology has become an attractive alternative to be used in these systems, Brydegaard et al. (2009). Colored LED elements have narrow-spectral emission and are available in several wavelengths over the different spectral ranges of ultraviolet (UV), visible (VIS) and near-infrared (NIR). Therefore, they allow lighting the sample with a large number of specific wavelengths or customized combinations of them in a fast way and in synchrony with the imaging sensors used. Following this idea, this work shows the characterization of a multispectral system with LED illumination. This characterization was carried out with experimental measurements of the temporal behavior of the LED emissions; with the correction of the spatial non-uniformity in the illumination; and the evaluation of the system performance in spectral reflectance estimation through simulations of ideal and real noise conditions of operation, for which the pseudo-inverse method has been used, Vilaseca et al. (2006). Different metrics were used to quantify the system performance in the simulations of reflectance reconstruction.

2. Experimental setup

The experimental implementation of the multispectral system has two different modules. The first module consists of a monochrome CCD camera with 12 bit depth, 1392 x 1040 pixels and 16 groups of LEDs where each group, consisting of four LEDs which were equi-spaced along a ring, has a specific central wavelength of emission. They cover the wavelength range from 350nm to

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950nm. In a similar fashion, the second module has an InGaAs based camera with 14 bit depth, 320 x 246 pixels and 7 groups of LEDs. This module covers the range of wavelengths from 900nm to 1650nm. Table 1 contains the measured spectral descriptive data for each LED element (Peak wavelength and full width at half maximum [FWHM]). Figure 1 shows one of the modules of the system.

Table 1. Spectral data for the LED elements comprising the illumination source (Peak wavelength and full width at half maximum [FWHM]). All data are given in nanometers (nm).

Module 1				Module 2	
Peak wavelength	**FWHM**	**Peak wavelength**	**FWHM**	**Peak wavelength**	**FWHM**
373	9.5	404	15	955	51
432	17	461	22	1071	53
500	32	535	34	1202	88
593	15	634	16.5	1297	89
665	21	693	23.5	1451	122
728	24	761	26	1540	126
801	28	835	31	1630	111
874	45	903	41		

3. Methods

3.1 Temporal characterization

The emission of all groups of LEDs was characterized as a function of the time in order to establish the necessary time to obtain a constant and stationary illumination over the samples.

3.2 Spatial characterization

The aim of the spatial characterization was the correction of the spatial non-uniformity of the imaging sensor together with the light source used, in our case the ring of LEDs. For it we used a flat field algorithm based on an offset and gain matrices proposed by de Lasarte et al. (2007), which takes into account a dark image and a base correction image with a mean digital level placed in the middle of the linear response range of the cameras to correct the raw image acquired.

3.3 Pseudo-inverse model to estimate reflectances and metrics for spectral evaluation

There are several methods to estimate spectral reflectances in multispectral systems. One of them is the widely spread pseudo-inverse method. This method relates the camera responses of the system through the different acquisitions channels with the estimated reflectances by means of a transformation matrix. This mapping matrix minimizes the least-squares-error for a training set of known reflectances with the correspondent camera responses and does not use prior knowledge of the acquisition system characteristics,Vilaseca et al. (2006).

Reconstructions were carried out for two different conditions in the simulations: under ideal conditions (IC) and under noise conditions (NC), where a 2% additive random noise and the quantization error of the imaging sensors were included.

To evaluate the performance of the system three different metrics were used. Two metrics serve to compare the estimated spectral curves with respect to the original spectra: the root mean square error (RMSE), which is a widely used metric for spectral evaluation, and the goodness-of-fit coefficient (GFC) proposed by Hernández-Andrés et al. (2001). GFC $\geq$ 0.999 and GFC $\geq$0.9999 are required for respectively good and excellent matches. The third metric is the CIEDE2000 formula (DE00) used over the reconstructions in the VIS range as a colorimetric evaluation, Sharma et al. (2005).

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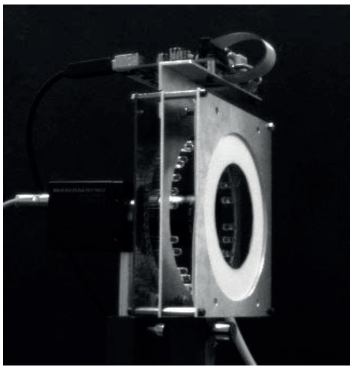
4. Results and discussion

Figure 2 contains the temporal stabilization curve for one of the LEDs used in the system (λ=535nm). The change in percentage between the peak of intensity and the stabilization zone for the different LEDs tested ranged between a maximum of 9.19% and a minimum of 2.12%, with a 5.43% for the case shown. In general, stabilization times longer than 40 sec were necessary to achieve a percentage of variation below 2%. Although we have a good control of the current in the system, a higher stability is not reached because of the temperature influence in the LEDs emission.



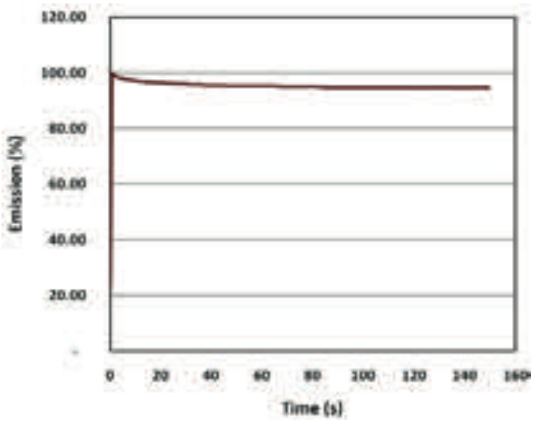
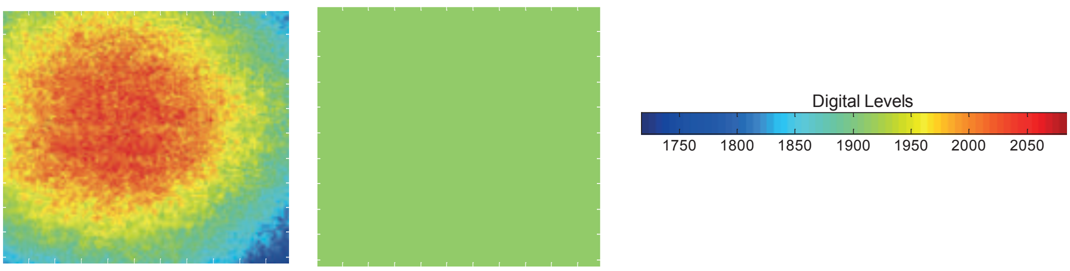


Figure 1. Multispectral system

Figure 2.Curve of temporal stabilization of LED emission

Figure 3 shows the result of applying the flat field correction to the system in terms of spatial non-uniformity percentage: SNUP = 100 × σ(mean)/mean, de Lasarte et al. (2007). This parameter changed from a value of 2.83% to a 0.012% with the application of the correction. A similar behavior was found in the different channels of the system. Table 2 shows the comparison of the implemented metrics for the evaluation of the reflectance estimation with and without noise. The results demonstrate that the system performs rather well even under noise conditions. Although the second module has poorer results than the first one, probably due to the lower number of LEDs and their wider spectral emission, its performance is still reasonably good.



a) b)

Figure 3. Spatial non-uniformity correction. a) Original image and b) corrected image.

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Table 2. Comparison of metrics for the evaluation of the reflectance estimation for two different conditions: ideal conditions (IC) and under noise conditions (NC).

	Module 1						Module 2			
	DE00		RMSE (%)		GFC		RMSE (%)		GFC	
	IC	NC	IC	NC	IC	NC	IC	NC	IC	NC
Mean	0.017	1.016	0.16	1.17	1.0000	0.9995	0.96	2.11	0.9991	0.9976
Min	1.2e-3	0.208	3.7e-3	0.11	0.9991	0.9962	0.04	0.10	0.9899	0.9790
Max	0.098	3.039	0.81	3.11	1.0000	0.9999	4.16	9.45	1.0000	0.9997

5. Conclusions

This paper shows the evaluation through simulations and the characterization of a multispectral system intended for its future use in the study of artwork. The temporal behavior in emission of the LED elements was measured showing good stability after 40 sec. A flat field algorithm was implemented for the correction of the spatial non-uniformity and simulations of the system in reflectance estimation were also carried out. Regarding the metrics for the evaluation of the reflectance estimation, the system performs very accurately for the two modules under ideal conditions. For the noise condition, the performance of the system decays but it is still good. Comparatively, the second module has less accuracy than the first module and that fact is closely related to the minor availability of LED elements in the range of wavelengths comprised by this module.

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A research on the esthetic relationship of LED color lighting on products

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Abstract
The objective of this research is to study the esthetic relativity of colored lighting used on products. The research is divided into two main parts: 9 types of esthetic experiments on the categories of colored LED lighting and a quantity survey for the sensibility evaluation on the colored LED lighting. First, a LED lighting unit, adjustable to R,G,B colors, were tuned into 32 phases, extracting 710 colors, of which 9 were esthetic colored lighting. Second, the relationship between the colors was analyzed by conducting a quantity survey on the 9 types of colored lighting selected by an evaluation frame of emotional color words. As a result, the image of the colors, within the result numbers, that was neither too strong nor weak showed high value evaluations while having no relationship with the exposure frequency or the color's images. Low exposure frequency, however, had a positive effect on the valuation process. (**Keywords:** LED lighting, esthetic relationship, products)

1. Introduction
The LED lighting started being used in our everyday appliances such as traffic lights, display boards and cars and currently has a significant effect on product lighting. In the recent cases of LED lighting appliance, the colors are determined by the designer's intuition. Adding to this, due to the focusing on symbolic colors of companies and an indiscrete use of colors, a set standard for color usages is absent. Therefore, this research aims to extract the typical colors that will be used in electronic products and by analyzing the effects of those colors, find the esthetic relativity of colored lightings.

The research was divided into two significant parts: an esthetic evaluation and emotion evaluation. The first part was the selection of 9 kinds of colored LED lighting which had esthetic characteristics and the second was an analysis for the emotion evaluation of types of colored LED lighting.

2. Research methods

A. Selection experiment of the nine kinds of colored LED lighting
To extract the 9 colors (Red, Orange, Yellow, Green, Cyan, Blue, Magenta, Purple, and White) from colored LED lighting, a selection experiment was conducted. The colored LED lighting used for this experiment is adjustable to each of the R, G, B colors of the 256 phases of 8 bit. By adjusting the R, G, B respectively in 32 phases, the experiment measured the 710 kinds of colors with CS-1000[1].

Among the results, to classify the color domains, 9 domains were divided (Figure 2) in reference to the CIE xy Color Diagram's color classification table (Figure 1).

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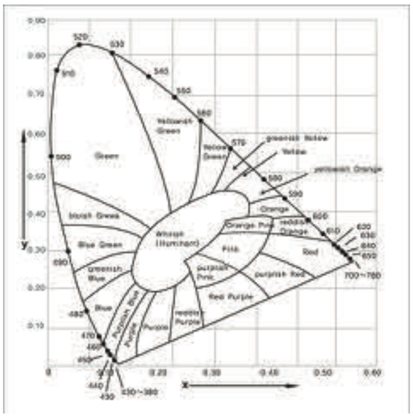

Figure 1(left): CIE xy Color Diagram's color classification table

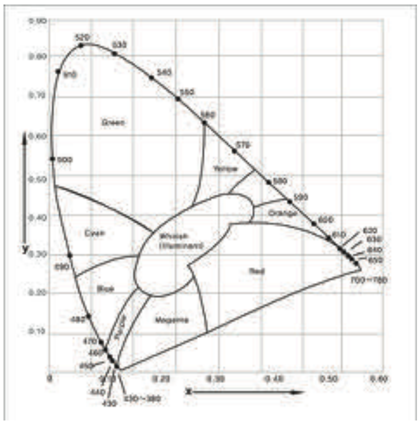

Figure 2(right): CIE xy Color Diagram's color classification

To utilize the ordinal scale, two color stimuli were simultaneously shown. For credible data, the stimulations were inserted irregularly nine times. The two LED lighting, both being 2cm in diameter, were each placed 3cm from the end point for distinction. The distance from the subject was 1 meter and the ambience lighting was 500lx which is equivalent to the average household lighting.

This research, which used the ordinal scale, marked '1' for colored LED lighting that was favorable and '2' for those that were not. Thus, the color with the least mean value was the most favorable within its group.

B. Emotion evaluation of selected lightening

This research conducted a preliminary survey for the emotion evaluation of the colored LED lightings. For the survey evaluation, an evaluation chart for color sensibility words was provided. For the selection of adjectives related to color, color emotional adjectives from magazines, papers, website describing product, visual, space and fashion where chosen. From this material, a total of 100 people, 10 chosen from each of the age groups, ranging from 10s to 50s, were surveyed. The survey used a 5 point scale, having subjects check '5' if the relativity to the color was high and '1' if the relativity was low. On the preliminary survey, the 100 hue test was conducted on 10 color professionals and words with high relativity to color were chosen. 15 words with a mean average of more than 3 points were chosen for the second survey.

To test the validity of the final 15 selected words, the overall significance of the relative line was evaluated by the Bartlett Test and KMO(Kaiser-Meyer-Olkin) sample appropriate measures. For factor analysis, the principal component analysis and the Varimax rotation was used[2]. To reduce the ambiguity of the final selected words, antonyms were provided by linguists. Linguists defined the different layers of the adnominal phrases for each word, and educed the higher evaluated words. Using the SD(Semantic Differential) method with the final 15 words and their antonyms, a survey about the 9 colored LED lighting was conducted.

3. Research results

A. Results of the nine colored LED lighting selection experiment

9 representing colors out of the 710 were selected by color experts through an aesthetic experiment.

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Table 1: Results of Experiment A

Red	L	a	b	Orange	L	a	b	Yellow	L	a	b
	82.65	45.94	13.31		86.12	25.70	32.08		81.57	6.37	32.08
Green	L	a	b	Cyan	L	a	b	Blue	L	a	b
	87.66	-58.48	31.57		74.64	-30.17	-12.66		72.26	-48.87	-16.78
Purple	L	a	b	Magenta	L	a	b	White	L	a	b
	52.37	20.79	-58.83		73.41	80.51	-12.23		100	0	0

Red has a shade of pinkish due to low colorfulness. Orange has low colorfulness and a strong shade of reddish. Yellow has high colorfulness with a shade of greenish and green has a slide shade of yellowish. Cyan has lower colorfulness than the selected blue and a large portion of bluish. Among the blue, this with greenish was selected more. Purple has more bluish than the general purple and the magenta has more colorfulness than the general magenta and this color, based on the purple standard, has a shade of reddish. White has more yellowish than the general white.

B. Results of emotion evaluation for selected lighting

A total of 15 words were educed through the evaluation of emotional color words, and were categorized into three factors by factor analysis: value evaluation factor, image of color factor, exposure frequency factor.

Table 2: Rotated Component Matrix

Factors	words used		1	2	3
Factor 1 Value evaluation factor	Classy	Question 12	0.799	0.148	-0.076
	Beautiful	Question 11	0.789	0.111	0.113
	Attractive	Question 5	0.779	0.217	0.004
	Luxurious	Question 1	0.767	-0.059	0.072
	Elegant	Question 14	0.763	-0.166	0.067
	Like	Question 9	0.751	-0.118	0.215
Factor 2 Image of color factor	Strong	Question 5	-0.036	0.805	-0.013
	Fancy	Question 10	0.102	0.798	-0.005
	Catching	Question 13	0.19	0.757	-0.078
	Vivid	Question 6	0.005	0.723	0.148
	Calm	Question 7	0.425	-0.677	-0.004
Factor 3 Exposure frequency factor	Warm	Question 2	0.055	-0.017	0.593
	Familiar	Question 4	0.282	-0.032	0.668
	Dark	Question 8	0.14	-0.185	-0.613
	Comfortable	Question 3	0.544	-0.323	0.546

* *Factor educe method: principal component analysis*
* *Rotation method: Varimax with Kaiser Normalization*
* *4 the factor rotation was collected in the repetitive calculation.*

Red selected from the esthetic experiment was not considered familiar due to it not being the general red. Orange had moderate exposure but had low value evaluation because the image factor results were low. Yellow had the most exposure of the 9 colors but the image of color factor was average and the value evaluation factor was the lowest. Green showed average results in

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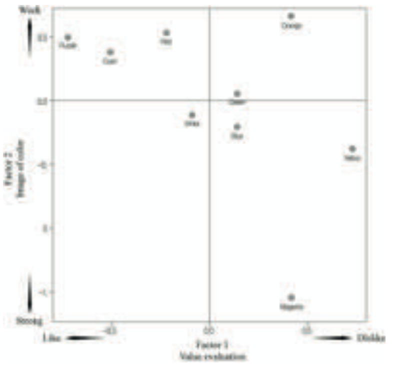
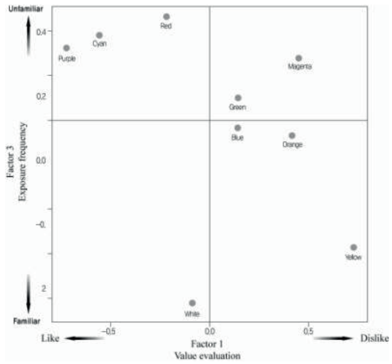
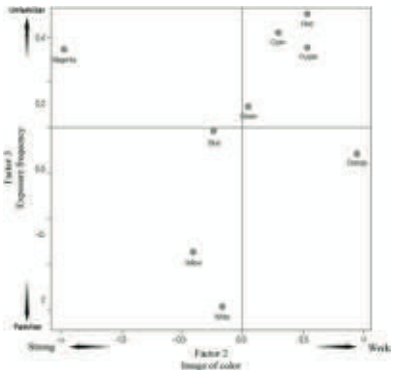
exposure frequency, image of color and value evaluation factor while cyan scored low in image of color and exposure frequency factor. Blue showed average numbers in image of color, exposure frequency and value evaluation factor. Purple had low image of color and exposure frequency factor because it wasn't the general purple. However, purple scored high on value evaluation factor. Magenta, having a higher colorfulness than the general magenta, had high numbers in image of color factor but low in both exposure frequency and value evaluation factor. White had high exposure factor but scored average in both image of color and value evaluation factor.



(a) Value evaluation- Image of color factor



(b) Value evaluation - Exposure frequency factor



(c) Image of color- Exposure frequency factor

Figure 3: Scatter diagram on colors

4. Conclusion

To conclude, upon comparative analysis on the value evaluation and image of color factor, it showed that the image of the color within the experiment that is not too strong or weak will receive high value evaluation. In other words, value evaluation will be low if the image of the color is too strong or weak. Second of all, upon comparative analysis on image of color and exposure frequency factor, no relation was found between the two. Finally, upon comparative analysis on value evaluation and exposure frequency factor, it showed that a low exposure frequency had a positive effect on value evaluation and a high exposure frequency had a negative effect. However, this result proves valid only on the premise that it is between the chosen 9 colors.

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Mandarin color terms eliciting from free color naming task

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Abstract

The purpose of present study is to document the use of synchronic Mandarin color terms with an empirical survey. The behaviral data in color naming experiment are considered to be an important mirror reflecting the inate structure of color perception. Also, some anthropological linguists believe that the number and the evolution of basic color terms are related to culture maturity. The amount of basic color terms and the diversity of secondary color terms could serve as an index to the complexity of a visual culture. Color naming studies has been intensively conducted on many languages, such as those reported in Berlin and Kay's studies. However, color naming data of Mandarin have seen fragmentary. In this study, the researchers conducted a free color naming experiment with 36 native Mandarin speakers as participants. The participants were screened with Ishihara test. All participants are capable of using spoken and written Chinese. There are 121 evenly sampled stimuli sweeping the 50 cd/m2 level of CIE x-y diagram within the available gamut constrained by the display media. The participant were presented with the stimuli and then asked to freely write down the name the color on a trial. They were also stressed to respond as fast as possible, and they were aware of that the response times were recorded. Further, following the production of a name, the observers were asked to give a confidence rating on a five-point scale. The results can be summarized as follows: (1) Locating the foci color of lexical color categories in color naming space within Mandarin speakers. (2) Collecting and classifying a large number of Mandarin color terms with rich diversity. The classes of color terms are landmark basic, other basic, Mono-lexeme Secondary, Modifier-Basic, Modifier-Secondary and Complex. (3) Comparing the naming results and behavioral data, such as response times, confidence rating, and the occurrence rate of each class, with related English color naming data. There are some significant differences in the quantity of color terms within each class, if comparing our results with English color terms in the previous study elicited from similar tasks.

1. Introduction

The purpose of present study is to document the use of synchronic Mandarin color terms and to plot these terms on the chromaticity diagram through an empirical survey. The color naming behaviours are considered to be related to culture maturity by some anthropological linguists. The amount of basic color terms and the diversity of secondary color terms could serve as an index to the complexity of a visual culture(Berlin and Kay 1969; Casson 1994). Language is a common way for communicating color experiences, but the lexical color categories revealed by color naming are not equal to the perceptual distance determined in known uniform color spaces (Hardin and Matffi 1997). Color naming behaviours and the establishment of basic color terms are two important issues in the area of cognitive and anthropological linguistics. Following the research line of anthropological field survey initiated by Berlin and Kay (Berlin and Kay 1969), there are systematic studies regarding basic color terms across world languages (Lindsey and Brown 2006; Kay et al. 1997). Also, the categorical structure of color naming space has been examined by

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psychological experiments (Guest and Van Laar 2000) and computational modelling (Lammens 1994). However, most of the previous studies are conducted with languages excluding Mandarin. A few studies were conducted with Mandarin speakers (Lu 1997; Lin et al. 2001; Lin et al. 2001; Lin et al. 2001), but the obtained color terms and behavioural results are outdated by now and probably not suitable for generalizing to current situation.

2. Experiments

Thirty six native speakers of Mandarin were enrolled for collecting color naming data. The participants were screened with Ishihara test. All participants, aged from 19-36, 19 females and 17 males, are fluent in spesking and writing Chinese, with the background ranging from undergraduates, graduates to staff on campus. There are 121 evenly sampled stimuli sweeping the 50 cd/m2 level of CIE x-y diagram within the available gamut constrained by the display media. The observers were presented with the stimuli and then asked to freely write down the color name on a trial. They were also stressed to respond as fast as possible, and they were aware of that the response times (hereafter RTs) were recorded. Further, following the production of a name, the observers were asked to give a confidence rating on a five-point scale. There are totally 121 naming trials presented in random order, and the researcher was present in the experiment chamber throughout all trials.

3. Results

One of the major findings in this study is the identification of foci of lexical color categories in color naming space within Mandarin speakers, as shown in Figure 1. This plot reveals the patterns of consensus use in Mandarin color terms. Also, this experiment collected a lot of Mandarin color terms with rich diversity. The classification and the descriptive statistics of the collected color terms are summarized in Table 1, including the examples of color terms, the mean response time (MRTs), mean confidence rating (MCR), and the occurrence rate of each class. Only frequently named color terms (frequency count more than 87, i.e. over 2% occurrence to total amount) would appear as examples in the column of Color terms in Mandarin and English translations. Notice that the column of MB (modifier-basic) class only listed the modifiers. The color terms shown in this table were reported with reasonably high consistency and frequency during the free naming experiment. There is no color term surpassing 2% occurrence threshold (87 repetition times) in the Modifier-Secondary class as this form of color term is rarely used by Mandarin speakers. Also the Complex class contains no item of high consensus. There are 39 color terms (for the MB class researcher counted the frequency of modifiers in order to bring out the modifier terms in common used) standing out when screened by the 2% occurrence consistency and frequency threshold. These terms provide valuable information about color idioms in current use. Further, there is significant difference in the quantity of various classes of color terms, if comparing our results with English color terms in the previous study elicited from a similar task (Guest and Van Laar 2000) . The discrepancy between the use of Mandarin and English color terms is shown in Figure 2.

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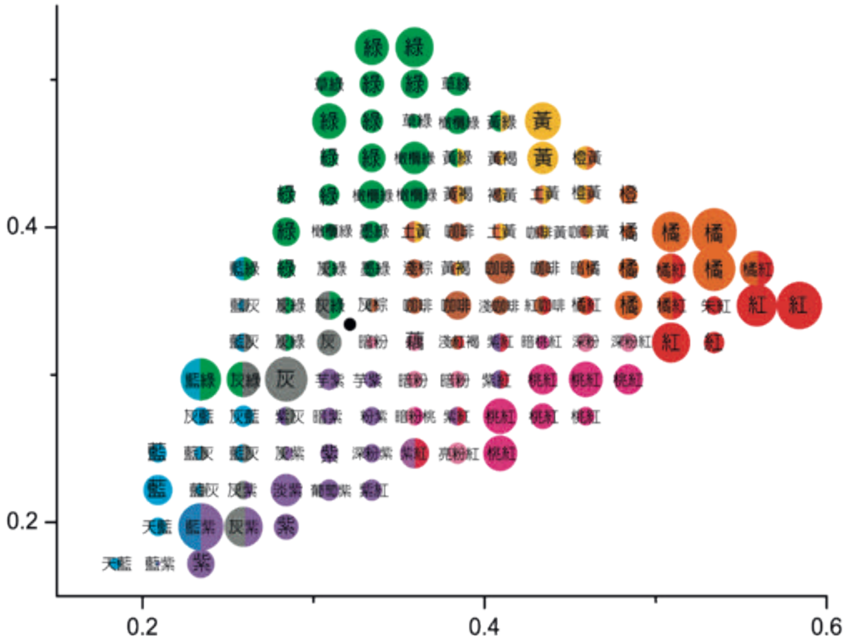

Figure 1. The color naming map derived from the results of color naming experiment. Each color bubble represents the location of the stimulus, and the color of the bubbles is the host color category defined by the mode of the collected terms. The size of the bubble represents the size of the mode. The black dot within the triangle of stimulus points is the reference white of the screen.

Table 1. The classification and the descriptive statistics of the collected color terms.

Class of color terms	Color terms (over 2% occurence)	MRTs (SD)	MCR (SD)	%
Landmark Basic	綠 Lu (Green)紅Hong (red) 藍 Lan (blue) 黃 Huang (yellow)	1854 (894.31)	3.84 (0.96)	6.48%
		1541 (903.57)	3.98(0.80)	2.21%
		3672 (1521.49)	3.45 (0.69)	3.53%
		2683 (1178.03)	3.67 (0.73)	2.28%
Other Basic	橘, 咖啡, 粉紅, 桃紅, 灰, 橙, 紫, 褐, 棕 Tangerine, brown, pink, hot pink, grey, orange, purple, tan, palm	4126 (1347.69)	3.27 (1.14)	17.2%
Mono-lexeme Secondary	藕 Ou (Lotus root)	4419 (1559.13)	2.48 (1.0)	6.8%
Classic	青 Ching (blue, green, black)	5263 (2305.42)	2.54 (0.77)	2.4%
Basic-Basic	藍綠, 藍紫, 灰綠, 藍灰, 橘紅, 黃褐, 紫紅, 黃綠, 橙黃 blue-green, blue-purple, grey-green, blue-grey, orange-red, yellow-brown purple-red, yellow-green orange-yellow	4673 (1724.60)	3.29 (0.95)	19.6%
Secondary-Basic	橄欖綠, 草綠, 芋紫, 天藍, 墨綠, 土黃, 葡萄紫 Olive-green, grass-green, taros-purple, sky-blue, ink-green, earth-yellow, grape-purple	4889 (1648.1)	3.02 (1.13)	17.1%
Modifier-Basic	亮, 暗, 淡, 粉, 淺, 深, 偏, 正 Bright, dark, pale, powder, light, deep, -ish, central/correct	3960 (1578.29)	3.60 (1.03)	24.9%
Modifier-Secondary	/	5142 (1910.88)	2.73 (1.27)	1.8%
Complex	/	5406 (1259.93)	2.42 (1.09)	3.96%

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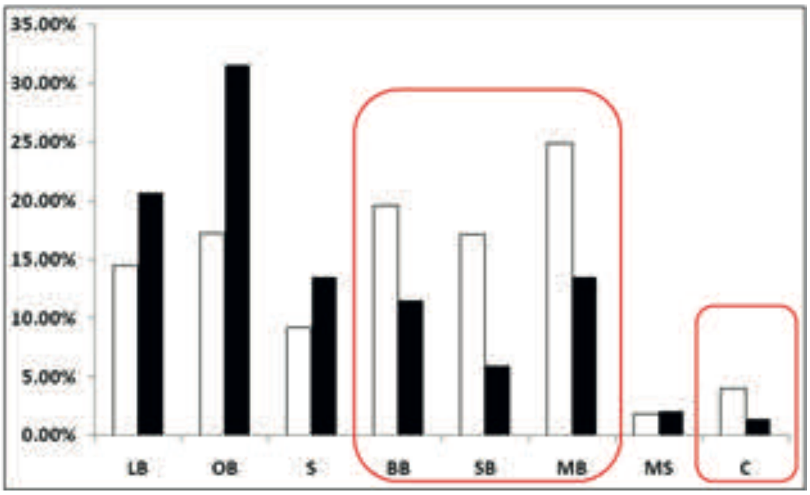

Figure 2. The occurrence percentage of color terms elicited from current Mandarin naming task ☐ and from previous English naming task ■.(Guest and Van Laar 2000)

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High color-rendering color tunable LED lighting for mediating noon drowsiness and mood

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Abstract

A high CT illumination is proved to induce human high arousal level that might ease our afternoon sleepiness. However, long time exposure to this illumination will not have long time arousal level. Thus, a color-temperature (CT) tunable LED light source not only for easing the afternoon drowsiness but also for mediating the mood based on different people with different needs in a working place is suggested. This color-temperature tunable LED light source is fabricated by 6-channel LEDs with high color rendering index (CRI) accordingly. Because of color adjustable and high CRI, this LED light source can be used for various applications, such as light booth for color measuring, floodlight in TV studio, and even general lighting such as intelligent lighting which might replace the lighting we are using now.

1. Introduction

Many people have experienced afternoon drowsiness especially right after lunch. Increased this sleepiness is recognized as a detriment to work efficiency in office. Except for taking a nap or a cup of coffee, high bright natural light exposure is an effective alternative to ease this symptom [Kaida, 2006]. However, it may not be available for indoor environments such as in the core of a building. Therefore, high color temperature lighting might be a choice, since a high CT illumination is proved to induce human high arousal level and may ease our afternoon drwosiness [Iwakiri, 1999]. However, such an illumination we are using to date is with fixed CT, and long time exposure to this illumination will not last long time arousal level. Thus, we may need different color temperature illuminations depending on different needs for different persons at different time slots. Therefore, a color-temperature adjustable lighting with high color rendering is required.

In order to realize this lighting, LEDs whose peak wavelengths can be arbitrarily manufactured theoretically are the only choice to realize such a novel lighting with dynamic range of colors and wavelengths which are important in biological meanings. LEDs play very important role in this novel illuminant since a set of different wavelength LEDs makes up different levels of daylights including dawn, noon, and dusk. Unlike red, green, and blue LEDs for color mixture, a better CRI lighting with 6-channel LEDs as a color-temperature adjustable is fabricated. This is based on the optimal selection of LEDs [Hu, 2008]. The CCT range of this set of LEDs are from 1800K to 12000K, and the corresponding averaged color rendering index measured by the spectra radiometer JETI is 88 with illuminance higher than 700 lux.

2. Arousal level and different CT illuminations

It has been shown that high color temperature lighting induces human high arousal level in terms of the alpha attenuation coefficient (AAC) which is the ratio of the alpha power of eye-close and eye-open in measuring brain wave by electroencephalogram (EEG) [Stampi, 1995]. Thus, bright

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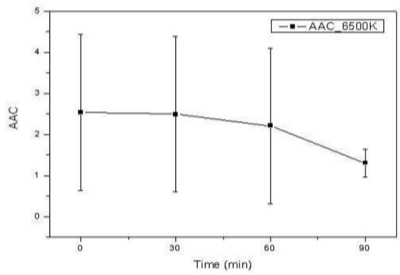
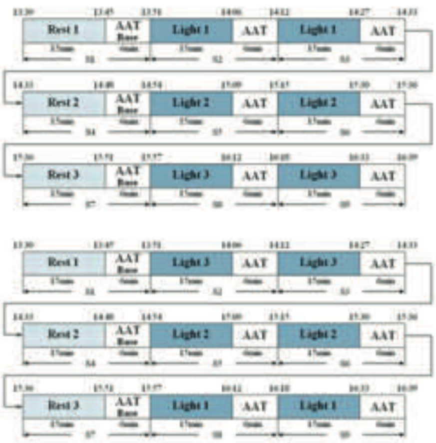
natural light for improving afternoon sleepiness can be substituted by high color temperature lighting. However, exposure to the high color temperature illumination constantly for a long period of time might not maintain high arousal level with such long time. Eight subjects are tested by exposing at 6500K illumination for 1.5 hours. The associated arousal level is decaying when the exposure time increases. The result is shown in Figure. 1. From this result, the arousal level maintains the same level after 30 mins , since the baseline AAC is already high and a high CT exposure will not make the AAC higher. And the AAC decays in the next 1 hr. Thus, an illumination with higher CT may be required if sleepy feeling still exists, or switch to low CT illumination depending on different mood. That means different CCT illuminations might be preferred in terms of mediating arousal level and mood.

The lighting with different color temperatures is for testing. It is a two-day experiment with the procedures are shown in Figure. 2. The lighting is controlled at the same illuminance with 500 lux. Ten participants aged 20 to 22 years old with 5 females and 5 males are involved. The three illuminations are denoted as 6500K for Lighting 3, 4000K for Lighting 2, and 3000K for Lighting 1. The corresponding AACs are shown in Figure. 3. From this figure, the illumination of 6500K induces higher arousal level than that of induced by either 4000K or 3000K illumination in each day. Therefore, 6500K illumination can prevent one from afternoon sleepiness compared with 3000K and 4000K. Since different people feel afternoon sleepiness in different time, different CCT illumination is required for different people at different time in order to have better working environments. For example, one has high arousal level, and she/he can use whatever CCT she/he prefers.



01_Figures. AAC of eight subjects exposed at 6500K illumination for 1.5 hours



02_Figures. The procedures the Experiments of Day 1 and Day 2.

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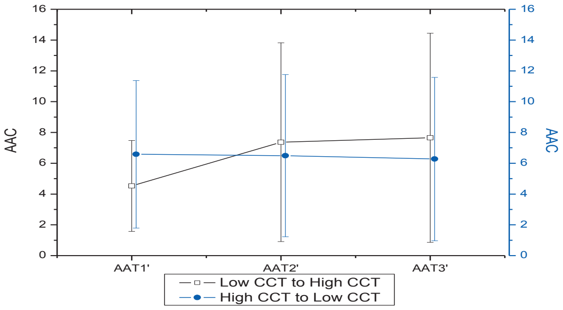

03_Figures. AACs of the experiments on Day 1(low CCT to high CCT) and Day 2 (high CCT to low CCT).

3. Realization of color-temperature adjustable LED light source

The SPD of an illuminant to be imitated, denoted by $E(\lambda)$, is synthesized by M number of LEDs as

$$\hat{E}(\lambda)=\sum_{i=1}^{M} c_i d_i(\lambda)$$

,where the synthesis coefficients of the SPD of an illuminant can be obtained by [Hu, 2008]

$$\vec{C}=(AA^T)^{-1}A\vec{E}=A^+\vec{E}$$

The synthesis coefficients are required to be positive, where A is the matrix whose entries are the sampled spectra of the LEDs with size $M\times 61$, and $\vec{E}$ is the sampled SPD vector of size 61 if every spectrum is sampled in every 5 nm from 400nm to 700nm. A^+, a matrix of size $M\times 61$, is a kind of pseudo inverse matrix of A. Optimal selection of an LED set means to have both minimal norm of $\vec{E}_i$ - $\hat{\vec{E}}_i=(I-A^TA^+)\,\vec{E}_i$ and positive synthesis coefficients owing to unrealizable negative coefficients. To achieve these two conditions with minimal number of LEDs, the pruning process is adopted resulting in an optimal LED set [Hu, 2008].

In order to realize the color-temperature adjustable lamp, we apply the above algorithm to the 61-channel LED set collected from different LED companies and obtain an optimal set of 6 LEDs to implement the illuminations with color temperatures ranged 1800K to 12000K of blackbody radiator. The peak wavelengths of the 6 LEDs are shown in the upper row of Table 1. However, it is difficult to purchase the same peak wavelengths as those LEDs in Table 1 from the LEDs manufactured currently. We, thus, use the 6 LEDs with peak wavelengths shown in the second row of Table 1 to implement the color-temperature adjustable lamp with CCT ranges from 1800K to 12000K shown in Figure. 4. The corresponding averaged color rendering index measured by the spectra radiometer JETI is 88 with illuminance higher than 700 lux.

Table 1 The LEDs at upper row are for daylight synthesis, while the LEDs at the lower row are for CCT tunable desk lamp.

Peak wavelengths for synthesizing daylight	400	455	510	555	605	670	Average CRI
FWHM	40	60	40	50	50	60	93.81
Peak wavelengths for the desk lamp	400	450	500	530	587	660	Average CRI
FWHM	12	20	35	35	20	20	88.2

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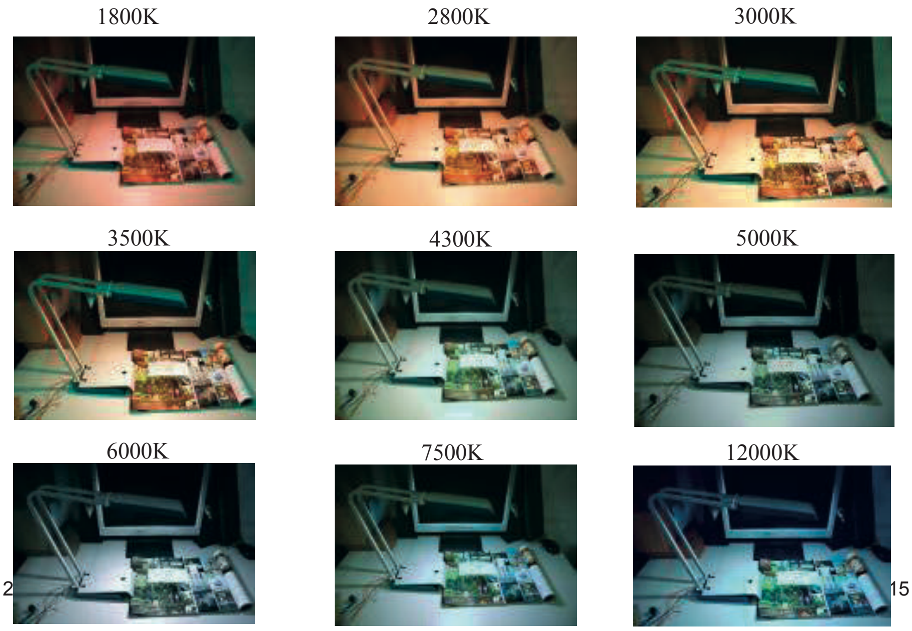

04_Figures. Color appearance of different CCT illuminations by the tunable LED desk lamp.

4. Conclusions

Different from exposing to a fixed high color temperature illumination which is a conventional lighting that we are using to date, the color temperature tunable LED light source is applied and shows that it can not only ease the afternoon drowsiness but also mediates our mood based on different people with different needs in a working place. Because of color adjustable and high CRI, this LED light source can be used for various applications, such as light booth for color measuring, floodlight in TV studio, and general lighting such as intelligent lighting which might replace the lighting we are using now.

Acknowledgments

This study was sponsored by the National Science Council of Taiwan under NSC 98-2221-E011-024-.

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Evaluation and optimization of spectral estimation algorithms for printer inks

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Abstract

We made a computational simulation of spectral recovery system for printer inks, based on different sensor sets and spectral estimation algorithms. We additionally performed an exhaustive search for the best group of sensors in order to improve the performance of the multispectral system. The result showed the algorithms based on neural networks do not offer the best quality for the non-optimal training set; then, the matrixR method, Wiener or pseudoinverse could be a best choice. For a large and well designed training set, neural network could be a very promising solution. Nevertheless, the majority of the optimal sensors would be covering the central portion of the spectral range.

1. Introduction

Spectral information of the printer inks is, nowadays, catching the attention of the printing society. Easy but precise spectral reflectance measurement method for printer inks is strongly desired for many applications. Two methods are generally used to measure the spectral reflectance of printer inks: one is directly measuring using a spectrophotometer, and the other is based on estimated measurements of the spectral reflectance using the camera responses of multi spectral imaging systems (Hardeberg 1999). Comparing to the latter spectral technique, a spectrophotometer is considered to be more expensive, more limited in measuring geometry, and more limited in spatial resolution.

In the last twenty years, there have been multiple spectral estimation algorithms and solutions proposed to deal with this problem, some based on real sensor responses and some on computational simulations of sensor responses, often adding noise to be closer to the real capture devices.

The purpose of this study is to obtain a useful set of preliminary data on which the practical development of this system could be based. Computational camera responses are simulated to study the influence of several factors on the estimation quality: the inclusion of noise in the camera responses, the training set selection, and the estimation algorithm. We additionally performed an exhaustive search for the optimal sensors for the task (as two of our sensor sets include 12 sensors, we have performed and exhaustive search to find the best six or eight sensors for the spectral estimation task).

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2. Methods

2.1 Simulation of spectral estimation system based on multispectral camera

The simulation of our multi-spectral imaging system with different sensor sets is based on the following equation (1):

$$r_{i,n_j} = \sum_{\lambda_1}^{\lambda_2} S(\lambda)E(\lambda)q_i(\lambda) + n_{i,j} \qquad (1)$$

Where S(λ) is the spectral reflectance of the ink sample, E(λ) is the spectral power distribution of the light source, $q_i(\lambda)$ is the camera response of the ith channel, and $n_{i,j}$ is the simulated representative noise including shot noise and flicker noise. A white LED source with a known spectral power distribution was assumed to be the light source.

We have used three different sensor sets to simulate the multispectral system camera responses. Sensor set A is composed of 12 ideal Gaussian filters of 40 nm FWHM from 380nm to 780nm, (Figure 1 left)**.** The two additional sensor sets are composed of real wideband filters (Optics Balzer AG, Liechtenstein) combined with a typical CCD sensor spectral responsitivity. Sensor set B is composed of 12 bandpass filters covering spectral range from 380 to 780 nm, (Figure 1 middle). Sensor set C is composed of six bandpass filters covering the central-visible range (Figure 1 right).

We have selected two training sets. Training set 1 is composed of 160 reflectances of printer ink samples from SunChemical Inc. (U.S.A), Hartmann Inc. (U.K.), and HKS (Hostmannn-Steinberg, K+E und Schmincke, Germany). Training set 2 is composed of the 24 reflectances of the Macbeth Color Checker (GretagMagbeth, X-Rite Inc., U.S.A.). This is a widely known chart used mainly for digital camera calibration.

We have analyzed the quality of the spectral estimations obtained by the different algorithms by using three indices. Two of them are based on spectral similarity between the original and estimated samples (the Root Mean Square Error or RMSE, and the Goodness-of-Fit Coefficient or GFC (Romero et al. 1997)), and one of them is based on visual perception (the CIE 94 Color Difference Equation).

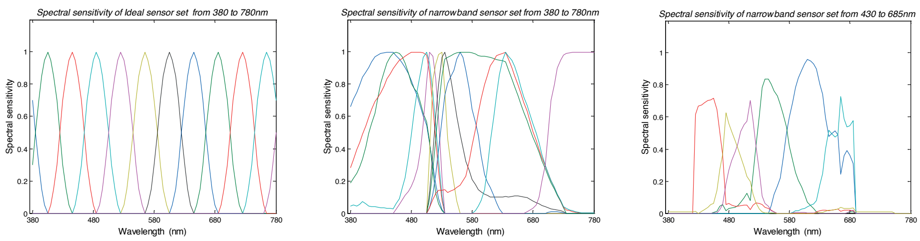

Figure 1.Spectral responsive curves of the three sensor sets used. left) Sesnor set A. middle) Sensor set B. right) Sensor set C.

2.2 Spectral estimation algorithms.

We have tested nine different spectral estimation algorithms, which have been selected as good examples of different strategies proposed to deal with the problem of estimating reflectance of samples from few camera responses which are : Maloney-Wandell (Maloney and Wandell 1986), Imai-Berns (Imai and Berns 1999), Pseudoinverse (Nieves et al. 2005), Shi-Healey (Shi and Healey 2002), Wiener (Pratt and Mancill 1976), matrix-R (Zhao and Berns 2007), Regularized Polynomial Regression (Heikkinen, et al. 2008), POCS (Stark 1998) and a radial basis function

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Neural Network (RBFNN) (Buhmann 2003, Ming et al. 2009) implemented using Matlab NN-toolbox, with a structure of 6-12 neurons in the input layer (same as the number of sensor responses), 30 neurons in the hidden layer and 81 neurons in the output layer (same as the dimensionality of the spectral signals).

3. Results

Table 1 shows the quality indices corresponding to the nine different algorithms and the sensor set A obtained for training set 1 (printer inks). We use the leave one out cross validation method for data sampling.

Table 1. Quality indices results for sensor set A, noisy data, and training set 1.

		RBFNN	POCS	Imai-Berns	Maloney	Shi-Healey	Pseudoinv	Wiener	matrixR	Regularized PR
RMSE	Average	0.0040	0.0049	0.0045	0.0057	0.0216	0.0046	0.0044	0.0044	0.0032
	STD	0.0024	0.0030	0.0027	0.0028	0.0188	0.0025	0.0021	0.0025	0.0018
GFC	Average	0.9946	0.9927	0.9894	0.9834	0.8949	0.9923	0.9921	0.9914	0.9950
	STD	0.0079	0.0064	0.0154	0.0230	0.1071	0.0093	0.0095	0.0147	0.0077
ΔE_{94}	Average	1.6715	0.7763	1.0909	1.6838	13.8184	1.0938	1.1089	0.8711	0.7934
	STD	1.5050	0.5125	1.1031	2.0672	14.0636	1.0902	1.0188	0.7081	0.5464

The best results are offered by the Regularized Polynomial Regression algorithm in the spectral quality indices (GFC and RMSE), and the average quality of the estimations except the Shi-Healey algorithm can be considered acceptable (GFC over 0.99, RMSE below 0.03 and ΔE_{94} below unity). The POCS gives the lowest average color difference.

For the training set selection, we use the Color Checker as training set. Different but interesting result arises here: the best performance is offered by the matrix-R and pseudoinverse algorithms, showing that they are most robust to non-optimized training set selection. Except for the POCS, all quality indices are worse than those corresponding to training set 1. This is not very surprising because the Color Checker is obviously a quite bad choice as a training set, due to its reduced number of samples and also to the samples origin, none of them being printer inks. The two algorithms which present a higher loss of quality are the Shi-Healey and RBFNN. This is due to the way they work to obtain the estimations: the Shi-Healey algorithm includes a last procedure of searching the most similar sample in the training set to the estimate obtained, and the RBFNN (as all Neural Networks) is extremely sensible to the quality of the examples provided in the training phase. So it is quite logical that they resent more from a bad choice of training set.

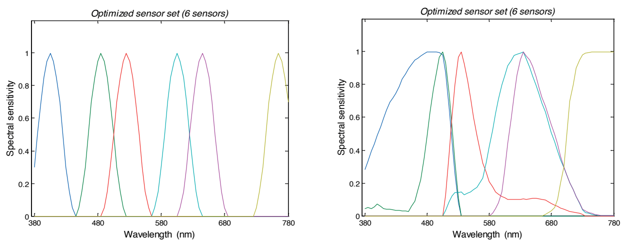

Figure 2. Optimal 6 sensors for sensor set A (left) and sensor set B (right). Using training set 1

In the next step we focus on examining the possibility of working with a reduced number of sensors (6 or 8) for the real sensor sets B and C. We use exhaustive search for determining the optimal sensor subset by comparing the average result for the whole dataset, the optimized 6

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sensors for set A and B are showed in Figure 2. The results also showed that adding two more sensors (8 sensors) slightly improves the result only for sensor set A but causes a decrease in global estimation quality for both real sensor sets (sensor set B and C). We can conclude then that it would be possible to obtain a high quality recovery with only six real sensors belonging to sensor set B. The result also shows the RBFNN gives the best performance by using a real sensor set.

4. Conclusions

We simulated a multispectral system to analyze different influence factors for ink reflectance recovery. We have found the best estimation algorithm is depends on the training set. Nevertheless, the results of our exhaustive search optimization show that the majority of the optimal sensors would be covering the central portion of the spectral range. These results show the future of real implementation of a multispectral capture system to measure printer ink reflectance.

Acknowledgments

We thank the Erasmus Mundus CIMET program for the bakcground and finantial support provided. Also we thank Chromasens GmbH and the Color Imaging Lab of the University of Granada for useful suggestions and help in the results discussion.

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Translucency perception

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Abstract

The appearance of all materials depends on perceptions of visual structure, colour, gloss, surface texture and translucency. This paper considers only translucency of which there are two types, pseudo and material. Pseudo translucency concerns the layering of colour patches so that one colour layer appears to be translucent. This phenomenon is an area for the artist and package designer. Material translucency concerns the physical property of a material whereby light passes or does not pass through, every material existing somewhere on a scale of transparent to opaque. This paper deals with material translucency particularly of foods.

1. Translucency and foods

In human evolution food colour always has been of paramount importance through the co evolution of vision and fruit colour and colour contrast with green foliage, also later perhaps with the colour clues of suitability of flesh for consumption. In the modern era colour still contributes much to the look of the foodstuff but other appearance factors can be critical. These are the visual structure (think of a slice of bacon), each element of which has variations and patterns of colour, translucency, gloss and surface texture (roughness). In addition, the way these attributes change with time and processing are characteristic of the particular food material.

An example of the importance of appearance is the human preoccupation of translucency as a quality. We seek the highest clarity in glass and plastic, and the slightest loss of transparency in wine or beer will lead to its rejection – except in some parts of the world where wheat beer must have a whitish-yellow haze.

Product identity can depend on the extent of the clarity. For example, clearer orange drinks may be seen as long, refreshing, probably containing artificial colorant, and more likely to be appreciated by younger people. More opaque, lighter coloured fruit drinks, on the other hand, are often regarded as health-giving breakfast beverages obtained from real fruit and more likely to be appreciated by adults. Turbidity in fruit juices can be a positive or a negative attribute depending on the expectation of the consumer. Visual impact is improved if jams (preserves) and gelatin based jellies are clear. Addition of milk to coffee or tea decreases transparency, increases opacity and this instantly changes product identification. The effectiveness of white fluids and pastes depends in part on emulsion stability and the rate of change of an emulsion can be calculated by the rate of change of light scattering with time. Expectations arising from the sight of a plate of food or restaurant display depends on the presence of a number of appearance attributes and is enhanced by inclusion of different opacities.

Translucency affects quality even though we may not be immediately aware of it. The colour of raw salmon flesh is a translucent deep pink-red which turns a more opaque light pink on smoking. Protein conformation changes during processing increasing light scattering. This has the effect of reducing the amount of light penetration so giving the pigment less opportunity to absorb light. Hence, as well as becoming more opaque it is a paler colour. It is the degree of translucency that allows us to discriminate between the more transparent raw salmon, the slightly

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more opaque smoked variety and the even more opaque cooked fish. This increase in the degree of light scattering within the structure governs the perceived depth of colour or chroma of flesh foods, for example, as a result of cooking. As cooking proceeds lightness increases and chroma decreases. Similar effects occur in meats.

Freezing rate also affects the perceived colour of foods, faster freezing leading to smaller ice crystals, increased light scatter, and paler, for example, beef. The colour of green vegetables immediately changes when they are plunged into boiling water. This occurs because water replaces air in cells just beneath the outer translucent layers of the structure, reducing light scattering and intensifying the depth of greenness. Transparency and translucency are brought to the meal through consommé, sauces, aspic, and a high transparency of gelatin is seen as desirable because it indicates purity of ingredients and careful preparation. However, since the advent of bland-flavored colorless waters, launched in a bid to extend the bottled water market, clarity may be seen as bringing artificiality and unnaturalness to foods. In the same way, some see clear apple juice as unnatural because it is a naturally cloudy product. Similar is the belief that white signifies high purity. This led directly to the over refining of sugars and the use of bleach to whiten flour for white bread. Recent application studies on foods include work on orange juice (Ji et al 2005), wines (Gonzalez-Miret et al 2009) and beer models (Ji et al 2009 a and b).

2. The translucency phenomenon

Degree of transparency is critical to other materials also. For example, light-scattering phenomena also contribute to powder reflectance properties, again colour changing with particle size. The smaller the particle size, the greater is the surface area, the higher the reflectance, the paler the colour. It is essential that for the highest perceived quality glass used for windows and drinking vessels must have a high degree of transparency. Vessels made from lower quality glass have less than perfect transparency. Similarly manufactured plastics usually must be transparent or opaque.

At present, translucency may be thought of existing somewhere on a continuous scale between transparent and opaque and all materials fall somewhere along it together their relevant industrial opacity terms. Paper has opacity, paints hiding power, shower screens opacity, molasses has cloud, beer haze and turbidity, and apple juice has clarity and cloud.

Paint films, print paper and some plastics in everyday use that are normally considered to be opaque are in fact slightly translucent. Measurements of the degree of opacity, that is the contrast ratio, are made on the unpigmented base material as the ratio of the reflectances of the material when placed over black and white backings. Naturally occurring mist and fog have different degrees of translucency (visibility) and foods cover a wide range. Translucency can be regarded as a generic term describing the phenomenon as a whole; it does not have a specific value. This is because as we move into the scale from either end the degree of translucency increases. In industry the term translucency is used to describe one product only, meat. That is because any change in translucency always takes place from the direction of more opaque. Normal meat, although translucent, is considered to be opaque, while flesh from badly handled animals becomes more transparent.

For translucency to be perceived there must be a colour contrast present. Illumination can be from the front or behind the object. Intensity of the perception is affected by illumination and viewing light intensity through modification of the colour contrast. Where the material is present as a bulk, rather than as a thin layer, scatterer within the body of the material acts as its own background. We can see into the material but the scatterer prevents us from seeing through it.

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Translucency in a material is caused by simultaneous transmission and reflection of light. It is visually perceived as colour contrast and as a phenomenon occurs between the extremes of transparency and opaqueness. Transparency or clarity occurs when there is no visually apparent light scattering. On 'ideal' materials such as paints, paper and plastics the degree of opacity is normally obtained for the unpigmented material. The question arises as to how much the inclusion of a colorant affects degree of translucency. Initial studies found that there were two populations of observers, one indicating that the presence of colouring material makes no difference to judgments, that is, estimates were influenced by the degree of diffusion or light scattering alone. The other population believes that for the same level of diffusion an increase in level of colour increases opacity (Hutchings and Gordon 1981).

Light scattering is affected by wavelength and particle radius (Hutchings 1999). For example, dilute skimmed milk contains a large proportion of small particles and light scattering is governed by the Rayleigh equations which predict that when seen by transmission the milk is red, when by reflectance is blue. Scattering from larger particles is governed by Mie and multiflux theories. Many biological materials such as natural foods contain ranges of particle sizes. Milk contains a range of sizes, meat and fruit juices tending towards larger particles, while beer can contain particles of varying sizes, haze being formed by smaller and cloud by larger sizes. In foods (as in smoke from coal fired steam railway engines) an added complication occurs. Particles that cause the scattering may also be coloured and both substrate and scatterer possess absorption functions.

The current industrial instrumentation for small particle biological liquids either deals with absorption through transmission and forward scattering, or with scattering at 90° to the light source (or at angles other than 180° to the source). These do not correlate well with human perception.

3. The future

Within the industry the Kubelka-Munk Theory has been used with reasonable success for larger size particle systems, for which it was initially designed. Although it is meant to be for single wavelengths its use with tristimulus functions gives reasonable agreement with visual perception of translucency. However, it does not lead to a complete understanding of mixed particle sized systems (Hutchings and Luo 2005). It is now suggested that we can move forward using a more sophisticated model that involves more than one absorber and more than one particle size range. The radiation transfer approach involves consideration of the incident radiation Io impinging onto a particle at a depth d within a material Id.

$$Id = \text{a function of } Io, \exp[-d(\mu S + \mu K)]$$

where μ indicates a coefficient, S = scattering and K= absorption.

Among the problems this equation raises is the fact that similar to the Kubelka-Munk Theory it refers to one wavelength only, also that there may be more than one absorption coefficient and more than one scattering coefficient from different sized particles. However, a successful implementation of this approach could lead to a better under-standing of the phenomena involved in the perception and handling of translucency and to a control system for industry.

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Effects of chromatic light on visibility-distinction threshold and equivalent veiling luminance

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Abstract
Evaluation of the visibility under chromatic light is important to maintain safety and comfortableness. In this report, the influence of chromatic light on the visibility is examined at the viewpoint of the detail identification threshold, the luminance difference threshold and the veiling luminance by using the fluorescent lamps of white, blue, green, yellow and red. The distinction threshold of detail/luminance under red light is lowest among four chromatic lights. Similarly, as for the veiling luminance, the case in the red glare source is smaller than that of another chromatic light. The blue light might have the highest possibility of decreasing the visibility.

1. Research background
Chromatic light has been easily multiused as lighting by the development of various light sources, especially by LED and OLED. Chromatic light in this report is the light that deviates from the planckian locus extremely. The relation between the monochromatic radiation of wavelength and the recognition sensitivity is analyzed well and known widely as, for example, spectral luminance efficiency. However, by the use only of the relation to monochromatic radiation, it is difficult to evaluate the visibility in the space illuminated by polychromatic light. Then, authors have been researching the influence of chromatic light on the visibility as part of the research on the visual environment with lighting by chromatic light.

In the previous report[1)], with visibility, impression and colour identification, the influences of chromatic light on visual acuity were discussed about the elderly person and the young. In this report, the influence of chromatic light on the visibility is examined at the viewpoint of the detail identification threshold, the luminance difference threshold, and the equivalent veiling luminance about the young person.

2. Experimental conditions
The influence of chromatic light is examined by using a fluorescent lamp. Figure 1 shows the spectral distribution of the lamp. Two kinds (5000K and 4200K) are used for white light, and a latter spectral distribution is similar to a yellow one.

Table 1 shows the experimental conditions and discussion items. Experiment A and Experiment B are measurements of the pause width threshold W_{th} of Landolt ring that is able to distinguish direction correctly. The visual acuity is defined as the reciprocal of W_{th}. Experiment C and Experiment D are measurements of luminance difference threshold by disc. Figure 2 shows the position of the glare source. The width of each source is 10 cm and the luminance is 2400 cd/m^2. Subjects are young persons.

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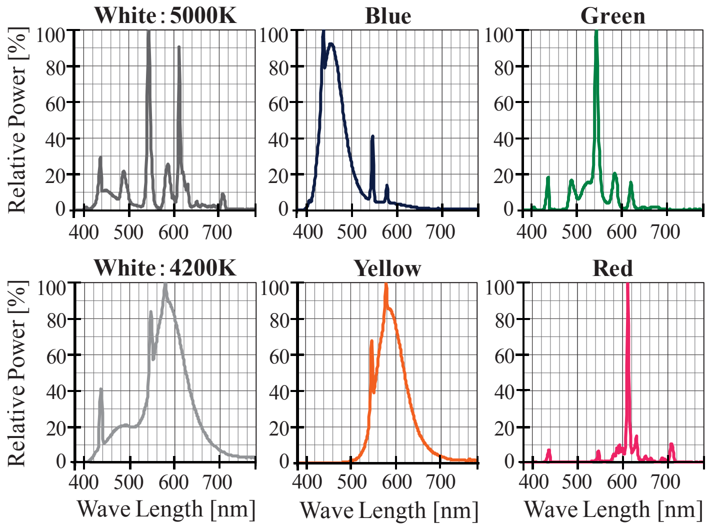

Figure 1. Spectral distribution of the lighting source (fluorescente lamp)

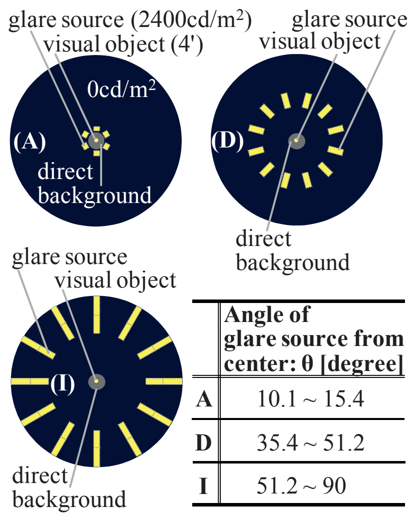

Figure 2. Position of glare source (equidistant projection chart)

Table 1. Experimental condition

		Experiment A	Experiment B	Experiment C	Experiment D
Measurement		Visual acuity by Landolt ring	Visual acuity by Landolt ring	Luminance difference threshold by Disc	Luminance difference threshold by Disc
Discussion	**Explanation item**	Detail identification threshold (=Visual acuity)	Detail identification threshold (=Visual acuity)	・Luminance difference threshold. ・Equivalent veiling luminance (= Scattering light)	・Luminance difference threshold. ・Equivalent veiling luminance (= Scattering light)
Discussion	**Induced variable**	Field luminance	Visual distance	Object size	Position of Glare source
Light Colour		Five kinds : Blue, Green, Yellow, Red, White(5000K)	Five kinds : Blue, Green, Yellow, Red, White(5000K)	Four kinds : Blue, Green, Red, White(4200K, near yellow)	Four kinds : Blue, Green, Red, White(4200K, near yellow)
Visual Object	**Shape**	Landolt Ring	Landolt Ring	Disc object	Disc object
Visual Object	**Size**	0.5-10 min. of Pause	0.92 – 5.5 min. of Pause	0.5 – 128 min. of Radius	4.0 min. of Radius
Visual Object	**Contrast**	0.93	0.93	Arbitrariness	Arbitrariness
Field Condition – Luminance Distribution	**Direct background**	0.025-460 cd/m²	0.076-0.76 cd/m²	0.2-300 cd/m²	0.2-1.0 cd/m²
Field Condition – Luminance Distribution	**Surrounding**	0.025-460 cd/m²	0 cd/m²	0 cd/m²	0 cd/m² and 2400 cd/m² of glare source.
Field Condition	**Visual distance**	75cm - 2.5 m	10 m - 50 m	90 cm to presentation window	90 cm to presentation window
Number of Subject		16 persons	5 persons	5 persons	5 persons

3. Results and consideration

3.1 Detail identification threshold by Landolt ring : Experiment A[1] & Experiment B

As shown in Figure 3, under the same field luminance when it is low, the pause width threshold W_{th} of Landolt ring obtained in red light and in yellow light is smaller than in another three light colour[1]. The significant difference in statistics is admitted between red light and blue/green/white light under the low field luminance. The higher the luminance is, the smaller the difference of W_{th}

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by light colour is. As shown in Figure 4, even if the visual distance is changed, the influence of chromatic light on W_{th} is the same. As the reason, there is the density difference of three kinds of the cone on fovea.

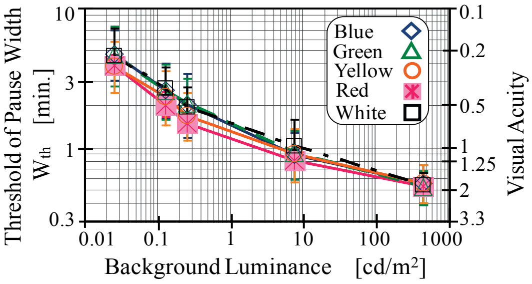

Figure 3-1.

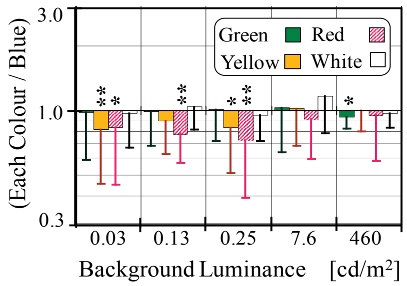

Figure 3-2.

*Figure3-1. Relation between the background luminance and the pause width threshold W_{th} of Landolt ring that is able to distinguish direction correctly. Figure 3-2. Ratio of W_{th} in each light to the result in blue light. (Result of Experiment A. '**' shows the significance 1.0% to blue light and '*' shows 5.0%.)*

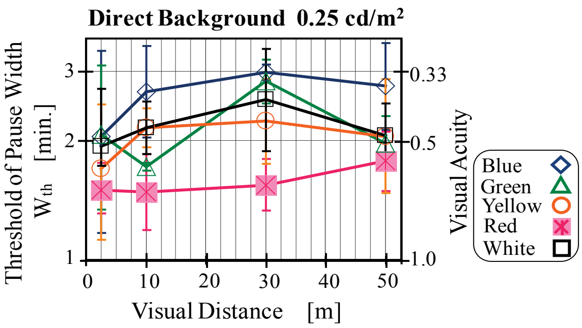

Figure 4-1.

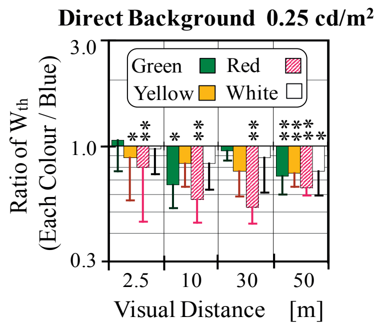

Figure 4-2.

*Figure 4-1. Relation between the visual distance and the pause width threshold W_{th} of Landolt ring that can distinguish direction correctly in the case of direct background 0.25cd/m². Figure 4-2. Ratio of W_{th} in each light to the result in blue light. (Result of Experiment B. '**' shows the significance 1.0% to blue light and '*' shows 5.0%.)*

3.2 Luminance difference threshold by Disc object: Experiment C

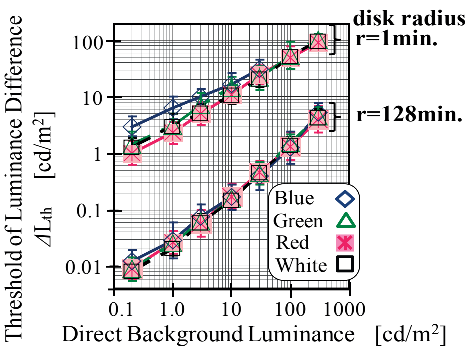

Figure 5-1.

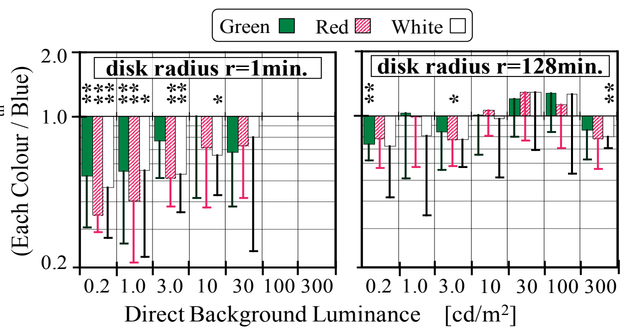

Figure 5-2.

*Figure 5-1. Relation between the background luminance and the luminance difference threshold ΔL_{th}. Figure 5-2. Ratio of ΔL_{th} in each light to the result in blue light. (Result of Experiment C. '**' shows the significance 1.0% to blue light and '*' shows 5.0%.)*

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As shown in Figure 5, under the same field luminance, the luminance difference threshold ΔL_{th} obtained by Disk object is highest in blue light, and lowest in red light. The significant difference in statistics is admitted between them. It means the lighting by red light is able to see the disc most easily, and in this respect, it is the same as the result of detail identification threshold (§3.1). The bigger the object size or the direct background luminance is, the smaller the difference of ΔL_{th} by light colour is. It is thought that these results are related to the scattering property in the eyeball.

As an intriguing result, the effect of white light (4200K) is similar in the effect of yellow light of experiment A and B. As the reason, it is enumerated to look like well as the spectral distribution of both lights shows in Figure 1.

3.3 Equivalent veiling luminance by glare source: Experiment D

As shown in Figure 6, equivalent veiling luminance Lv by the chromatic glare source tends to be low in the case of red light source, and tends to be high in blue. The nearer the view point the glare source is, the greater the difference of Lv by light colour is. This shows that the reduced visibility by red glare is smaller than by blue glare.

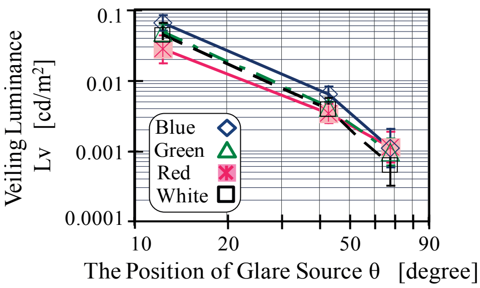

Figure 6-1.

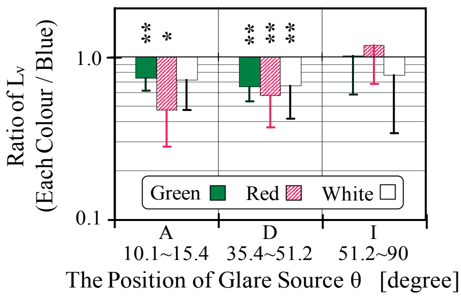

Figure 6-2.

Figure 6-1. Relation between the position of glare source and the equivalent veiling luminance Lv.
Figure 6-2. Ratio of Lv in each light to the result in blue light.
*(Result of Experiment D. '**' shows the significance 1.0% to blue light and '*' shows 5.0%.)*

4. Conclusion

For young person, the visibility is highest in red and lowest in blue among four chromatic lights that are blue, green, red and yellow.

1. The Visual acuity/Detail threshold under the lighting of red light is highest/lowest among five colours used in the experiments. It doesn't depend on the visual distance.
2. The luminance difference threshold is lowest in red light and highest in blue light. The bigger the object size is, the smaller the difference by light colour is.
3. For both threshold of the detail identification and the luminance difference, the difference of light colour disappears when the background luminance is high.
4. The equivalent veiling luminance is lowest in red glare and highest in blue one. The influence of glare source colour becomes small when the source is on the edge of field.

Acknowledgments

This research was supported by a funding from Research Foundation for Safe and Society and by Grants-in-Aid for Scientific Research (C21560612) from Japan Society for the Promotion of Science.

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Correcting for non-uniform lighting when photographing the mural in the royal tomb of Amenophis III (II): Applying a lighting model to mural images

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Abstract

We are attempting to digitize the mural at the royal tomb of Amenophis III. When photographing the mural, two strobe lights with umbrellas were used to provide uniform illumination. Nonetheless, the illumination was still somewhat nonuniform. We corrected for this non-uniform lighting by applying a lighting model, which we evaluated using images with white patches and images of the model mural without white patches. The lighting model was then extended to two light sources and applied to images of the actual mural. The corrected images were observed as more uniformly illuminated.

1. Introduction

The tomb of Amenophis III, one of the pharaohs of ancient Egypt, is in the Valley of the Kings in Luxor, Egypt. The burial chamber is 8.2 m wide, 15.4 m long, and 3.1 m high (4.7 m in places), and four walls are painted with the Amduat. We have been attempting to create a full-size digital image of this mural that will be accessible to many researchers in the world and can be displayed on computer displays: Inui et al. (2009, 2010a, 2010b). We took 99 images (small-size images) of a part of the mural with a 21mega pixel camera at one position. These 99 small-size images were stitched, and a 380mega pixel image (middle-size image) was produced. From these middle-size images, we are attempting to produce a full-scale large-size image corresponding to the entire area of each wall, north, south, east, and west.

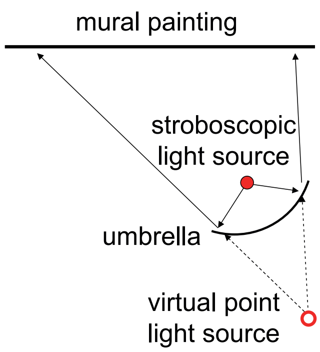

Fig. 1 Lighting model in which illumination provided by light from a strobe light reflected from an umbrella is assumed to act as a virtual point light source.

To avoid non-uniform lighting, the mural was illuminated with diffuse light from two strobe lights with umbrellas positioned on either side. However, this still does not provide highly uniform lighting. We are currently attempting to correct this non-uniformity by applying a lighting model : Inui et al. (2011).

2. Lighting model

If we consider a strobe and an umbrella as a point light source located at a long distance (Fig. 1), an inverse-square relationship holds for the reduction in the intensity of this virtual light source with distance. The illuminance E at any point (x, y) on the mural will then be given by:

$$E = \frac{p}{d^2} = \frac{p}{(x-x_0)^2 + (y-y_0)^2 + d_0^{\,2}}$$

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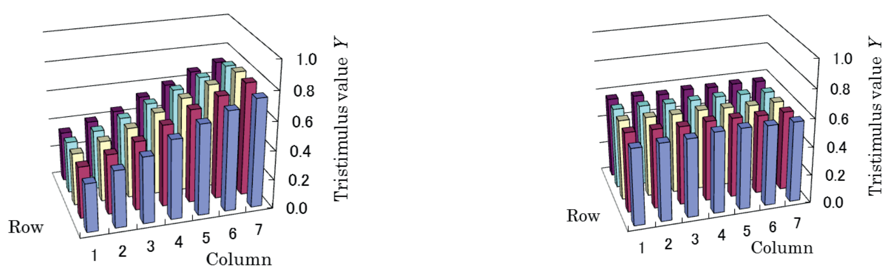
where p is the luminous intensity of the light source, d is the distance of the light source from the point (x, y), x_0 and y_0 are the coordinates of the light source, and d_0 is the distance between the light source and the mural. To compensate for the non-uniformity, the illuminance at each point (actually, at each pixel) is corrected by the illuminance at a standard point (pixel) using a model equation. The coordinates used to specify each point are not its actual spatial coordinates but the location of the pixel in the stored image. Since it is difficult to measure the illuminance, the tristimulus value Y evaluated from the digital RGB values for a location that is judged to have the same reflectivity in the photographed image is employed as the relative value.

3. Verification of lighting model using white patch image

A model mural (2.4 m wide × 1.6 m high) was created from a set of photographs taken in a preliminary survey and used to verify the effectiveness of the model lighting. 35 white patches were attached to the model mural and lighting was set up to illuminate it solely from the right-hand side. The white patches were then removed and the model mural was photographed again under the same conditions. The tristimulus value Y was found using the sRGB space from the digital RGB values in the white patches in the image: IEC, 1999. This Y value was the relative illuminance value E. The four constants p, x_0, y_0, and d_0 to be used in the lighting model were calculated by nonlinear optimization using the tristimulus value Y on the location coordinates (x, y) of the 35 white patches and at the respective locations. In other words, we estimated a relative luminous intensity p and location (x_0, y_0, d_0). The RGB digital values of each pixel in the original image were transformed to the tristimulus values XYZ, and the XYZ values at each location were corrected based on the relative illuminance value Y at that location. The corrected XYZ values were then reverse-transformed to RGB. The white patches of image were corrected from the pixel-by-pixel color correction. Fig. 2 shows the tristimulus value Y before and after the correction based on the white patches. Fig. 2 reveals that the large variation in the tristimulus values Y prior to correction is greatly reduced after correction. The white patches in the corrected image are nearly the same, which confirms that the lighting model selected in this study was effective.

4. Verification of the lighting model on an image without white patches

The white patches used in the test of the lighting model could not be applied to an ancient monument such as the mural at the royal tomb. Instead, we used background regions that were nearly the same color. 44 nearly uniform background regions were selected (indicated by the squares in Fig. 3). The four constants employed in the lighting model were calculated using the digital RGB values for each square region and the correction was applied to the non-uniformity in



(a) (b)

Fig. 2 Tristimulus values of white patches (a) before and (b) after correction for non-uniform lighting.

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the lighting. Fig. 4 shows the tristimulus values *Y* before and after correction. The horizontal axis shows the background image number, beginning from the upper left corner and proceeding to the right, then down to the lower right corner. A standard deviation of tristimulus values of the background of the corrected image is approximately 1/4 of those of the original image. This confirms that the correction successfully eliminated non-uniformity using the background of the image.

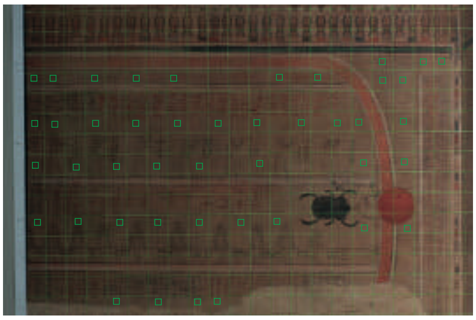

Fig. 3 Extracted uniform background regions.

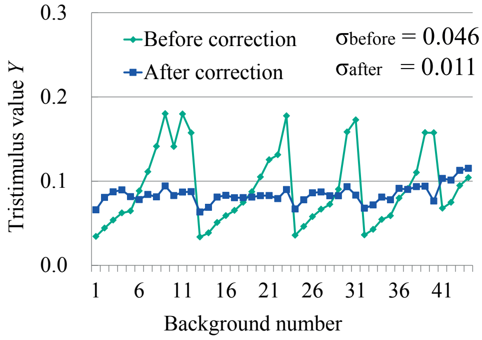

Fig. 4 Tristimulus values before and after correction by lighting model.

5. Application to the Amduat

The photography was performed using two lights on the right and left sides, so the lighting model was extended to two sources as follows:

$$E = E_1 + E_2 = \frac{p_1}{(x - x_1)^2 + (y - y_1)^2 + d_1^2} + \frac{p_2}{(x - x_2)^2 + (y - y_2)^2 + d_2^2}$$

The subscripts 1 and 2 indicate the constants indicating virtual point light sources 1 and 2, respectively. Fig. 5 presents an image of the actual mural and 53 uniform background regions extracted from the image. The values of the eight constants employed in the lighting model were determined from these background colors by the nonlinear optimization process described in the previous section. The values to which this process converged sometimes varied for different initial values. Some calculations even converged to negative values for the relative luminous intensity *p*. This will be described later, but when the luminance became negative, it disrupted the calculation process. When this happened, the initial values were changed and the calculation was performed again. When negative luminous intensity values were no longer found and reasonable solutions had been obtained with low errors, the values were used as the constants.

(a) *(b)*

Fig.5 An example of real mural painting image (a), and its extracted backgrounds which assumed as uniformly illuminated (b).

Fig.6 An example of corrected image shown in Fig.5

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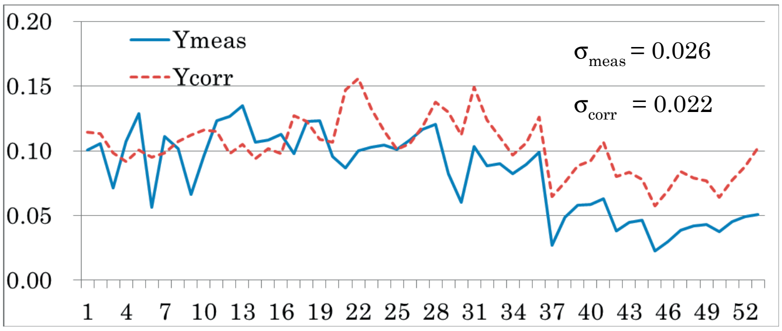

Fig. 7 Tristimulus values Y of backgrounds in images of the actual mural before and after correction.

These values for the eight constants were employed to perform the correction described in the previous section. Fig. 6 shows the corrected image. Tristimulus values Y before and after corrections are given in Fig. 7. Comparing the corrected image with the original, the dark lower portion has been improved (although it is still deficient) while the middle portion has become a little lighter. We can anticipate these effects from the graph in Fig. 7. After correction using a mean tristimulus values Y of 0.10, backgrounds #37-52 in the lower portion of the image became a little dimmer, while backgrounds #21-36 in the middle portion became a little brighter. The correction reduced the standard deviation of tristimulus values Y by only a small amount (about 15%), but the image after correction seems to be considerably enhanced compared with the image before correction.

6. Summary

A lighting model for photography was constructed and its effectiveness was examined using a model mural illuminated by imbalanced lighting from one side. The lighting model was extended to the actual use of photography with lighting from two sides and applied to the image of the actual mural. It was confirmed that the non-uniformity in lighting had been reduced. This procedure will be applied to all previously obtained images.

Acknowledgments

This research was conducted under Grants-in-Aid for Scientific Research from the Japan Ministry of Education, Culture, Sports, Science and Technology (2008–2010, Project No. 20401026).

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Effect of correlated colour temperature on individual variation in the impression of lighting with regard to season

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Abstract

The purpose of this paper is to clarify the tendency how within/between-subject variation in impression of lighting is changed by the correlated colour temperature. The experiment variables are the correlated colour temperature, illuminance and season. The subjects evaluate 4 items which are brightness, glare, comfort and relaxation of the lighting. The results are as follows; 1) the effect of the correlated colour temperature to the within-subject variation is smaller than the effect of illuminance. 2) The between-subject variation receives the influence by the correlated colour temperature and the illuminance. 3) Regardless of correlated colour temperature and season, the between-individual variation is larger than the within-individuals variation.

1. Introduction

People are exposed to the changing level and amount of illuminance during a day or a year. And the changing one is the colour of light as well as the illuminance. We have received various influences from such changes and adapt our sensibility of lighting to environment. Therefore, it is important to clarify the relationship between the one's feeling and the illuminance or correlated colour temperature change through a year.

This study investigates how the correlated colour temperature and illuminance affect the impression of lighting with seasons. However, subjective evaluation inevitably has individual variation. Accordingly, the purpose of this paper is to clarify the degree to which the correlated colour temperature and illuminance affects the within/between-subject variation in impression of lighting in summer and in winter.

2. Conditions of the experiment

The size of the evaluation room is W2.7m × D2.7m × H2.6m, the floor reflectance is 26 percent and the wall reflectance is 93 percent. The lighting is a uniform luminous ceiling set in fluorescent lamps sized with 2.7m ×2.7m, and it can be adjusted from 0.5～2000 lx. The experimental condition is shown in Table 1. The experiment variables are three: 1) The correlated colour temperature of fluorescent lamp (3000K or 6700K). 2) The vertical illuminance at the subject's eyes position (12 levels, from 0.5 lx to 2000 lx). 3) The season（summer or winter.

Table 1 Experimental conditions

1) Correlated colour temperature	2) Season	3) Vertical illuminance at the subject's eyes position
3000K（Fluorescent lamp） 6700K（Fluorescent lamp）	Summer（2003.8） Winter（2003.12～2004.1）	0.5, 1, 2, 5, 10, 20, 50, 100, 500, 1000, 2000 lx （12levels, start is 0.5 lx and finish is 2000 lx）

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27 healthy young women take part in the summer's experiment, and 31 healthy young women in the winter's experiment. They evaluate 4 items which are brightness, glare, comfort and relaxation of the lighting. The measurement frequency in summer is three times for each subject and in winter two times.

The experimental procedure (Figure 1) is as follows: 1) Subjects evaluate the lighting after staying in the evaluation room for 5 minutes with 0.5 lx. They are able to look around the room. 2) The illuminance is changed to next level. 3) Subjects adapt for 2 minutes and evaluate 4 items. Thereafter 2) and 3) are repeated. The illuminance in this paper means the vertical illuminance at the subject's eyes position.

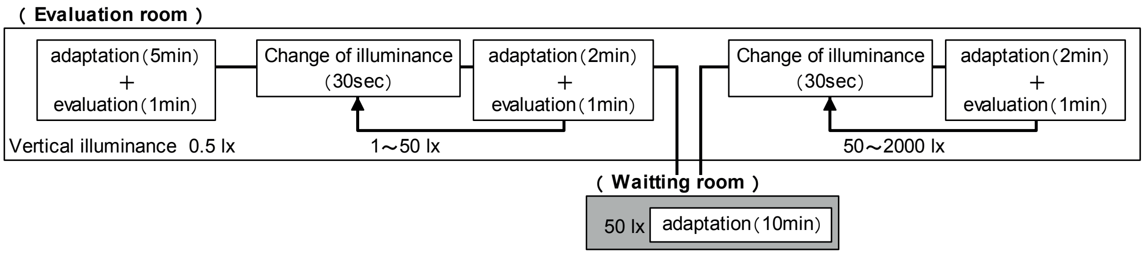

Fig. 1 Experimental sequence

3. Results and discussion

3.1 Relationship between the illuminance and the within-subject variation

Figure 2 shows the relationship between illuminance and within-subject variation. The figure shows a result for 4 items in the summer. The within-subject variation is referred to V_W.

In all 4 items, the relationships between illuminance and the incidence rate of V_W in 3000K are similar to that in 6700K. V_W of Brightness, glare and comfort changes depending on the illuminance. The influence on V_W of the relaxation by the illuminance is small, and the relation is clear in each individual. People have own suitable illuminance level for relaxation.

The difference of V_W by the correlated colour temperature appears in glare and comfort. In glare, the illuminance in which percentage of V_W begins to rise in 3000K is higher than that in 6700K. In comfort, the percentage of V_W within the low illuminance range in 6700K is higher than the percentage in 3000K.

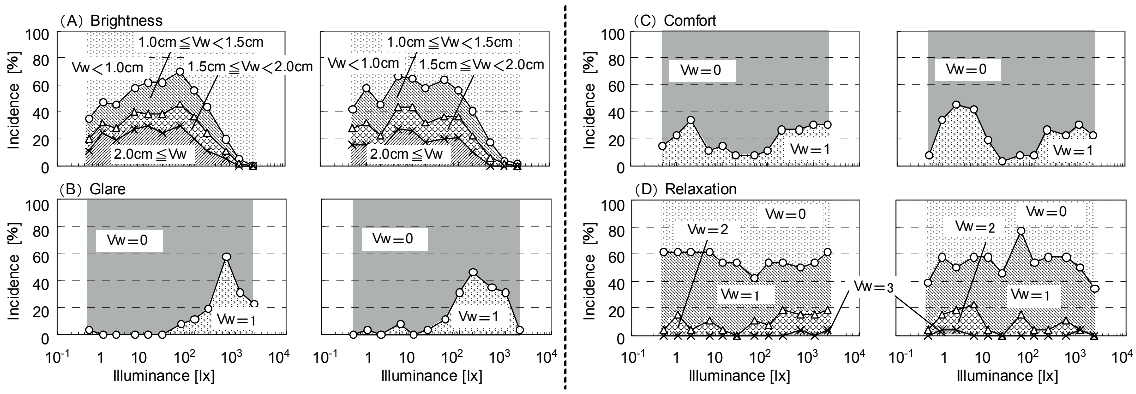

Fig.2 Relationships between the illuminance and the within-subject variation in summer.
V_W is the within-subject variation. Left panels show result in 3000K, right panels in 6700K.

$$V_W = EVmax - EVmin$$

EVmax — maximum value in the subject's evaluation of 3 times
EVmin — minimum value in the subject's evaluation of 3 times

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3.2 Relationship between the illuminance and the between-subject variation

The between-subject variation is examined with the standard deviation. The standard deviation of the between-subject variation is designated as V_B. The relationship between illuminance and V_B is shown in Figure 3. The figure is shown for summer.

Regardless of correlated colour temperature and season, the relation between illuminance and V_B is nearly alike. V_B of Brightness, glare, comfort and relaxation of the lighting are changed by the illuminance. There is no the tendency of the within-subject variation in relaxation. Although the tendency is similar, there are differences caused by the colour temperature. In brightness, V_B of 3000K is smaller than V_B of 6700K in the low illuminance range. In glare and relaxation, the illuminance range in which the difference of V_B by the correlated colour temperature appears is from 20 lx to 200 lx. Within this range of V_B in 3000K is smaller than that in 6700K. In comfort, V_B of 3000K is smaller than V_B of 6700K within 5 lx to 20 lx.

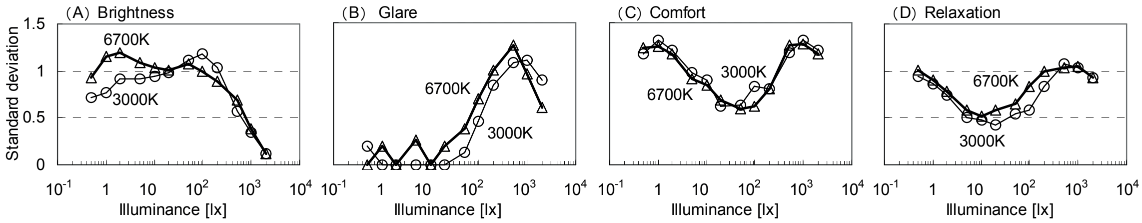

Fig. 3. Relationships between the illuminance and the between- subject variation in Summer.
The between-subject variation is standard deviation. Circles show 3000K, and triangles show 6700K.

3.3 Comparison with the within-subject variation and the between-subject variation

Within-subject variation and between-subject variation are compared by the coefficient of variation (CV). The average coefficient of variation about within-subject variation is CV_W, and the coefficient of variation about between-subject variation is $CV_{B.}$ The coefficient of formula about CV_W and CV_B are shown in Figure 4.

Figure 4 shows comparison with CV_W and CV_B in every condition. The relation between illuminance and CV_W or CV_B has similar tendency in each item, regardless of correlated colour temperature and season. In addition, CV_B is larger than CV_W. This result shows that the between-subject variation is larger than the within-subject variation.

The difference between CV_W and CV_B is shown at range of low illuminance in the brightness, and the range is at high illuminance in the glare. The influence on CV_W by the illuminance is small in comfort and relaxation. However the influence on CV_B by illuminance is big. And as the illuminance becomes lower than 20lx or higher than 100lx, the difference between CV_W and CV_B becomes bigger. The difference between CV_W and CV_B of "comfort and relaxation" is bigger than that of "brightness and glare". People have own suitable illuminance level for comfort or relaxation, and each people have different suitable illuminance.

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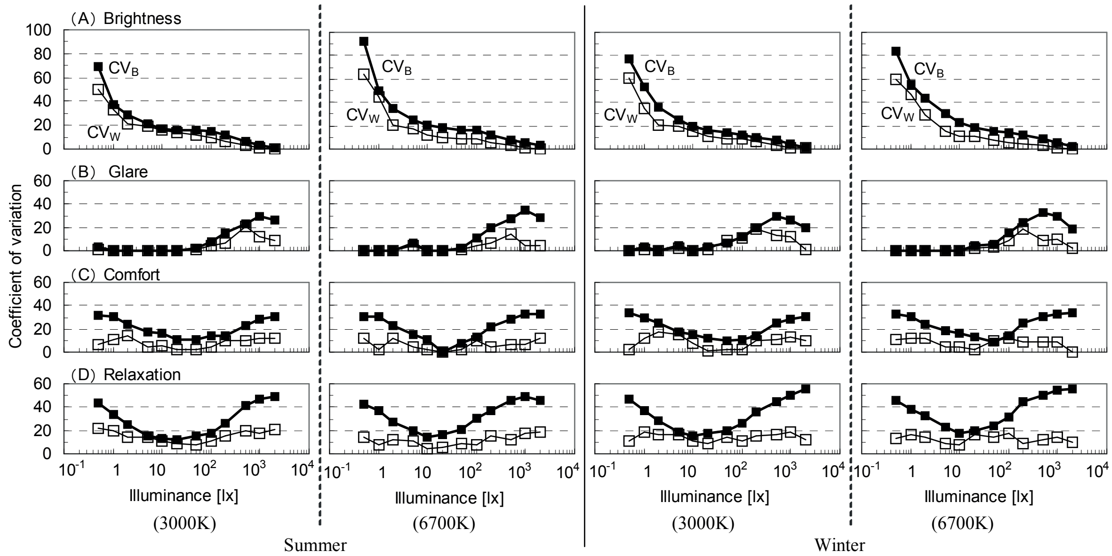

Fig.4 Comparison of the within-subject variation and the between-subject variation by coefficient of variation. CV_W(□)is the average coefficient of variation about the within-subject variation. CV_B(■) is the average coefficient of variation about the between-subject variation.

$$CV_i = SD_i / X_i \times 100$$

$$CV_W = \sum_{i=1}^{m} CV_i / m$$

X_i — average of subject's evaluation at the each illuminance
SD_i — standard deviation of subject's evaluation at each illuminance
m — number of subject

$$CV_B = SD / X \times 100$$

X — average of every subject's evaluation at the each illuminance ($X = \Sigma Xi / m$)
SD — standard deviation of every subject's evaluation at the each illuminance

4. Conclusion

1. The illuminance has a great influence on within-subject variation in brightness, glare and comfort. The relation between the incidence of within-subject variation and illuminance in 3000K is similar to that in 6700K. The effect of the correlated colour temperature to the within-subject variation is smaller than the effect of illuminance.
2. The between-subject variation (V_B) receives the influence of the correlated colour temperature and the illuminance. The illuminance range in which the difference between V_B in 3000K and that in 6700K appear is different in each evaluation.
3. Regardless of correlated colour temperature and season, the between-individual variation is larger than the within-individual variation, although there is little difference depending on the illuminance.

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Effect of knowledge and experience of fabric on the cross-modal linkage between tactile sensation and visual image of solid black and multi-color printed fabrics

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Abstract

Aim of this study is to investigate the effect of knowledge and experience on the ability of fabric identification using visual and tactile information as well as to explore a key property of image to be used in the cross-modal linkage. We carried out two fabric identification experiments with using only solid black fabric (Experiment 1: E1) and both the other solid black fabric and multi-color printing (Experiment 2: E2). These experiments were done by two subject groups – engineering and clothing students, but these of E1 and E2 are difference. Two kinds of pictures with and without drapes (Pattern A, B: PA, PB) were employed for the cloth image. Result of E1 indicated that the clothing students showed better performance than the engineering students, and average percent correct was statistically higher in the sessions showing PA than that in the sessions showing PB. However, no significant difference was observed indicating that the showing the cloths on just before the experiment doesn't contribute to form the linkage between visual and tactile recognition. On the other hand, result of E2 indicated that no significant difference was observed on the two groups, whereas percent correct showed the same tendency as E1.

1. Introduction

Recently, many people purchase cloths using internet-shopping where they have to select things by looking at digital images presented on a display. Although quality of digital color image has become fairly good level, web-shop consumers still have disappointed experience sometimes that the color, texture, and the tactile touch of the cloth differ from what they expected. High fidelity of image reproduction is not so difficult for high quality displays nowadays, but small displays such as cellular phones or board computer such as iPad, have limitations for resolution, dynamic range as well as color gamut. On the other hand, some trained observers can estimate what kind of fabrics or quality of cloths quite well even seeing the image on non-high-quality displays. To clarify their skills for fabric identification is useful not only for establishing a better photographic technique which would reduce consumer problems but also developing an effective educational method for clothing course. It is also interesting from scientific point of view to reveal how the knowledge and/or experience affect on cross modal linkage between vision and tactile. As our first approach to this issue, the aim of this study is to investigate the effect of knowledge and experience on the ability of fabric identification using visual and tactile information as well as to explore a key property of image to be used in the cross-modal linkage. We carried out the fabric identification experiment using two subject groups, one is the students in the engineering, and another is the student in the clothing. Knowledge and experience levels of the two groups supposed to differ and to be checked by questionnaire. In the fabric identification experiment, subjects were

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asked to select a real cloth by blind touch while seeing the image of the cloth on a display. Two kinds of pictures with and without drapes were employed for the image of the cloth in order to investigate the contribution of image property to fabric identification. Two experiments were done with using only solid black fabric (Experiment 1: E1) and both the other solid black fabric and multi-color printing (Experiment 2: E2). These subject groups with using the E1 and the E2 are difference. Effects of knowledge and experience and image property on the cross modal linkage between vision and tactile are discussed.

2. Experiment

Before the blind touch experiment, observers were asked to answer the questionnaire to estimate a level of knowledge on the fabrics names, visual experience, tactile experience, and wearing experience of the fabrics. Eleven fabrics that selected by the difference of characteristic were prepared in E1, while seven or ten fabrics that can print in multi-color or dye in solid black were prepared in E2. Each fabric for blind touch experiment was cut to 20cm X 20cm square piece and the small square tag was attached to the corner of each piece to indicate the front surface of the piece. We called them “test cloths”. Also, each fabric for photography was cut to a circular piece with a diameter of 40cm, and then two types of pictures were taken for each of them. One was that the circular cloth covered a wooden cylinder to make drapes, and was taken by the camera from lateral position. Another was that the circular cloth was flatly placed on the floor and taken by the camera from upper position. We call the former, Pattern A (PA), and the latter, Pattern B (PB). Moreover, two kinds of PA pictures that took by using the spotlight (PA1) and a uniform light (PA2) were employed. PA and PB picture took Back satin shantung are shown in Figure 1 (a) and (b), and PA1, PA2 and PB picture in the case of multi-color printed fabric: silk shantung were shown in Figure 2 (a), (b) and (c).

(a) (b)

Figure 1. (a)Pattern A and (b)Pattern B picture took Back satin shantung

(a) (b) (c)

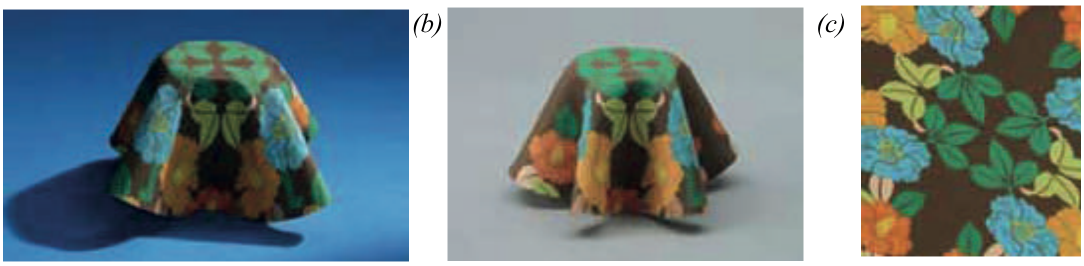

Figure 2. (a)Pattern A1, (b)Pattern A2 and (c)Pattern B picture in the multi-color printed fabr: Silk shantung

14 or 10 female students in each of engineering and clothing participated to E1 or E2, respectively. Furthermore, each subjects group in case of E1 was divided into two groups with and without showing test cloths before the blind touch experiment. In the blind test, one of the pictures of the test cloths, either PA (A1 or A2 in E2) or PB was presented on a 14in display of note personal

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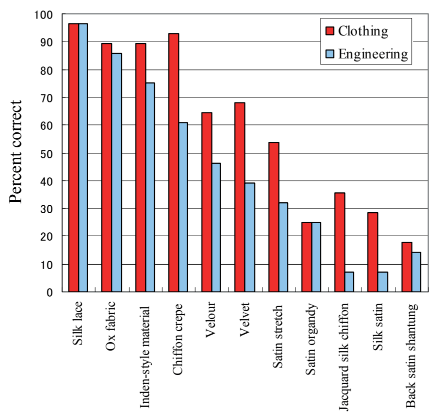
computer, and the observer was asked to select one of the test cloths corresponding to the image by touching 11 (or 10 or 7 in E2) test cloths without seeing them. Order of the sessions showing PA (A1 or A2 in E2) or PB is randomized among the subjects.

3. Results and analysis

Results of the questionnaires clearly indicated that the clothing student group has higher level of knowledge and experience on fabrics than that of the engineering students group in both E1 and E2. Then, percent correct was calculated for each test cloths in all conditions. Three comparisons between subject group, patterns, and experiences with showing the test cloth on just before the experiment, were made in E1. In the first comparison, statistically significant difference was observed between the subject groups that the clothing students showed better performance than the engineering students (Figure 3(a)). In the second comparison, average percent correct was statistically higher in the sessions showing PA than that in the sessions showing PB (Figure 3(b)). In the third comparison, no significant difference was observed indicating that the showing the test cloths on just before the blind test doesn't contribute to form the linkage between visual and tactile recognition.

(a)



(b)

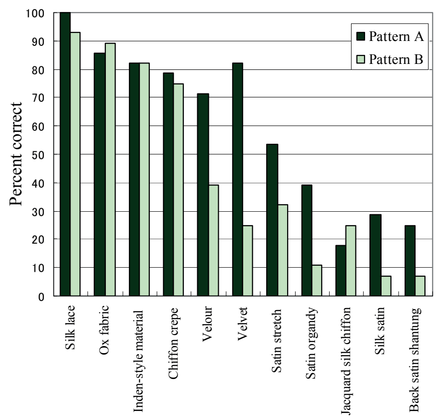


Figure 3. Results of (a)subject group and (b)Pattern comparison in Experiment 1

Results of Patterns comparing indicate that more useful information is included in the PA picture than PB. Therefore we calculated the skewness [Motoyoshi et al. (2007), Sharan et al. (2008)] and kurtosis of images for 11 test cloths of both PA and PB. In the case of PA where a large variation is found for both skewness and kurtosis among the images of different test cloths, multiple linear regression using those two values showed a strong correlation to the percent correct of the test cloth identification. Weighting coefficients of the skewness is much larger than that of kurtosis for both clothing and engineering students' results. In contrast, no correlation between the skewness and/or kurtosis and the percent correct of the test cloth identification was observed in the case of PB where neither skewness nor kurtosis showed large variation among the images of different test cloths.

On the other hand, result of E2 indicated that no significant difference was observed between the subject groups (Figure 4(a)), whereas average percent correct had the same tendency of E1, that is, higher in the sessions showing the pictures of PA1 and PA2 than that in the sessions showing PB (Figure 4(b)).

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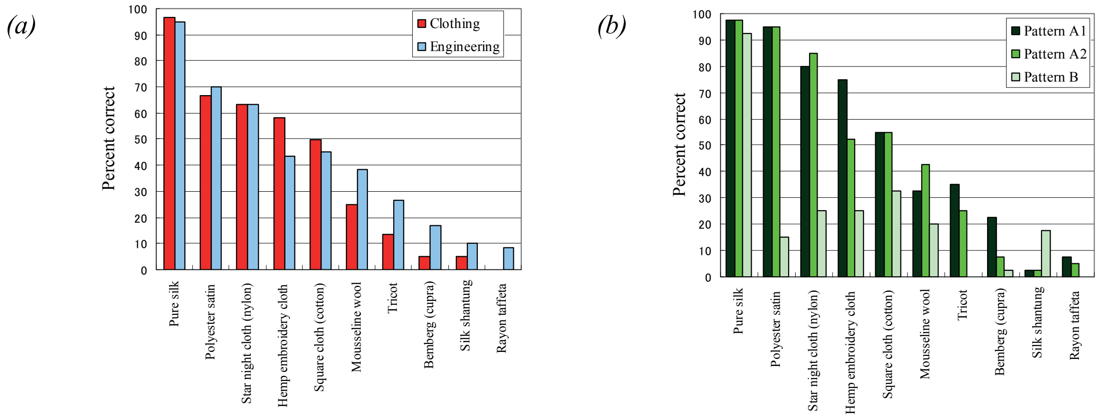

Figure 4. Resuts of (a)subject group and (b)Pattern comparison in Experiment 2

4. Discussion and summary

In this study, results of E1 comparing the two subjective groups - clothing and engineering students - indicate that knowledge and experience on fabrics accumulated for a long period form a rigid linkage between visual image and tactile sensation in subject brain and it contributes to combine tactile sensation to visual image in order to label the certain fabric name to the test cloth with the aid of knowledge database. Result of multiple linear regression using skewness and kurtosis values showed a strong correlation to the percent correct of the cloth identification. Weighting coefficients of the skewness is much larger than that of kurtosis. Therefore skewness is a key property of image to be used in the cross-modal linkage. On the other hand, result of the E2 indicated that no significant difference was observed on the two groups, whereas average percent correct showed the same tendency as the E1. These results indicated that further investigations of the quality of subjects' experience on the fabrics, the criterion for selecting cloths et al. are required.

Acknowledgments

This research was supported by a Grant-in Aid from Japan Society for the Promotion of Science (No.22500184) and the Eminent Research Selected at Utsunomiya Univ. in ‘09-‘10.

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Determination of spectral dimensions of Munsell neutral samples

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Abstract

In this article, the dimensional behavior of the neutral samples of Munsell sets is investigated. According to the Munsell color system, the perfect gray samples, locate in the line with different lightness (values) while, their chroma values are equal to zero. To analysis the dimensional behavior of neutral samples, the principal component analysis technique is employed on the reflectance domain. Then, the reflectance spectra of samples are compressed in the reduced spaces and are reconstructed by employing the linear combination of the weighted sum of characteristic vectors. The recovery errors between the original and the reconstructed spectra are investigated spectrally and colorimetrically by calculating the root mean square error percentages and the color difference values. Results show that the gray samples of Munsell set could be synthesized by at least 2 characteristic vectors. Besides, calculating of the metric chroma and lightness values of neutral samples show some type of deviation of specimens from the perfect greys. It means that, the spectral and the CIELAB properties of neutral samples do not indicate to one dimensional behavior of them while, they are visually form a one dimensional system.

1. Introduction

The Munsell color order system is known as the most popular color specification system based on actual colored samples. The system employs the color appearance arrangement based on colored chips which are identified in a cylindrical coordinates. The colors are arranged in this system by their values, hues and chromas: Tyler and Hardy (1940), Grum and Bartleson (1980).

According to the Munsell color system, the perfect gray samples, i.e. the achromatic colors, locate in the line with the chroma vlues of zero. The values of actual neutral samples change between 0.5 to 9.5 with the steps of 0.25. Therefore, a set of 37 neutral samples which benefit from C=0 and different V values are available: Spectral Database (University of Joensuu). While the samples visually provide a one dimensional greyscale system, the spectral behaviors of such set has not been investigated: Romney and Indow (2003). Hence, this paper tries to determine the actual spectral property of such achromatic samples. In order to determine the dimensional behavior of Munsell's neutral samples, their reflectance were extracted from 400-700 nm by 10 nm intervals. Simply to trail the linearity of the spectral reflectances of samples, each spectrum was normalized by dividing it to its maximum value. Figure 1, shows the normalized reflectance spectra of Munsell neutral samples. According to Figure 1, the spectra are deviated from linearity by achieving of different curves for normalized reflectances. In other words, a scaling factor could not transfer each spectrum to other reflectance spectra.

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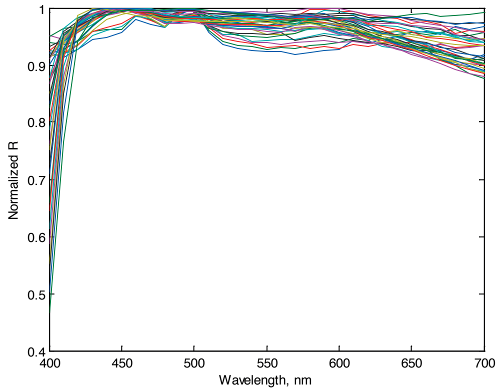

Figure 1. The normalized reflectance spectra of Munsell neutral samples.

2. Method

To analysis the dimensional behavior of samples, the principal component analysis technique: Jolliffe (2002), Fairman and Brill (2004), Tzeng and Berns (2005) was employed on the reflectance spectra. More clearly, the principal directions of the mean subtracted data, i.e. the covariance matrix were computed. By this way, the most important directions of reflectance dataset were extracted and their corresponding cumulative variance percentages calculated. Up to five eigenvectors were extracted due to the spectral behaviors of samples. Besides, the reflectance spectra of samples were compressed in the reduced spaces and then were reconstructed by employing the linear combination of the weighted sum of characteristic vectors. The recovery errors were investigated spectrally and colorimetrically by calculating the root mean square error percentages and the color difference values between the original and the reconstructed spectra. The color difference values were measured under C, D65 and A illuminants and the 1964 standard observer. The C standard light source was chosen since the Munsell samples show the maximum uniformity under this standard source. Figure 2 shows the extracted first three important eigenvectors along with the average of reflectance spectra. Besides, the recovery results of reflectance data are shown in Table 1.

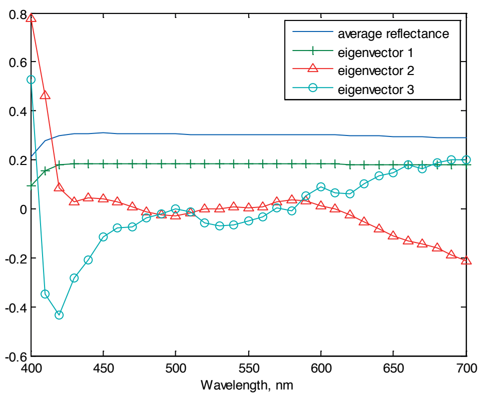

Figure 2. The first three most important characteristic vectors.

3. Result and discussion

As Table 1 shows, simply the gray samples of Munsell set could be synthesized by at least 2 feature vectors. It means that, while the neutral samples are identified as one dimensional objects by the human observer, spectrally they are two dimensional samples. In other words, one dimension is missed during the conversion of spectral data to colorimetric information.

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Table 1. Results of recovery of spectral data of Munsell neutral samples in reduced spaces, using different basis functions.

To interpret such achievement, the samples were introduced in CIELAB color order system by calculation of their XYZ tristimulus values under C light source and 1964 standard observer. The corresponded metric chroma, i.e. C* and lightness value L* were calculated. Figures 3 and 4 show the specification of samples in a*b* as well as C*L* diagrams. As the Figure 4 shows, the C* values of samples change between 0.14 to 1.13 which indicates to some type of deviation of neutral samples from the perfect grays. In fact, while the samples visually form a one dimensional system, their spectral and the CIELAB color behaviors do not confirm such sensation.

# of Eigen-vectors	Cumulative variance%	RMS%			ΔE 94								
					C			D65			A		
		Mean	Max	Sd	Mean	Max	Sd	Mean	Max	Sd	Mean	Max	Sd
1	99.88	0.72	2.73	0.48	0.38	0.77	0.20	0.40	0.83	0.21	0.40	0.95	0.24
2	99.99	0.20	0.68	0.15	0.30	0.69	0.17	0.30	0.69	0.17	0.30	0.80	0.18
3	100.00	0.13	0.42	0.09	0.25	0.65	0.13	0.25	0.65	0.13	0.26	0.58	0.13
4	100.00	0.08	0.27	0.05	0.17	0.48	0.10	0.17	0.48	0.10	0.16	0.49	0.10
5	100.00	0.07	0.17	0.04	0.15	0.37	0.09	0.15	0.38	0.09	0.14	0.37	0.08

According to Figures 3 and 4, the samples benefit from different hues with different degrees of saturation while, visually they form the neutral gray samples of Munsell chips with the chroma of value of zero.

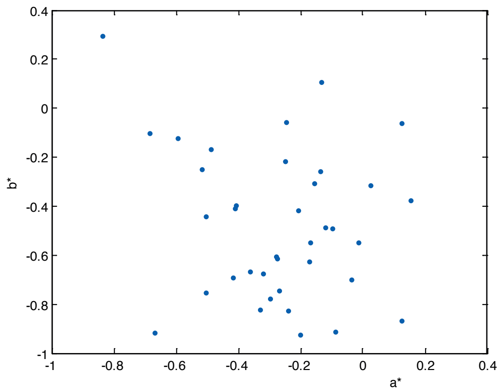

*Figure 3. The a*b* distribution of Munsell neutral samples.*

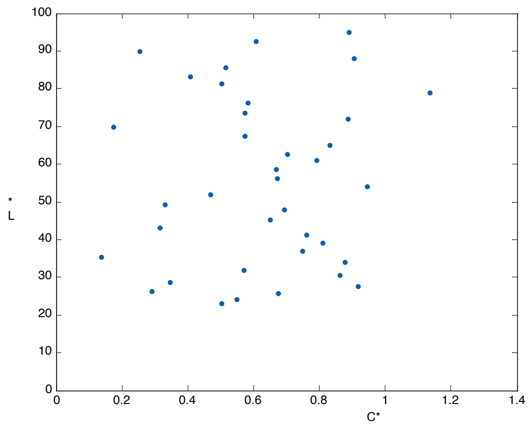

*Figure 4. The C*L* distribution of Munsell neutral samples.*

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4. Conclusion

The dimensional property of the neutral samples of Munsell color system was investigated. According to the Munsell color system, the perfect grays are a set of 37 neutral samples which benefit from C=0 and different V values. By applying the principal component techniques on spectral reflectance of neutral samples, their most important characteristic vectors were extracted. Then, samples were reconstructed in the reduced spectral spaces and their recovery errors were investigated by calculating the root mean square errors and color difference values between the original and reconstructed reflectances. Results showed that, at least 2 characteristic vectors were needed to reconstruct the gray samples, suitably. To prove this achievement, the corresponded metric chroma, i.e. C* and lightness value L* of neutral samples were calculated. The different amounts of C* indicate to some type of deviation of neutral samples from the perfect greys. It means that, while the samples visually form a one dimensional system, their spectral and the CIELAB color behaviors do not confirm such sensation.

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Comparative study of color emotion of university students between Korea and Canada

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Abstract

Today, the color takes an important position to move consumers' emotion in the era of globalization where there are active interaction among countries in fields of political, economical, cultural, and etc. The purpose of this study is to compare the color emotions between the East and the West by researching the color emotions of Korea and Canada. The samples of this study are 150 university students in Korea and 198 university students in Canada. The study conducted a survey using PCIS color charts of hue and tone. The survey asked to select a like color and a dislike color, then analyzed by categorizing like color, dislike color, like hue, like tone, dislike hue, and dislike tone. The study result finds similarities and differences in color emotion between Korea and Canada. The first similarity is that both countries university students like 1080-R, 1050-B, 1565-B, and 9000-N colors and dislike 6020-Y color.

The second similarity is that B class hue and bright tone have high preference. The third similarity shows that Y class hue and dkg tone are highly disliked. The differences of both countries' color emotion are as follows. First, there was different preference rate on RB and R class hue and, light, vivid, deep and neutral tone. Second, both countries differed in disliking YR class hue and dark, deep, and neutral tone. Third, the likeness of gray class hue in Canada and the likeness of light grayish and the dislikeness of white class hue in Korea showed 0%. A color is used as a means of communication with other countries and the color shows the characteristics of the country and its citizens in the globalization. Therefore, it is necessary to study on color emotion consistently to comply with the globalization. (**Keywords**: Color Emotion, Like color, Dislike color)

1. Introduction

The interaction among countries has been increased in the global era and the standardization of technology had led a color to become an important factor to decide a product's success. According to the U.S.'s industrial material manufacture company DuPont's Report of 2008 automobile favorite hues, the U.S. prefers beige, Europe prefers blue, red, and yellow, Russia and Brazil prefer silver. On the other hand, Korea prefers neutral colors like silver, black, white, and etc. Likewise, as different countries prefer different colors in same products, the color becomes the important factor to move emotional consumer's decision and gains recognition of further research in need. This research selects Canada as a test location, where the history of Europe is based on and the influence of the U.S. is great due to geographical location, to compare color emotion with Korea. From this study, it is expected to provide fundamental data to understand the characteristics of market and interaction of both countries representing the West and the East by analyzing the characteristics of color emotions in both countries.

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2. Method

The research method used in this study is a survey using questionnaires. The samples of this study was male and female university students in their 20s who reside in Seoul, Korea and Hamilton, Canada where culture, politics, and economics are well developed to have least differences on socio-economic factors. The reason for selecting students in their 20s is that based on the research by Mee Young Choi and Young Wan Shim4, age group between 20 to 29 shows most sensitive to color trend and strong desire in colors. The total number of samples is 198 Canadian students, and 150 Korean students. Further, the average age of Canadian sample is 21.25, and Korean sample is 21.9.

This study has used questionnaires with PCIS(Psychological color image scale) color chart in each language to samples. Further, to increase the accuracy, both countries used the identical color charts. In addition, a face to face interview method was selected and made the sample to respond within 5-6 seconds. The study took place on October 2010, and used a classroom with full of daylights to minimize the artificial luminous source.

This research used PCIS color charts composed of hues and tones corresponding to NCS and ISCC-NBS color systems. The background color was white color to minimize the distraction to the stimulus colors, and the stimulus colors were size of 1.2cm x 1.0cm on the background color paper sized 21cm x 30cm, with 104 different colors. The hues of stimulus colors were total of 11 hues, 8 chromatic colors of R, YR, Y, GY, G, BG, B, and RB and white, gray and black. Total of 13 tones were used, v:vivid, s:strong, b:bright, sf:soft, lt:light, p:pale, ltg:light grayish, g:grayish, d:dull, dp:deep, dk:dark, dkg:dark grayish, and N:Neutral. The survey provided the color chart and made the respondents to select a like color and a dislike color and record the corresponding number on the survey.

3. Result

The result of Korea and Canada color emotion study has been analyzed by three categories; first the like and the dislike color, second the like and dislike hue, and third the like and the dislike tone.

A. Color

As seen in Table 1, Korea prefers 0530-R and Canada prefers 1080-R the most, and 1080-R, 1050-B, 1565-B, and 9000-N are preferred colors in both countries. In the dislike color, Korea dislikes 6020-Y and Canada dislikes 3560-Y the most. Further, the common dislike color is 6020-Y, there are less commonality on the dislike color.

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Table 1. Korea, Canada Regional like color & dislike color rate

	Rank / Country	1	2	3	4	5
Like Color	Korea	0530-R 11.3 %	1080-R 1565-B 9000-N 8.4 %			1050-B 6.7 %
	Canada	1080-R 10 %	1050-B 7.6 %	1565-B 6.1 %	3055-R50B 5.1 %	9000-N 4.5 %

	Rank / Country	1	2	3	4	5
Dislike Color	Korea	6020-Y 6.7 %	6030-R 5.3 %	6030-Y 4.7 %	6530-B50G 6020-B 4 %	
	Canada	3560-Y 7.5 %	9000-N 7 %	6030-Y50R 6020-Y 6 %		6020-Y50R 5 %

B. Hue

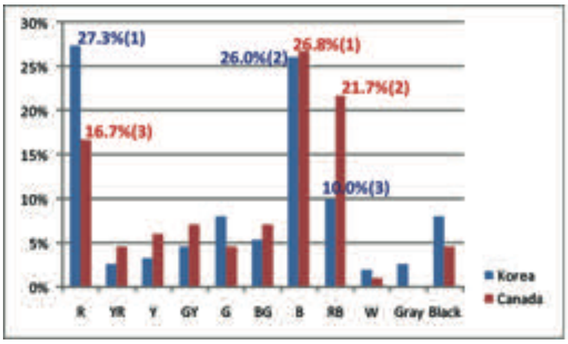

Figure 1. Regional like color hue rate

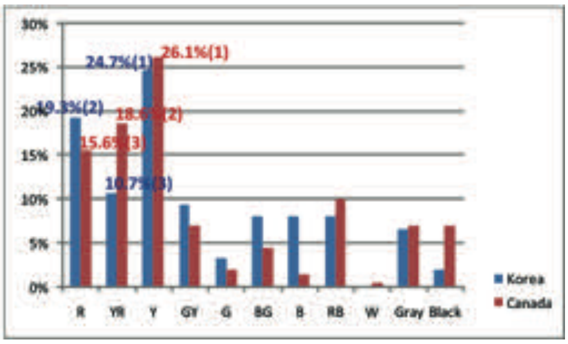

Figure 2. Regional dislike color hue rate

Figure 1 shows that, Korea prefers R(27.3%) > B(26%) > RB(10%) classes and Canada prefers B(26.8%) > RB(21.7%) > R(16.7%) classes hues in that order. Both countries have similar preference rate of B class, but show a significant difference on preference of R and RB classes. Further, Canada's preference on gray is 0%, showing different characteristics of preferences of each country.

Figure 2 shows that, Korea dislikes Y(24.7%) > R(19.3%) > YR(10.7%) classes and Canada dislikes Y(26.1%) > YR(18.6%) > R(15.6%) classes in this order. The dislike rate of Y class is similar, while YB class shows a difference. Further, Korea has 0% dislike on white, showing different characteristics of dislikeness of each country.

C. Tone

In the like tone, Figure 3 shows that, Korea prefers lt(30.7%) > b(19.3%) > v(16.7%), Canada prefers v(32.8%) > b(18.7%) > dp(12.6%). Both countries have similar preference toward Bright tone, but have significant differences on vivid and light tone, showing different characteristics of the like tone of each country.

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In the dislike tone, Figure 4 shows that, Korea dislikes dk(23.3%) > dkg(20.7%) > dp(10.7%) and Canada dislikes dkg(18.1%) > dk(17.1%) > dp(16.1%). Neutral was the tone that showed the biggest difference on the dislikeness. Further, while both countries dislike dp tone and dk tone, there was a significant difference on the dislike rate, showing characteristics of the dislike tone of each country.

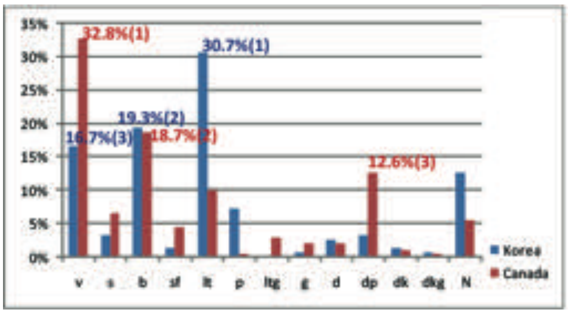

Figure 3. Regional like color tone rate

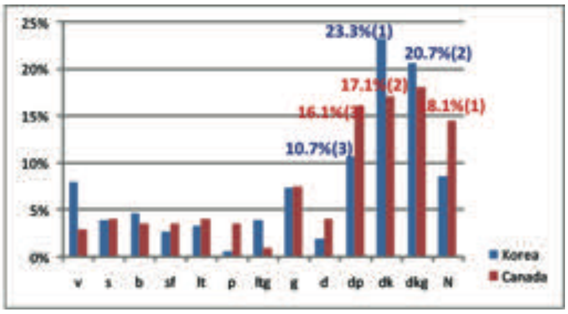

Figure 4. Regional dislike color tone rate

Conclusion and discussion

After analyzing color emotion of Korean and Canadian university students, this study were able to find the similarities and differences of both countries.

The similarities are, first, both countries like 1080-R, 1050-B, 1565-B, and 9000-N colors, while dislike 6020-Y color. Second, there is a high preference rate of B class hue and bright tone. Third, there is a high dislike rate of Y class hue and dkg tone.

The differences of color emotion of both countries are as follows. First, there was a different preference rate on RB and R class hue and light, vivid, deep, and Neutral tone. Second, both countries differed in disliking YR class hue and dark, deep, and neutral tone. Third, the likeness of gray class hue in Canada and the likeness of light grayish and the dislikeness of white class hue in Korea showed 0%. Color emotion is a product of culture, environment, etc., and shows different characteristics among other countries. Further, the change of color emotion depends on the generation; thus, a consistent study is necessary to analyze unique characteristics of different countries' traditional color emotions.

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Extension of colour emotion model for complex images

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Abstract

The purpose of this study was to investigate the relationships between the image colour characteristics and the emotional responses including three factors of colour emotion (activity, weight and heat) and overall emotional responses (preference, pleasantness and excitement). A psychophysical experiment was conducted using ten images presented on a 40” LCD screen, manipulated in terms of image colourfulness, lightness contrast, and lightness. Seventeen observers were asked to assess the images in terms of *pleasant-unpleasant, arousing-calming, like-dislike, warm-cool, heavy-light*, and *active-passive*. The experimental results showed that image colourfulness, lightness and lightness contrast had a consistent influence on the observers’ responses of colour emotion and image emotion. The responses of image emotion were significantly affected by the image content whereas such impacts were not found for the responses of colour emotion. Models of image emotion were developed as a function of colour attributes and factors of colour emotion.

Introduction

Images play emotional functions as well as informational ones. Thus, if we know how to modify an image in order to influence the viewer’s emotional responses to the image, we can improve the existing imaging devices for better user experiences.

Colour emotion models (Ou 2004a) help define the relationship between colours and reactive-level emotional responses determined by the configurations of colour stimuli. According to Ou et al.’s models, all colour emotions can be represented in a three-dimensional space with the independent axes of colour activity, weight and heat, and every single colour is located in the colour emotion space by these three coordinates. Moreover, colour emotion of any colour pair is a simple mean of the two colours in that pair.(Ou 2004b) However, whether this ‘additivity principle’ works well for any complex images still remains to be seen as an image includes millions of colour pixels. Nevertheless, having this model for complex images will enable us to modify image’s emotional impact more easily and more systematically.

For this reason, the relationship between three factors of colour emotion model in complex images and colour attributes of images were explored in the present study, where quantitative equations of colour emotion factors were developed. The relationship between colour emotion models and overall image emotion was investigated, and predictive models of image emotions were developed.

Experimental setup

Ten test images were selected as shown in Figure 1. Image subjects were divided into three groups, positive, negative and neutral, according to visual ratings of image *pleasure* reported by the International Affective Picture System (2005). A personal group was added which includes observers’ own portrait photos.

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All original images were firstly adjusted to have equal pixel resolution of 1024 by 768. The image RGB were converted into XYZ using a characterisation model for a 40” LCD screen used in the experiment with a peak white close to D65, and were then transformed to CIECAM02 system. Six manipulations in lightness contrast were performed using three sigmoid and three inverse sigmoid functions. For chroma manipulation, six linear functions were used. (Jun 2010) For lightness manipulation, XYZ values of each original image were converted to CIELAB space and four levels of transfer functions were applied. (Oicherman 2008) In total, 208 images, including the original and the manipulated, were presented to each observer. In the experiment, all images were presented on the LCD screen in a darkened room with viewing distance of 1.3m. Seventeen observers with normal colour vision, including 12 Korean, 4 Chinese and 1 European, assessed images on Bartleson(1984)’s nine-point category scales for six word-pairs: *pleasant-unpleasant, exciting-calming, like-dislike, active-passive, heavy-light and warm-cool*.

Figure 1. Nine original images for use in the experiment

Results

Dependency of image content

To investigate whether observers’ responses showed image dependency, principal component analysis (PCA) methods were applied to classify images using the observer responses. It was found that the observer response for each of the three colour emotion factors: *active-passive, heavy-light* and *warm-cool* had only one component extracted from ten images; this suggests that all images shared similar trends for these three factors due to changes in colour attributes in each image. However, responses of image pleasantness and excitement had two principal components extracted, with 75.5% and 77.1% of total variances, respectively. The two principle components were labeled Groups 1 and 2. For both image pleasantness and excitement, Group 1 includes seven images which were pre-categorised as positive, neutral and personal, while only the negative images were found in Group 2. This result indicates that the trends of emotional responses for those two image groups were significantly different. Thus observer responses were analysed separately for each group of images and models of image emotion were developed for each group.

Colour emotion model as a function of colour attributes of images

To investigate the impact of colour appearance attributes on image emotion, in terms of the relationship between CAM02-UCS (Luo 2006) attributes (colourfulness, lightness contrast and lightness) and the observer responses, the changes in visual results for the three colour emotion factors were plotted against the changes in colour attributes between each original and manipulated image. Figure 2 shows the changes in visual results for colour weight plotted against the changes in colour attributes between each original and manipulated image. According to these plots, models for each colour emotion factor were developed based on the experimental data for image colourfulness, lightness contrast and lightness. The final models were constructed as functions of the three colour attributes, as summarised in Table 1. In general, colour activity can be enhanced

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by increasing colourfulness; colour weight can be enhanced by increasing contrast of lightness; and colour heat can be enhanced by increasing colourfulness.

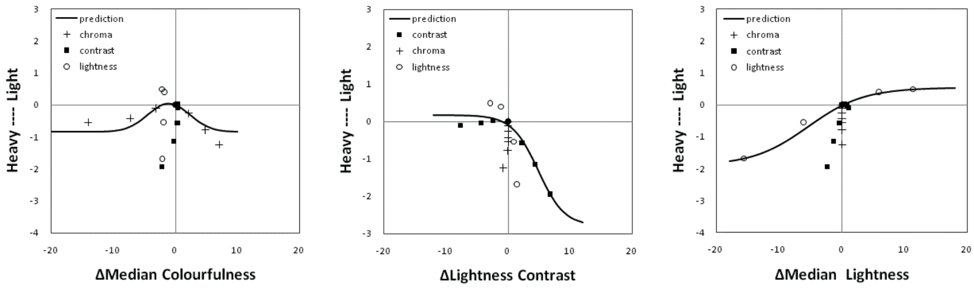

Figure 2. Changes in colour weight plotted against changes in image colourfulness (ΔM), lightness contrast (ΔCO) and image lightness (ΔJ), with the curvy lines representing predictive models for each relationship

Table 1. Predictive models for three Colour Emotion factors developed as a function of changes in colourfulness(M), contrast(CO) and lightness(J).

Colour Emotion	**Colour Emotion Models**	**R^2**
Activity	ΔActivity = 1.07*Activity(Δ*M*) + 1.00*Activity(Δ*CO*) - 0.15*Activity(Δ*J*)	0.92
Weight	ΔWeight = 0.59*Weight(Δ*M*) + 0.88*Weight(Δ*CO*) + 0.84*Weight(Δ*J*)	0.89
Heat	Δ Heat = 1.07*Heat(Δ*M*) + 0.71*Heat(Δ*CO*)	0.82

Image emotion model as a function of colour emotion factors

To develop the predictive image emotion models of pleasantness and excitement, two approaches were used. Firstly, the relationship between the changes in visual results and the changes in colour attributes between each original and manipulated image were modeled for the two groups of images as classified by PCA in previous analysis. The final models for two image groups were built as a function of the three colour attributes, as summarised in Table 2.

The visual responses of image pleasantness and excitement were then modeled as functions of the three colour emotion factors constructed previously, as shown in Table 3. These models performed slightly worse than the one based on colour attributes of images (see Table 2). Having these models shown in Table 3, however, we can get the idea of how to enhance the emotional impact of images by changing the intensity of its colour semantic meanings (i.e. the three colour emotion factors). For instance, to enhance the image pleasantness of an image belonging to group 2 (i.e. a negative image), we need to make the colours of images more passive and cooler. In addition, to make the image feel more exciting, we need to adjust the image colours into more active, heavier and warmer.

Table 2. Predictive models for image pleasantness and excitement as functions of changes in colour attributes of colourfulness(M), contrast(CO) and lightness(J).

		Image Emotion Models	**R^2**
Pleasantness	**Group 1**	ΔPleasantness= 0.94*P(Δ*M*) + 0.96*P(Δ*CO*) + 0.36*P(Δ*J*)	0.80
	Group 2	ΔPleasantness = 0.96*P(Δ*M*) + 1.38*P (Δ*CO*) + 1.28*P(Δ*J*)	0.84
Excitement	**Group 1**	ΔExcitement = 1.17*E (Δ*M*) + 0.90*E (Δ*CO*) - 0.11*E (Δ*J*)	0.86
	Group 2	ΔExcitement = 1.07*E (Δ*M*) + 1.23*E (Δ*CO*) + 0.21*E (Δ*J*)	0.85

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Table 3. Predictive models for image pleasantness and excitement as functions of changes in colour emotion models (see Table 1).

Image Emotion Models			R^2
Pleasantness	**Group 1**	ΔPleasantness= -0.33*Activity + 1.06*Weight + 1.32*Heat	0.47
	Group 2	ΔPleasantness = -0.47*Activity + 1.43*Weight + 2.27*Heat -0.02	0.70
Excitement	**Group 1**	ΔExcitement = 1.54*Activity + 0.06*Weight + 0.08*Heat – 0.02	0.82
	Group 2	ΔExcitement = -0.58*Activity + 0.70*Weight + 1.41*Heat – 0.10	0.76

Conclusion

Three factors of colour emotion: Activity, Weight and Heat for complex images were developed as a function of image colourfulness, contrast and lightness. Overall emotional responses for complex images in terms of pleasantness and excitement were developed as functions of colour attributes (see Table 2), and as functions of colour emotion factors (Table 3). Comparing these two models, the one based on colour attributes (Table 2) performed better. For images which are pleasant in terms of image content, we can only enhance image excitement, and this can be done by making the colours more active and warmer. For negative images, image pleasantness can be enhanced by more passive and cooler colours; image excitement can be enhanced by more active, heavier and warmer colours in the image. These models are believed to be useful tools of image enhancement for achieving pre-defined emotional qualities.

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Perceived colour in transparent materials and objects

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Abstract

The perception of transparent glass colours depends on both concentration of the colouring agent and the sample thickness, i.e. the optical density of the sample. In this study, the effect of increasing optical density was investigated for cobalt (Co), chromium (Cr) and iron (Fe). The colours were defined by trained human observes using two different observation techniques: one of them utilized the NCS atlas and the other virtual screen images of the NCS colours. The results show that whiteness decreases more or less exponentially with increasing optical density, in a similar manner for both observation techniques. Chromaticness increases first but at higher density values it either levels off (Co) or reaches a maximum and then decreases (Fe and Cr). Blackness increases with increasing optical density (Fe and Cr) or levels off at higher densities (Co). For Co and Cr, the difference in hue between the two techniques is quite small and it decreases with increasing optical density. For Fe, the difference is larger and it remains roughly constant throughout the density interval. The main conclusion is that increasing optical density causes non-linear variation in both hue and nuance, and this variation is specific for each colouring agent.

1. Introduction

The overall aim of this multidisciplinary research project is to explore the human perception of transparent glass colours and also to create a virtual tool that can make it easier to communicate the mental notion of the colour (Jung et al 2010). The main industrial problem in colour generation process in glass is that there are no standards for measuring or representing the colour perception in glass systems (Gladushko and Chesnokov 2007). Consequently, it is not straightforward to transform the mental notion of the colour into the right chemical composition and right manufacturing conditions (Weyl 1990; Bamford 1995).

In a previous pilot study made by Jung et al. (2010), the traditional Natural Colour System (NCS) atlas and its virtual form were used to represent the perceived colour for transparent glass samples (Hård, Sivik and Tonnquist 1996a, 1996b; Stahre 2009). The main conclusion in the pilot study was that it seems possible to use the NCS representation also for glass colours. However, the transparent colours entail that the standard viewing conditions must take into account the light that is transmitted through the object. What is more, the transparency also suggests that the perception of glass colours depends on both concentration of the colouring agent and the sample thickness. In the current study, the joint effect of colour concentration and sample thickness, i.e. the optical density (OD) of the sample, was investigated for three transition elements in glass: cobalt (Co), chromium (Cr) and iron (Fe). The purpose is to explore how the increasing optical density affects the human perception of the glass colour.

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2. Materials and methods

The studied samples were 24 glass objects, which contained different concentrations of one colouring agent: Co, Cr or Fe. The concentration interval that was used varied depending on the colouring agent; the concentration of Fe was about 10 times higher than concentration of Cr, and about 1000 times higher than concentration of Co. The optical density was calculated as the mathematical product of colour concentration (gram /batch) and sample thickness (mm). The approximate shape of the glass samples was a rectangular cuboid with the upper face area of 40*40 mm and with a thickness within an interval of 5 - 25 mm. A total of 624 colour observations were conducted by 13 trained human observes using NCS notation. The glass colours were matched by two different techniques:

1. The glass sample was placed on a metal frame 50 mm above a white surface and the colour was matched with the opaque colours in the NCS atlas.
2. The sample was placed on a colour calibrated computer screen and the glass colour was matched with screen images of the NCS colours.

During all observations, the light source, viewing distance and angle as well as other significant conditions were according to Swedish Standards, SS 019104, colour specifications with NCS. The observers indicated in a questionnaire sheet, which colour was the best match in the NCS atlas and screen images. The NCS notation includes hue (Φ) and nuance, the relationship between blackness (s), chromaticness (c) and whiteness (w). For each sample and each observation technique, an arithmetic mean of Φ, s, c and w were calculated using the results from all 13 observers. The mean values were then plotted as a function of the optical density.

3. Results and discussion

The results show that for all three colouring agents, NCS whiteness (w) decreases more or less exponentially with increasing optical density, in a very similar manner for both observation techniques, as shown for chromium in Figure 1.

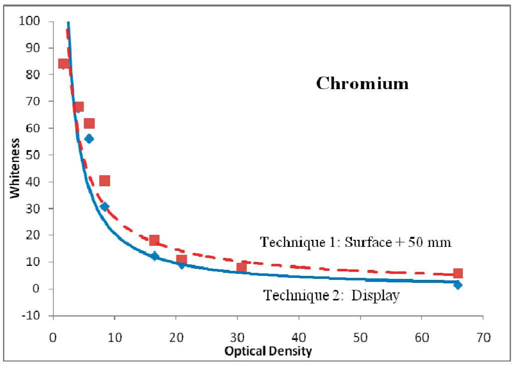

Figure 1: Whiteness as a function of optical density (OD) for Cr.

NCS chromaticness (c) increases first but at higher density values it either levels off (Co) or reaches a maximum and then decreases (Fe and Cr), as illustrated in Figures 2a, 2b and 2c.

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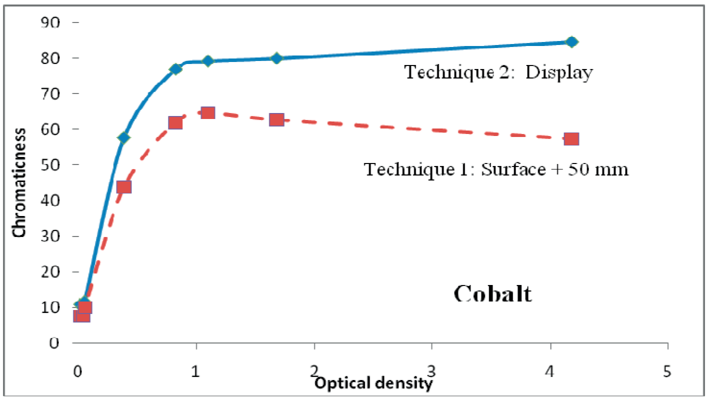

Figure 2a: Chromaticness versus optical density for Co.

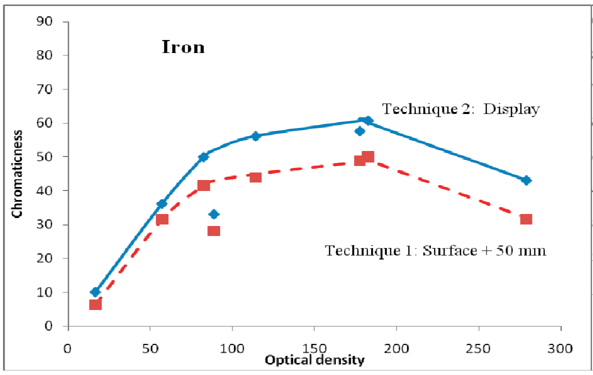

Fig 2b: Chromaticness vs optical density for Fe.

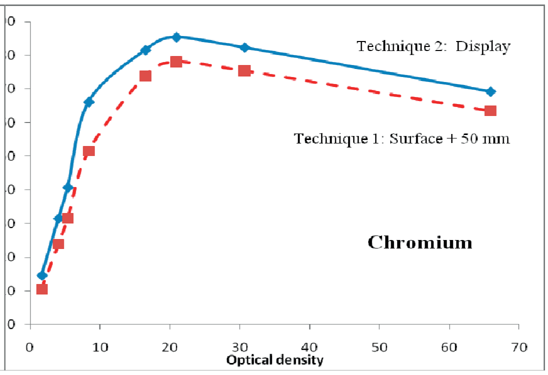

Fig 2c: Chromaticness vs optical density for Cr.

Blackness (s) increases with increasing optical density (Fe and Cr) or levels off at higher densities (Co); as shown in Figures 3a, 3b and 3c. For all samples, colour matching that is made using the virtual NCS colours (technique 2) appears to have higher chromaticness and lower blackness.

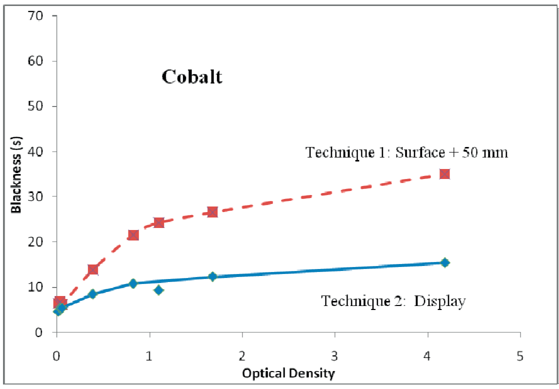

Fig 3a: Blackness versus optical density for Co.

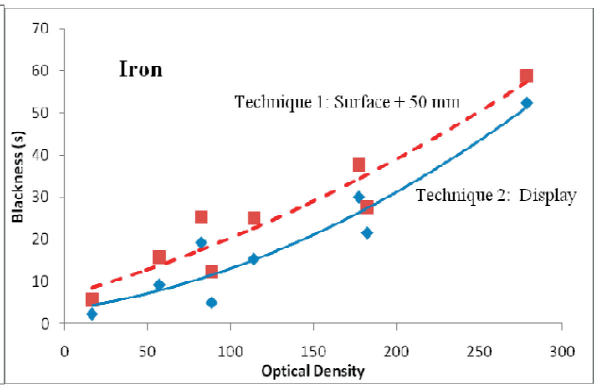

Fig 3b: Blackness versus optical density for Fe.

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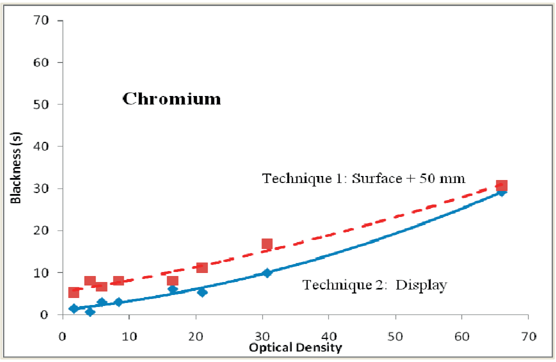

Fig 3c: Blackness versus optical density for Cr.

For Co and Cr, the difference in hue (Φ) between the two techniques is quite small and it decreases with increasing optical density. For Fe, the difference is larger and it remains roughly constant throughout the density interval. It is important to note that at higher optical densities the vivid blue colour of cobalt glass cannot be matched with opaque colours in the NCS atlas, whereas the virtual colours seem to give a slightly better match. This is indicated in Figure 2a, where the difference in chromaticness between the observation techniques increases at higher optical densities. An interesting notion is also that the most intensely coloured cobalt samples appear to have a distinctive red tint, which was perceived by all observes. The main conclusion is that increasing colour concentration and/or sample thickness cause a non-linear variation in both hue and nuance and, what is more, this variation is also specific for each colouring agent.

Acknowledgments

This project was conducted in co-operation with Glass Research Institute, GLAFO (Växjö, Sweden). The co-production project was supported by an external grant from the Knowledge Foundation, Sweden.

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Whiteness of paper containing fluorescent whitening agent under white LED and fluorescent lamp illumination

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Abstract

A visual evaluation of perceived whiteness was conducted for three types of white paper containing a fluorescent whitening agent under white LED and fluorescent lamp illumination of the same chromaticity. At the same time, the relationship with a whiteness index was considered. The results led to the following conclusions: (1) Under white LED illumination that includes little near-ultraviolet radiation, blueness derived from fluorescence decreases as compared to fluorescent lamp illumination, but there are cases of both decreased and increased perceived whiteness; (2) Change in perceived whiteness between white LED illumination and fluorescent lamp illumination cannot be predicted in CIE whiteness, but the *C/V* index developed by the author is valid.

1. Introduction

White LED light sources are drawing attention as a potential new light source that may replace fluorescent lamps. Most white LEDs for lighting that are currently on the market are a combination of blue LEDs and yellow phosphor, and have little ultraviolet radiation unlike fluorescent lamps (Taguchi 2003). On the other hand, white paper used in offices and at home often contains fluorescent whitening agent in order to increase perceived whiteness. This fluorescent whitening agent absorbs near-ultraviolet light and has characteristics of radiating fluorescence at as near as 450nm and therefore, the whitening effect changes due to the amount of near-ultraviolet included in the illuminating light (Springsteen 1999). This study compares the perceived whiteness of white paper containing a fluorescent whitening agent under white LED and fluorescent lamp illumination by visual evaluation as well as considering the relationship with a whiteness index.

2. Experiment

With three types of white paper containing a fluorescent whitening agent as samples, a white daylight LED and a three-band type daylight fluorescent lamp were used as light sources. White paper and lamps are commercial products for general use. For a white LED and fluorescent lamp, those having approximately the same chromaticity were selected. Relative spectral power distribution and chromaticity of the light sources were obtained from the spectral radiance of a PTFE plaque displayed in the center bottom of a visual evaluation experiment light booth by using a Specbos1211UV (JETI) spectroradiometer. The white LED's *xy* chromaticity was (0. 3197, 0.3346) and that of the fluorescent lamp was (0.3191, 0.3339). If we consider *UVA* to be radiance in the near-ultraviolet range with wavelengths from 300nm to 380nm, and *V* to be radiance in the visual range with wavelengths from 380nm to 780nm, then the ratio of *UVA* to *V* was calculated as 0.1% for the white LED used in the experiment, and 1.1% for the fluorescent lamp.

After installing the white LED and fluorescent lamp in the visual evaluation experiment light booth, the total spectral radiance factors of the white paper were measured by using the

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spectroradiometer under the effect of each light source. Geometrical condition of irradiation and observation for the measurement is 0°: 45°. *Y* values of the white paper were measured by using a CM-2500d (Konica-Minolta) spectrophotometer of geometrical condition di: 8°.

A visual evaluation of the perceived whiteness by paired comparison method was conducted for two types of light sources and three types of samples, for a total of six cases. The light booth used for the visual evaluation experiment has a binocular bulkheading structure so that an observer can compare samples between different light sources by haploscopic comparison. Different samples can be compared under a single light source with natural binocular vision in either the right or left light booth. The sample size is 6cm × 9cm and either case is observed at 45° with a viewing angle of approximately 8.1° × 7.6°. The inner walls of the light booth are of N5 achromatic color, and the illuminance of the sample surface is 2000 lx. The observers are 12 males (average age: 20.8) with normal color vision.

3. Results and discussion

Fig. 1 shows each of total spectral radiance factors of the three types of white paper under white LED and fluorescent lamp illumination. All samples show lower fluorescent radiance factors around 450nm under the white LED illumination as compared with the fluorescent lamp illumination. Tristimulus values and chromaticity coordinates of each sample's corresponding color under standard illuminant D65 are shown in the second and third columns of Table 1, and the chromaticity coordinates of the samples on the *xy* chromaticity diagram are shown in Fig. 2. Von Kries' law was used for the calculation of colorimetric values of corresponding colors. As seen in Fig. 2, each sample has less blue tint purity under the white LED illumination as compared with the fluorescent lamp illumination.

From verification of the consistency of each observer's visual evaluation results by paired comparison method, 9 were significant at the 1% level, and 3 were significant at the 5% level of a χ^2 test. Additionally, verification of agreement in evaluation results among the observers showed significance at the 0.1% level (Kendall 1948). The above results indicate that the observers conducted a subjective evaluation of whiteness with common one-dimensional criteria. Fig.3 shows interval scale values of perceived whiteness composed from the visual evaluation results (Gulliksen 1956). In Fig.3, the ordinate indicates interval scale values of perceived whiteness and the abscissa indicates combinations of light sources and samples. Fig.4 shows changes in the perceived whiteness of each sample between the light sources. Perceived whiteness under the fluorescent lamp is the standard for all samples. Samples 1 and 3 have reduced perceived whiteness under white LED illumination as compared with fluorescent lamp illumination, but sample 2 has higher perceived whiteness under white LED illumination than fluorescent lamp illumination. It may be that sample 2 has stronger bluish tint and its purity was further enhanced with fluorescence evoked by near-ultraviolet illumination under the fluorescent lamp, and that excessive blueness caused whiteness to be less perceived.

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Table 1. Tristimulus values and chromaticity coordinates of each sample's corresponding color under standard illuminant D65, CIE whiteness and C/V index.

	***X,Y,Z* tristimulus values**			***xy* chromaticity coordinates**	**CIE whiteness**	***C/V* index**
Sample 1 under FL	85.78,	87.87,	107.99	0.3046, 0.3120	123.1	91.5
Sample 1 under LED	82.50,	86.82,	94.21	0.3130, 0.3295	85.6	85.0
Sample 2 under FL	83.17,	84.31,	111.69	0.2979, 0.3020	141.8	90.3
Sample 2 under LED	79.64,	82.93,	96.16	0.3078, 0.3205	101.0	83.3
Sample 3 under FL	72.79,	74.67,	92.49	0.3034, 0.3112	112.2	77.8
Sample 3 under LED	70.13,	73.38,	84.20	0.3080, 0.3222	88.5	73.4

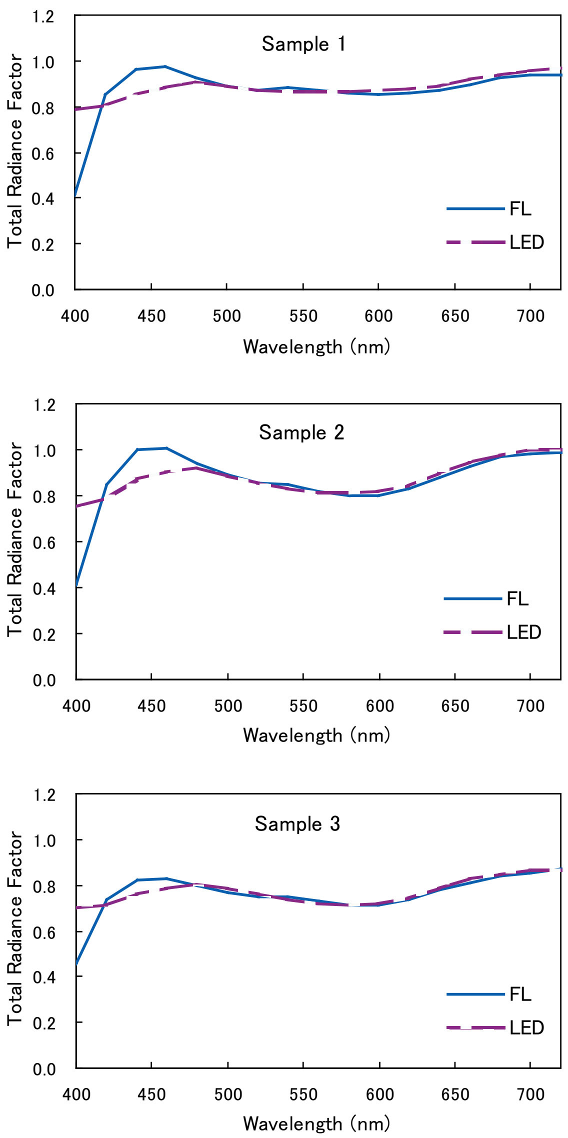

Fig. 1 Total spectral radiance factor of each sample.

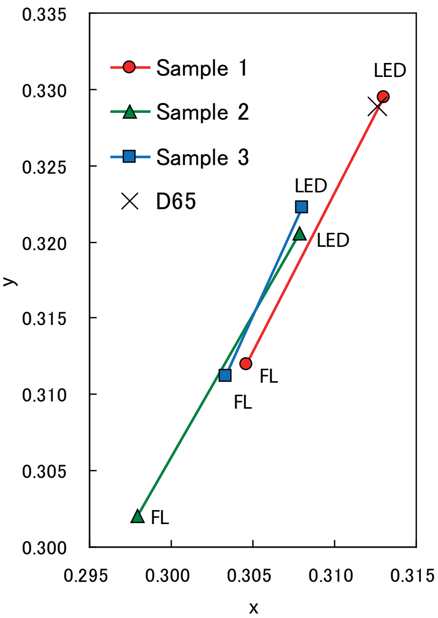

Fig. 2 Difference of chromaticity between white LED illumination and fluorescent lamp illumination for the same white paper.

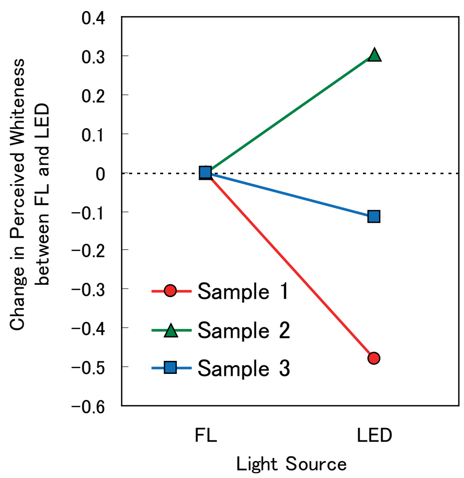

Fig. 4 Changes in the perceived whiteness of each sample between different light sources.

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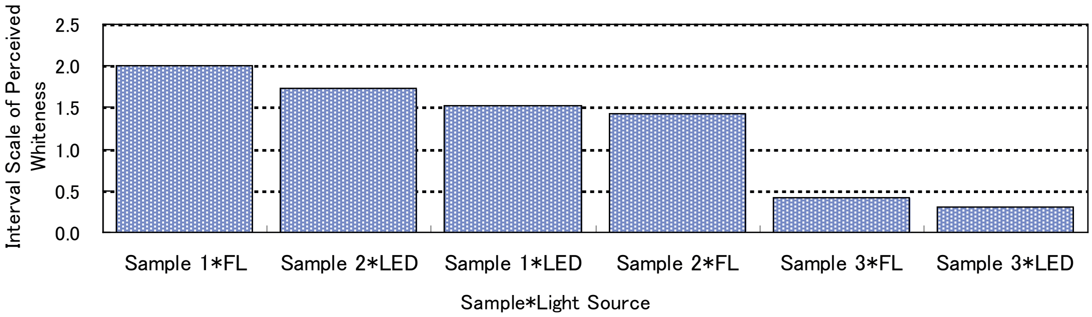

Fig. 3 Interval scale values of perceived whiteness derived from the results of the visual evaluation experiment.

Next, CIE whiteness (CIE 2004), and *C/V* index values developed by the author (Katayama et al. 2010) were calculated for each sample, and the relationship with the visual evaluation results was discussed. Table 1 shows CIE whiteness and *C/V* index values of each sample under white LED and fluorescent lamp illumination in the fourth and fifth columns. CIE whiteness was calculated from the colorimetric values of the corresponding color under standard illuminant D65, and *C/V* index values were calculated from the total spectral radiance factors of the samples. As a result, *C/V* index values had good correlation with the visual evaluation results (r = 0.882) while no significant correlation was seen between CIE whiteness and the visual evaluation results (r = 0.304). CIE whiteness has a structure that predicts higher whiteness in samples with a higher purity of blue tint and therefore it cannot predict a reduction of perceived whiteness due to excessive blueness.

4. Conclusions

1. Under white LED illumination containing little near-ultraviolet radiation, blue tint caused by fluorescence decreases compared with fluorescent lamp illumination and there are both a decrease and an increase in perceived whiteness against white paper.
2. Changes in perceived whiteness between white LED illumination and fluorescent lamp illumination cannot be predicted by CIE whiteness, but the *C/V* index developed by the author is valid.

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Colorimetric prediction of halftone prints with pale-ink model

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Abstract

In the offset processes or digital printing, photographic images are printed onto paper by converting them into halftone dot patterns. Dot size is measured in terms of dot area. The difference in dot area between an original dot and its reproduction is called dot gain. In this study, we create a model in which pale-ink is introduced in consideration of light scattering term and investigate the validity of the model. The pale-ink reflectance spectrum is estimated based on the modified Beer-Lambert law, which was introduced to estimate the attenuation of light for scattering media. The path length factor and scattering loss factor are estimated from the modified Beer-Lambert law. In the pale-ink model, the reflectance spectra of the pale-ink, solid area, and paper substrate are converted to *XYZ* tristimulus values, and the actual colour is predicted by a linear combination of weighted tristimulus values. We attempted to predict dot gain using our pale-ink model and found that our proposed model offered improved prediction accuracy over the conventional Murray-Davies and Yule-Nielsen models.

1. Introduction

In the offset processes or digital printing, photographic images are printed onto paper by converting them into halftone dot patterns. Dot size is measured in terms of dot area. The difference in dot area between an original dot and its reproduction is called dot gain, and it should be noted that variations of approximately 3% in either growth or reduction of a dot area will be sufficient to cause a noticeable change in the tone or hue of a reproduced image.

The Murray-Davies model (Eq. 1) describes image reflectance as a linear combination of ink dot and paper reflectance: Murray (1936). However, the reflectance values calculated using the Murray-Davies formula do not always coincide with the measured values.

$$R = a_s R_s + (1 - a_s) R_p \qquad (1)$$

where R is predicted spectral reflectance, a_s is fractional dot area of the ink, R_s is the spectral reflectance of the ink at solid (full coverage), and R_p is the spectral reflectance of the paper substrate.

Yule and Nielsen, in their model (Eq. 2), interpreted the discrepancies as the result of light penetration and scattering in the paper substrate: Yule and Nielsen (1951).

$$R = \left[a_s R_s^{1/n} + (1 - a_s) R_p^{1/n}\right]^n \qquad (2)$$

where n is a parameter accounting for light spreading in paper, and all other variables are as described above.

Their theoretical analysis showed that the nonlinear relationship between measured and predicted reflectance could be described well using a power function. The n value of the Yule-Nielsen model, which is compatible with offset printing, is known to be $n = 1.7$: Pearson (1980). This provides a numerical approximation, but does not provide any physical insight into the actual constituent materials.

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Equation (3) can be obtained by inserting 2 into n of equation (2). Thus, the Yule-Nielsen model contains, in the second term, the square root of the product of the reflectance of ink and the reflectance of the paper substrate. The second term of equation (3) corresponds to the optical dot gain, which is the scattering component of a halftone dot.

$$R = a_s^2 R_s + 2a_s(1 - a_s)\sqrt{R_s R_p} + (1 - a_s)^2 R_p \qquad (3)$$

We studied the causes of dot gain deviations using a halftone dot representation based on the Murray-Davies model. Our core-fringe model assumes that a halftone dot consists of two regions; a central core area that contains a solid ink layer of equal thickness, and a marginal fringe area that has a thinner ink layer: Azuma et al. (2002). This model can describe the non-linear behaviour of single-ink halftone prints as well as predict the reflectance spectra more precisely than the Murray-Davies model. Furthermore, we think that evaluating dots from their colorimetric characteristics can be helpful when attempting to intuitively understand the effect of dot gain on hue. In this study, we create a model in which pale-ink is introduced in consideration of the second term of equation (3) and the third ink in the core-fringe model, and investigate the validity of the model. Our goal is the development of a generally usable model by examining the ways in which the material characteristics are considered.

2. Model creation by the introduction of pale-ink

The variables and constants used in this model were selected to develop physically based approaches. In the pale-ink model, the reflectance spectra of the pale-ink, solid area, and paper substrate are converted to *XYZ* tristimulus values, and the actual colour is predicted by a linear combination of weighted tristimulus values. To develop the pale-ink model, we used offset prints spectral reflection data in the Standard object colour spectra (SOCS) database: ISO, 2003.

2.1 Modified Beer-Lambert Model

The effect of optical dot gain depends on the length of the lateral scattering of light within the substrate and the size of the halftone dots. For scattering media, the modified Beer-Lambert law was introduced to estimate the attenuation of light, and is commonly used in the field of near-infrared tissue spectroscopy: Delpy et al. (1988).

$$A = \log(I_0 / I) = B\mu_a d + G \qquad (4)$$

where term A is the light attenuation between the incident light I_0 and the transmitted light I, G is the attenuation resulting from scattering loss, and B is the path length factor, which, when multiplied by the geometric distance d between the source and detector, accounts for the increase in optical path length caused by scattering.

2.2 Estimation of reflection spectrum of pale-ink

The pale-ink reflectance spectrum is estimated based on the modified Beer-Lambert law. In equation (4), we presume absorption coefficient μ_a for the solid area is constant and d is the mean optical path length. Therefore, μ_a d is assumed to correspond to the attenuation of the solid area. The transmitted light I is considered to be the detected reflected light.

$$I = I_0 R_{pale} \qquad (5)$$

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By determining B and G in equation (4), the predicted pale-ink reflectance (R_{pale}) can be obtained. In the halftone, the lights transmitted into the layer presumably pass through the ink layer and the paper substrate due to scattering. The contribution of this light to absorption is expected to be small compared with the solid area. Thus, B is 1 or less ($B \leq 1$). The term B and G in equation (4) are selected so that the squared error sum between the measured reflectance (R_{meas}) at the dot area coverage of 50%, where the dot gain becomes the maximum, and the pale-ink reflectance (R_{pale}) becomes the minimum. In the calculation process of B and G, the calculation range of B can be limited by allowing $G = 0$ and confirming the variation of the squared error sum between R_{meas} and R_{pale}. Then, B and G are determined so that the minimum sum of squared error is attained.

2.3 Pale-ink Model

A model in which pale-ink is integrated into the Murray-Davies equation can be obtained, as shown below, by the conversion of reflectance to tristimulus values.

(1) CIE tristimulus values XYZ $\vec{T}$ of the solid area, paper substrate, and pale-ink are determined from the respective spectral reflectance, R_{solid}, R_{paper}, and R_{pale}.

$$\vec{T} = \begin{bmatrix} \bar{x} \\ \bar{y} \\ \bar{z} \end{bmatrix} = k \int P(\lambda)R(\lambda) \begin{bmatrix} \bar{x} \\ \bar{y} \\ \bar{z} \end{bmatrix} d\lambda \qquad (6)$$

Here, $k=100/\int P(\lambda)\bar{y}d\lambda$, $P(\lambda)$ represents the relative spectral distribution of the standard illuminant, $R(\lambda)$ represents the sample spectral reflectance, and $\bar{x}, \bar{y}, \bar{z}$ represents the colour matching function.

(2) Similarly, the tristimulus values of the halftone area are determined from the measured reflectance.

(3) Each linear combination $\vec{T}_{sum}$ of the tristimulus values $\vec{T}_{solid}, \vec{T}_{pale}, \vec{T}_{paper}$ is determined by using the weighting factors as variables, and by minimizing the squared error sum with the measured values.

$$\vec{T}_{sum} = a_s\vec{T}_{solid} + b_p\vec{T}_{pale} + (1 - a_s - b_p)\vec{T}_{paper} \qquad (7)$$

where a_s is fractional dot area of the ink, b_p is fractional dot area of the pale-ink.

(4) The chromaticity coordinates x and y are calculated from the tristimulus values.

3. Results and discussion

Figure 1 shows the reflectance spectra for the solid areas of cyan, magenta, and yellow as well as the reflectance spectrum of the paper substrate.

Figure 2 shows the change of the squared error sum between the pale-ink reflectance spectrum and the reflectance spectrum of a magenta 50% halftone area when the attenuation factor (G) due to scattering was assumed to be zero in equation (4), and the A value was varied by parameter B.

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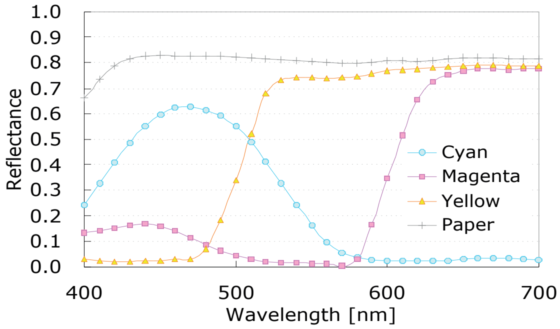

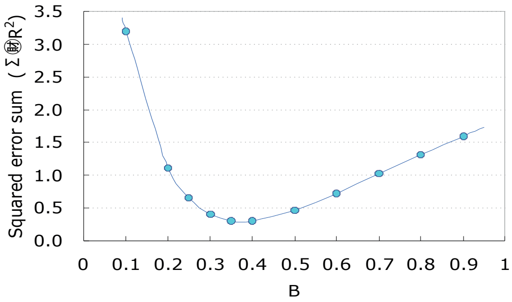

Figure 1. Spectral reflectance for the solid area of cyan, magenta, yellow and the paper substrate printed with offset printer.

Figure 2. Squared error sum of 50% magenta halftone area spectral reflectance between the measured data and pale-ink which estimated by factor B as variable.

From this figure, it is deemed likely that the squared error sum becomes the minimum when the optical path length factor (B) is about 0.4. Based on these results, the light attenuation A that includes the attenuation factor (G) due to scattering was determined (using the method described above) for cyan, magenta, and yellow, when the optical path length factor (B) was about 0.4.

Table 1. The estimated values of B and G of pale-ink for cyan, magenta and yellow

	B	***G***
Cyan	0.471	0.0442
Magenta	0.376	0.0459
Yellow	0.436	0.0471
Average	0.410	0.0457

The results are shown in Table 1.For each colour, the values B and G are close, at about 0.41 for B and about 0.046 for G, on average. Thus, the optical path length for the light that passes through the colorant of a halftone dot image is considered to be about 40% of the mean optical path length of the solid area. The cause of this is probably the lateral scattering of the incident light in both the ink and paper layers. Furthermore, judging from the G value, it is estimated that about 10% of the light dissipates over the entire wavelength range.

Figure 3 shows the estimated reflectance spectrum for the 50% halftone area of magenta pale-ink, as well as the measured reflectance spectra for the solid area, the 50% halftone area, and the paper substrate. Figure 4 shows the weighting factors, in accordance with each dot area coverage, for the solid area, pale-ink, and the paper substrate. The estimated reflectance spectrum for the pale-ink is very close to that of the measured 50% halftone area.

The pale-ink represents the scattered light of the halftone dot area, and is considered to correspond to the optical dot gain. The weighting factor for the pale-ink in our model is parabolic, with the maximum estimated at about 33%. Accordingly, if the dot gain is measured at 20%, the optical dot gain is estimated at approximately 7%.

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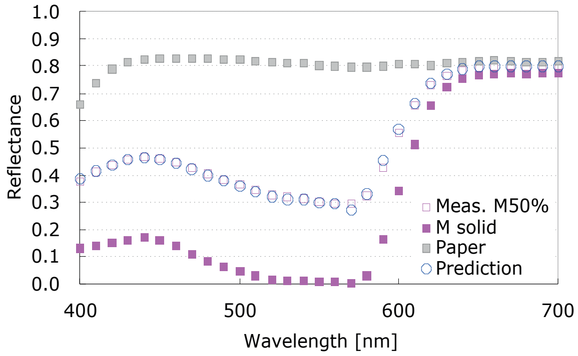

Figure 3. The estimated reflectance spectrum for the 50% halftone area of magenta pal- ink, and the measured reflectance spectra for the solid area, the 50% halftone area, and the paper substrate.

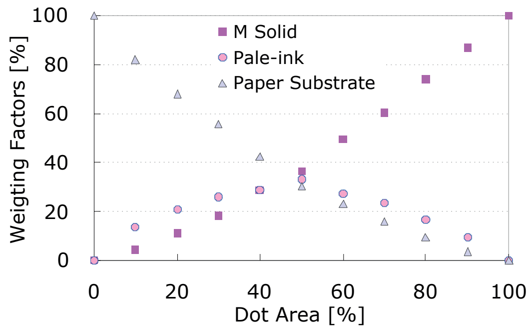

Figure 4. The weighting factors as a function of nominal dot area coverage, for the solid area, pal- ink, and the paper substrate.

On the *xy* chromaticity diagram shown in Fig. 5, the predicted values with the dot area coverage change of magenta ink, based on the Murray-Davies, Yule-Nielsen (n=1.7), and pale-ink models are shown, along with the measured values. Table 2 shows the pale-ink chromaticity coordinates *x* and *y* for cyan, magenta, and yellow; which are calculated based on the results in Table 1. Figure 6 shows chromaticity coordinates *x* and *y* for the pale-ink model of cyan, magenta, and yellow, along with the measured values.

Table 2. The calculated chromaticity coordinates of pale-ink for the cyan, magenta and yellow.

	x	*y*
Cyan	0.23	0.31
Magenta	0.41	0.28
Yellow	0.42	0.46

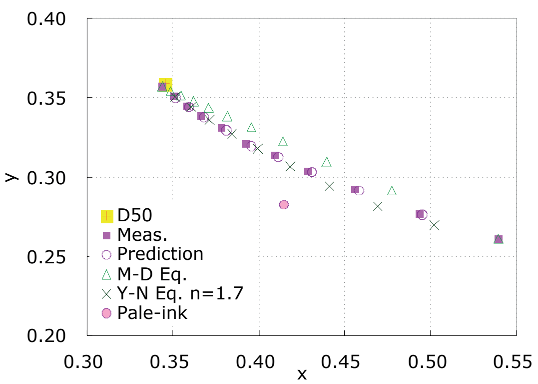

Figure 5. The predicted chromaticity coordinates with the dot area coverage change of magenta ink, based on the Murray-Davies, Yule-Nielsen pale-ink models and the measured data.

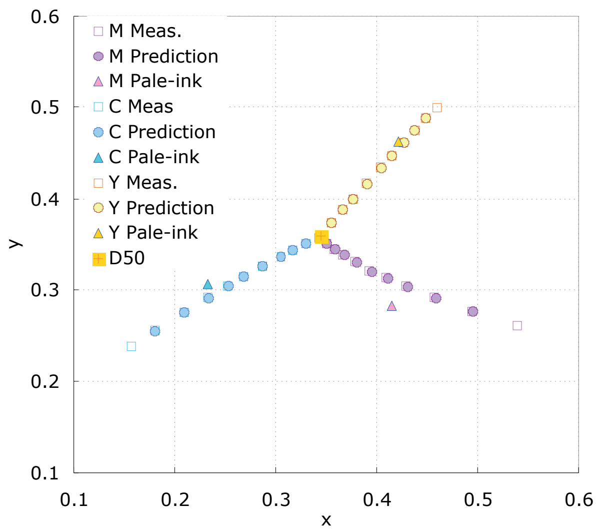

Figure 6. The chromaticity coordinates for the pale-ink model of cyan, magenta, yellow, and the measured data.

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From these results, we can see that pale-ink model can accurately reproduce the change of hue in accordance with the dot area coverage. On the *xy* chromaticity diagram, the position of pale-ink is separate, in the order of magenta, cyan, and yellow, from the respective lines connecting the solid area and the paper substrate. One of the reasons for this is considered to be the presence of multiple absorption peaks in the spectra of the magenta and cyan solid areas (Fig. 1). Thus, the positions of the magenta pale-ink and cyan pale-ink seem to be separate, especially at the halftone, from the straight line. Using our pale-ink model, we found that prediction accuracy had improved over the results obtained with the conventional Murray-Davies and Yule-Nielsen models.

4. Summary

We attempted to predict dot gain, which is generated in the halftone dot pattern of reproduced photographic images, using our pale-ink model and found that our proposed model offered improved prediction accuracy over the conventional Murray-Davies and Yule-Nielsen models. The results of our examination indicate that the proposed model adequately explains the effects of the ink properties and paper substrate on optical dot gain. From a practical point of view, this model is expected to be helpful in efforts aiming at understanding the effects of dot gain on hue.

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Performance of multi-angle spectrophotometers

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Abstract

In high quality printing, special effect inks are used more frequently. Several multi-angle spectrophotometers have been developed for the measurement of such gonio-chromatic materials. This paper presents a study on the performance of commercial multi-angle instruments. We found that short-term is better than medium-term repeatability. Repeatability is better for a white reflection standard than for printed samples. Univariate and multivariate methods show the same geometry-dependent trends. Reproducibility and accuracy is less good for geometries with detection near specular direction.

1. Introduction

Due to their unique visual appearance, inks with special effect pigments (Pfaff 2007) are used more frequently for high quality printing e.g. in packaging. For process control and quality assurance of such gonio-chromatic materials, multi-angle spectrophotometers have been developed. In this study, the performance of three commercial multi-angle instruments was investigated using statistical parameters.

2. Background

The evaluation of the performance of colour-measuring devices using statistical parameters is explained in the ASTM E 2214 standard practice (2008).

Performance evaluations:

Performance is characterized by repeatability, reproducibility and accuracy.

Repeatability is the ability to generate the same results over a certain span of time. Short-term, medium-term and long-term repeatability determined from seconds to minutes, from hours to days and from weeks to months are distinguished.

Reproducibility stands for the ability of an instrument to generate the same results as another instrument. For evaluations on instruments with identical or different designs, inter-instrument and inter-model reproducibility are the corresponding specifications.

Accuracy describes the ability of an instrument to generate the same result as a reference instrument. Such instruments are found at National Metrology Institutes, e.g. the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig, Germany.

Statistical methods:

Univariate and multivariate statistical methods to quantify the performance of colour-measuring instruments are investigated by Wyble and Rich (2007a, 2007b).

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Univariate methods estimate one single statistical variable with parameters like the mean value or the standard deviation. They are easy to handle and well established. Possible correlations to other statistical variables are ignored.

Multivariate methods typically use the covariance matrix to compute parameters such as the volume of the confidence ellipsoid. The relationship between statistical variables is considered. Chorro et al. (2009) investigated reproducibility of two multi-angle spectrophotometers using multivariate methods.

3. Measurements

The robot-based gonioreflectometer at PTB was used for reference measurements (Höpe 2010). All measurements with commercial multi-angle spectrophotometers are performed at the Institute of Printing Science and Technology (abbrev. IDD) in Darmstadt, Germany.

Test sequences:

The measurements at IDD are organized in short-term and medium-term sequences.

Sixty short-term (ST) measurements were made as quickly as possible without replacement of the sample. The instruments were calibrated immediately prior to the sequence using the respective calibration standards and manufacturer procedures.

Medium-term (MT) measurements were made with replacement of the sample, five times per hour for six consecutive hours per day on five not necessarily consecutive days. The calibration was performed once per hour before each set of five measurements.

Measured samples:

The three samples measured in this study are a white standard (WS) and two solid prints of an interference effect ink on a white paper (WP) and black paper (BP).

Evaluated instruments:

BYK-Gardner's BYK-mac, Datacolor's Multi FX10 investigated by Hupp and Dörsam (2006) and X-Rite's MA98 are the three multi-angle instruments examined in this study.

4. Evaluations

For multi-angle spectrophotometers, performance parameters have to be determined for more than one geometric configuration of light source, sample and detector.

Mean colour difference and ellipsoid volume:

In this study, the well-known mean colour difference from the mean (MCDM) is used for univariate repeatability evaluations. It describes the average deviations of several measurements from their mean value. The mathematical operation is transferred to the evaluation of reproducibility and accuracy. We use measurements with another commercial instrument or with the reference instrument instead of the mean. The resulting parameters are called mean colour difference between instruments (MCDI) and mean colour difference to the absolute (MCDA), respectively.

For multivariate evaluations of reproducibility, Wyble and Rich (2007a) use the volume of the confidence ellipsoid for a confidence level of 95 %. We denote the ellipsoid volume for deviations from the mean as EVM in this study. Replacing the mean as described above yields to the ellipsoid volume for deviations between instruments (EVI) and the ellipsoid volume for deviations to the absolute (EVA).

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Geometric coniigurations and parameter illustration:
The performance is evaluated for six geometric configurations realized in all instruments. The light source is located at an incidence angle of 45°. The aspecular angle, i.e. the angular difference between specular and detection direction, takes values of -15°, 15°, 25°, 45°, 75° and 110°. The itemized performance parameters are illustrated in a polar coordinate system. The angular coordinate indicates the aspecular angle. The radius vector specifies the value of the statistical parameter.

5. Results

The polar-like plots are used to analyse the influences of test sequence, measured sample, statistical method and geometric configuration.

Short-term versus medium-term test sequence:
As shown in figure 1a, short-term (ST) repeatability is better than medium-term (MT) repeatability. Presumably, the replacement of the sample between the individual MT-measurements is the reason instead of temporal deviations of the instrument. To exclude this influence, the following evaluations are based on ST-measurements.

White standard versus printed samples:
The repeatability for the white reflection standard is much better than for the printed samples as shown in figure 1b. The standard practice recommends repeatability evaluations for a white plaque only. Thus, instrument manufacturers specify repeatability for a white sample. In the light of our results, this seems to be not sufficient.

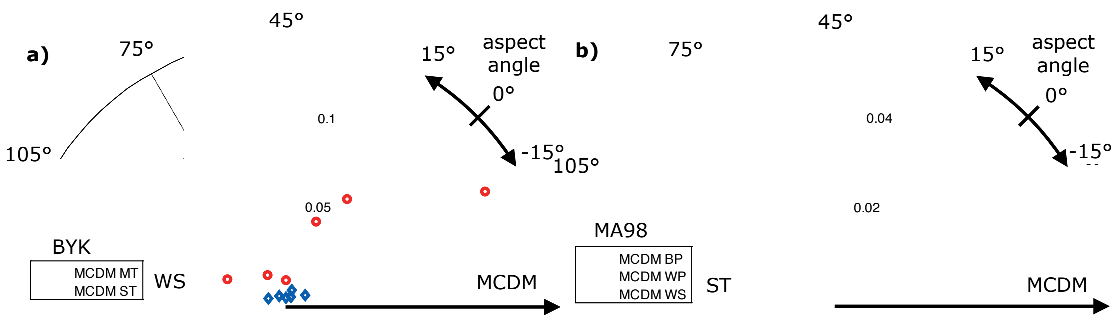

Figure 1: MCDM for a) MT- and ST-measurements with instrument BYK on sample WS and b) ST-measurements with instrument MA98 on samples BP, WP and WS.

Univariate versus multivariate methods:
To compare univariate MCDA and multivariate EVA, we normalize the maximum value to one. $MCDA_{NORM}$ and EVA_{NORM} are shown in figure 2a for two combinations of instrument and sample. For both pairs, the curves have almost similar shape. Univariate and multivariate methods show the same geometry-dependent performance tendency.

Near-gloss versus far-from-gloss geometries:
The influence of geometry is highlighted in figure 2b by means of the MCDA. For all samples and instruments, the MCDA and MCDI are high at low aspecular angles. Thus, reproducibility and accuracy are poor for geometries with detection near specular direction. Further investigations on the reason of the deviations are necessary.

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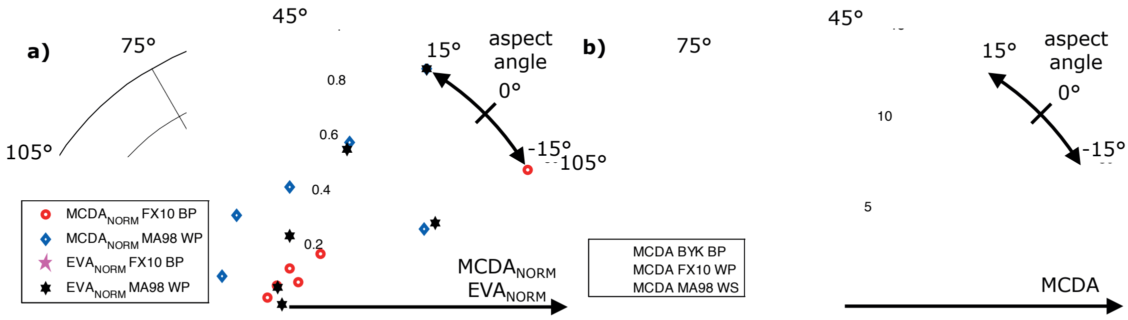

Figure 2: a) $MCDA_{NORM}$ and EVA_{NORM} and b) MCDA for ST-measurements with instruments BYK, FX10 and MA98 on samples BP, WP and WS.

6. Conclusion

A study on the performance of three commercial multi-angle spectrophotometers is presented. Short-term repeatability is better than medium-term repeatability. Compared to printed samples, repeatability is better for the white reflection standard. Univariate and multivariate methods show the same angle-dependent trends. Reproducibility and accuracy are less good for geometries with detection near the specular direction.

Acknowledgments

The authors thank Astrid Bothner, Kai-Olaf Hauer, Ludger Fischer and Uwe Schröder.

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A study on appropriate correlated color temperature subsequent to activity types of housing space

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Abstract
The aim of this study is to draw the scope of color temperatures people prefer according to the types of indoor activity in residential space. For this purpose, this research manufactured the mock-up model which reproduced a living room, dining room, bedroom and study room identical to actual space, and suggested the scope of color temperatures over the 7 steps in all in the sector from 3000K to 6000K by applying LED lighting equipment. The indoor activity types at this time were divided into daily routine, work, and relaxation. As a result of evaluation, it was found that the color temperature preference scope was varied according to the kinds of activities in each space type. It was found that high color temperature was preferred, especially in study room.
In addition, the preferred color temperature scope according to the space type was found to be different despite the same type of activity.

1. Introduction
When it comes to the harmony of quantitative and qualitative elements of lighting influencing the psychological response of human beings, Kruithof's research is often cited; Kruithof in his research suggested that the lighting source of high color temperature feels comfortable in high illuminance; on the contrary, the lighting source of low color temperature feels comfortable in low illuminance. So far, a lot of researchers at home and abroad have examined Kruithof's suggestion from several viewpoints.

However, it's true that the elements suggested as the standard of the present lighting environment deals with only the scope of illuminance by work type consequent upon the kind of space. Such an illuminance standard is the one in time of consideration of the clear visibility of lighting as a major evaluation element, so there is a limit to using it as the standard for the lighting environment of indoor space in consideration of the comfort of working environment and users' sentiment.

Accordingly, this research is going to look at the scope of generally preferred color temperatures based on indoor activity types in residential space.

2. Kruithof's comfort curve
Kruithof's comfort curve is presenting an illuminance sector in which people feel comfortable with a variety of color temperatures that can be used an indoor lighting. According to the graph, it's judged that people feel comfortable in the low illuminance scope of 50-100lx in color temperature of about 2,500K while the higher the color temperatures are, they feel comfortable in high illuminance. However, the recently presented research results reveal that Kruithof's research results without considering the sorts of indoor activities are not always useful for real life.

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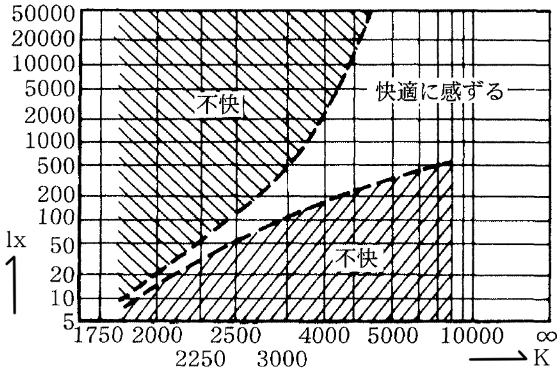


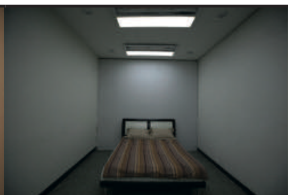
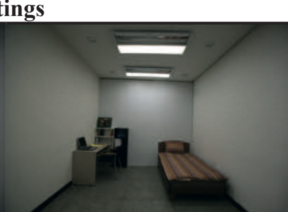
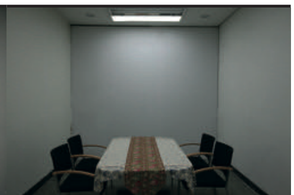
Figure 1. Kruithof's comfort curve

3. Experimental methods

This research manufactured a Mock-up model by limiting its space size to 32.4 cubic meters [3*4*2.7m] for doing experiments. Then, this research had the subjects do a preference evaluation by selecting a living room, dining room, bedroom and study room as evaluation objects and reproducing the room identical to actual space respectively.

In addition, this research conducted a preliminary experiment targeting 20 people living in an apartment house with the aim of classifying the kinds of activities that could take place in indoor space. In the preliminary experiment, this research listed the behavioral pattern of all family members in each space. As the result, this research conducted this experiment by classifying their behavioral pattern into 'daily routine', 'work', and 'relaxation' in the living room, bedroom and study room, and also into 'daily routine' and 'relaxation' in the dining room.

Table 1. Experimental settings

settings			
			
living room	bedroom	bedroom	dining room
Actiivities			
'daily routine', 'work', 'relaxation'			'daily routine', 'relaxation'

The lighting equipment used for this experiment is a surface light source by applying LED which consist of two sort of LED Chip-cool white and warm white-and was manufactured so that a user can adjust the color temperature using a controller. The suggested color temperatures comprise 7 steps in all including 3000K, 3500K, 4000K, 4500K, 5000K, 5500K, and 6000K.

This research organized an evaluation panel with a total of 20 architecture majors [12 females, 8 males]. They were senior students and postgraduate students in the architecture department who are recognized to have sensibility to evaluate a lighting environment in an interior building space. And subjects were free of dyschromatopsia with above 0.8 in corrected vision, so there was no problem in evaluating the lighting environment.

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4. Result

As a result of doing experiments, there came out a difference in the scope of color temperatures preference according to activity types and this research discovered the fact that the preference scope of color temperatures varied according to the kinds of space albeit the same activity type.

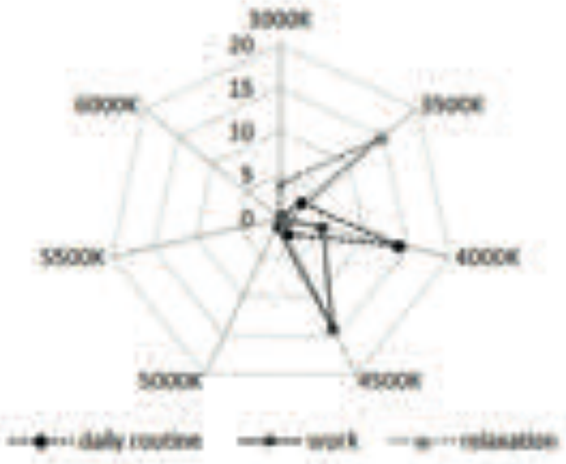

Figure 2. Preference in living room

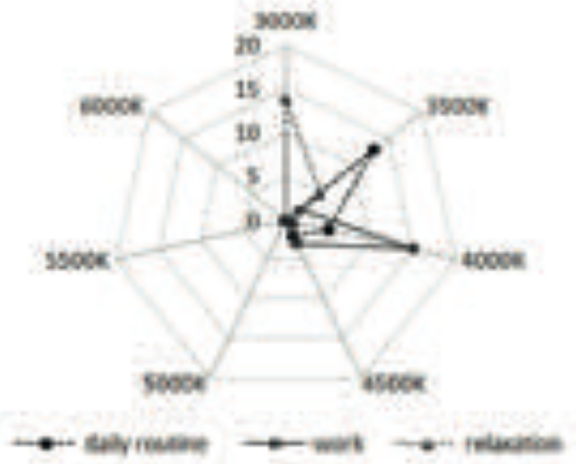

Figure 3. Preference in bed room

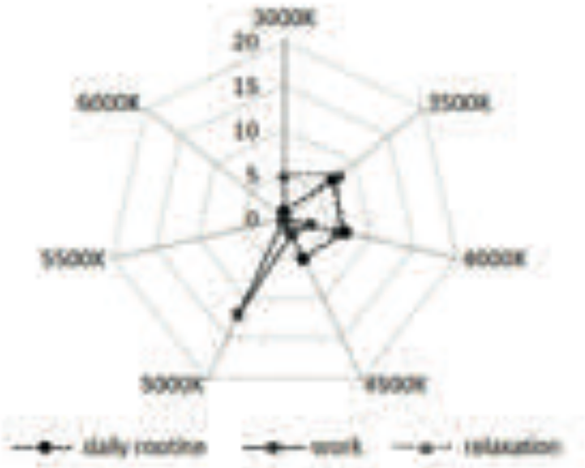

Figure 4. Preference in study room

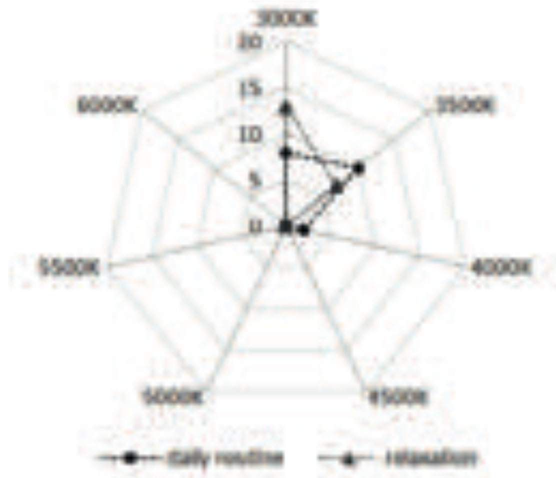

Figure 5. Preference in dining room

In general, it was found out that the preferred color temperatures got higher in order of relaxation, daily routine, and work in activity types; in case of 'relaxation', people commonly preferred the low color temperature about 3000~35000K while the evaluators preferred the scope of comparatively higher color temperatures with 3500~4000K in case of "daily routine'" and 4000~5000K in case of "work." In addition, this research found out that the evaluators preferred the highest color temperature, especially in the study room while showing no preference for the lighting beyond 5000K at all.

Unlike such research results, the color temperatures of lighting applied to the present residential space is being planned in a lump by a planner without any clear standard or trend as to a plan. Considering the present situation where the space function and room matching the current era and occupants' activity characteristics are not reflected, there needs to be a systematic analysis about diverse evaluation elements for more pleasant and high-quality lighting environment.

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Research on the influences self image has on the preference of visual image and visual color – focused on Korean females in their twenties

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Abstract

The purpose of the research is to identify the tendency and emotional wants of consumers. The research was conducted on Korean female students in their twenties, focusing on actual self-image and ideal self image based on I.R.I adjective image scale. This research can be divided into three parts. The first part indentifies the actual and ideal self-image of Korean women in their twenties. The second part extracts representative triad colors of perfume advertisements that can influence one self. The last part identifies preferred visual emotion image and the colors of the Korean female students in their twenties with the perfume advertisement. The research resulted that the majority of Korean female students in their twenties have identical self-image, verbally and visually, and generally showed a high level of color in the pale, light, bright, vivid P-R range reflects their self-image. (**Keywords:** self image, image scale, korean female students)

1. Introduction

Today because of the improvement of life standards consumers think highly of products that can reflect the consumers' image. In this sense it is needed to find out the consumers tendencies and emotional desires. Subjects to the research were Korean female students in their twenties who are the leaders of trends and the principal sources of economic activities. Research was conducted by analyzing actual self-image and ideal self-image which are the most important factors in influencing consumer brand evaluation (Sirgy, 1982, 1985). IRI adjective image scale made in 1992 to meet the Korean mind was used as a basis. In the research the actual and ideal self-image of the female students in their twenties and through a perfume advertisement which shows one general view and also can influence oneself is used to examine their preferred visual sensitive image. Lastly with the correlation of the two factors find out what color is ideal for communicating ones emotional state, image and characteristics. This research was significant because it identified the preferences of female students in their twenties in Korea and is hoped that through this research companies that target those demographical areas will have a design standard.

2. Method

2.1 Actual and ideal self-image based on I.R.I image scale

To analyze their actual and ideal self image we used IRI adjective image scale (a positioning where you express what a majority of people feel about a certain color with an adjective). With this as our basis we asked 198 female students about the emotional group of their actual self-image, ideal self-image and asked them to identify an adjective describing their images. To look into the research problem materials were collected in questionnaire forms and to prevent any vagueness in the answering of the questionnaires we explained in person the notions and how to

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answer the questions before giving out the questionnaires. Data was analyzed with SPSS 15.0 for windows using multiple answer analysis.

2.2 Choosing the advertisement

To examine the tendency of visual emotion image of female students in their twenties in Korea a perfume advertisement was chosen. A perfume isn't too eager in short sales but wants a long lasting sale like the smell of the perfume so they advertise the product continuously for a long period of time. So to gather perfume advertisements of different brands we searched ELLE and Vogue magazines that were published from 1996 to 2010 and gathered 86 perfume advertisements. To analyze the visual emotion of the advertisements a survey was conducted on 30 professors and lecturers, professionals of visual communication design, of Ewha womans university, school of design. With the IRI adjective scale we asked them to identify each advertisement's images with the 12 emotion groups.

2.3 Preference of visual emotion image through perfume advertisement and color

The 198 female students in their twenties were asked to choose their preferred visual emotion image between the 36 advertisements that exclude the IRI adjective scale standards. To prevent any vagueness in the answering of the questionnaires we explained in person the notions and how to answer the questions before giving out the questionnaires. Data was analyzed with SPSS 15.0 for windows using multiple answer analysis. And with the results, through image clustering extracted the representative triad colors and its values into L*, a*, b* and changed those values into Munsell .

3. Results

3.1 Actual and ideal self-image through I.R.I. image scale

Table 1. The actual self-image.

	Percent	Grade
Clear	5.3	7
Cute	13.9	3
Airy	15.5	2
Natural	25.7	1
Graceful	2.7	10
Mild	8.0	4
Distant	7.5	5
Lofty	4.3	9
Modern	7.5	5
Gentle	2.7	10
Gorgeuous	1.6	12
Dynamic	5.3	7

Table 2. The ideal self-image.

	Percent	Grade
Clear	13.9	2
Cute	7.0	7
Airy	8.6	5
Natural	4.3	10
Graceful	19.3	1
Mild	4.8	9
Distant	4.3	10
Lofty	1.6	12
Modern	10.7	4
Gentle	5.3	8
Gorgeuous	11.8	3
Dynamic	8.6	5

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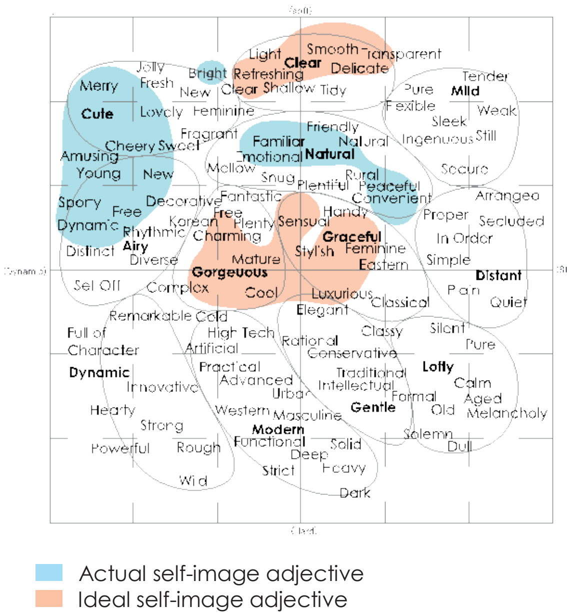
The survey results of the actual and ideal self-image, emotion group and adjective word of the female students in their twenties are shown on the table. From the answering you can determine 25.7% chose ‘natural’, 15.5% chose ‘airy’ and 13.9% chose ‘cute’ for the emotion group and ‘natural’, ‘airy’, ‘cute’ had the highest percentage in that order. In detail, in the ‘natural’ group peaceful and friendly, in the ‘airy’ group liberal and active, in the ‘cute’ group delightful and bright words were chosen the most. Their ideal self-image showed that 19.3% of ‘graceful’, 13.8% of ‘clear’, 11.7% of ‘gorgeuous’ as the highest emotion groups. In detail in the ‘graceful’ group sensuous, feminine, luxurious, in the ‘clear’ group smooth, transparent, bracing, in the ‘gorgeuous’ group attractive, mature showed a high tendency.

Therefore, you can see that female students in their twenties show a soft and dynamic actual self-image and a more dynamic ideal self-image. This can be translated as female students in their twenties see themselves as tranquil, active and cheerful but want to be more luxurious and smooth.



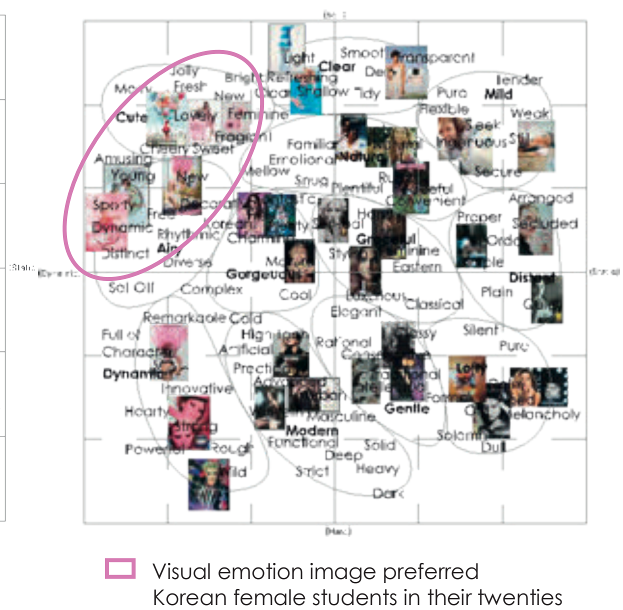


Fig 1 : The actual and ideal image

Fig 2 : Perfumes in IRI image space positioning

3.2 Choosing the advertisement and extracting the color

By sorting the 86 advertisements chosen from the ELLE and Vogue magazines that were published from 1996 to the IRI adjective scale of 12 emotion groups 36 advertisements were sorted 3 in each emotion group.(Fig 2)

3.3 Preference of visual emotion image through perfume advertisements

Visual emotion image preferred Korean female students in their twenties are positioned on ‘cute’ and ‘cheerful’ group. The results of the advertisements after image clustering and extracting the representative triad colors are shown in the figure 3.

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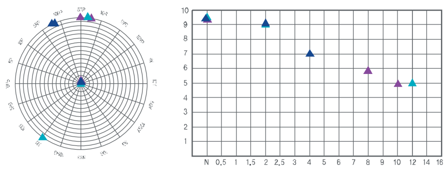
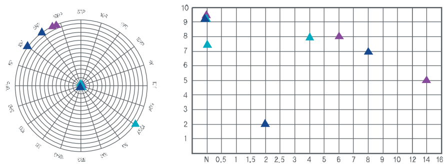
Table 3. Distribution chart of preferred visual emotion image of female students

Adjective	Perfume Ad	Triad colors	Distribution color of Muncell color System
Cute			
			
			
Airy			
			
			

4. Conclusions

In conclusion, when compared adjectives from the IRI image scale and preferred visual emotion image, verbally 'natural', 'cute', 'airy' and visually 'cute', 'airy' showed a high preference. This means that 'cute' and 'airy' reflects the general self-image of the female students in their twenties in Korea. Analyzing the colors of preferred visual emotion image, Hue is distributed P-R. and, Value is distributed 5-10 mostly, Chroma is distributed N-14. Therefore Korena female in their twenties prefer pale, light, bright, vivid P-R colors according to general self-image.

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Colour and light in space: Dynamic adaptation and spatial understanding

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Abstract

Based on our own observations and on scientific and scholarly references this paper discusses the appearance of colour constancy and the adaptation of colour and lightness in space. It presents part of an ongoing work, the aim of which is to formulate a spatially based colour knowledge.[1] Our scientific approach is holistic and mainly directed towards colour and light phenomena as such, not towards underlying physiological processes. Earlier research has discussed lightness perception in colours very near neutral grey, with so low chromaticness that you can ignore the hue. In our research we have found that surfaces with nominally chromatic colours under special circumstances can be perceived as white and thus serve as anchors for perception of other colours in the field of vision. We also discuss how distinctions are made between perceived colours caused by on the light colour and such caused by the surface qualities. What we call adaptation is not limited to basic perception. Experience of colour in space is both perceptive and cognitive, as part of interaction between the individual and the world on many levels.

1. Colour perception and physical measurement

In the field of colour and light, visual/perceptual phenomena are too are often described and analysed with the use of physically based concepts. This can give the false impression that physical measurements also measure what we see. The relationship between the physically measurable and our vision is, however, very complicated. Our vision is based on a continuous adaptation, which strives to keep the colours of the surrounding world such as we recognize them. But our adaptation not only depends on basic perceptual *reactions* but also on cognitively based *understanding* of the colour and light situation in the surrounding world. Traditionally, research about colour has most often neglected the need of knowledge about spatial visual perception, and although colour and light are mentally inseparable in our experience of the world around, the complicated relation between colour and light experiences has not been paid attention to.

2. Anchoring of lightness perception

Our visual sense adapts to current light conditions: we perceive almost the same colour of an object independent of the light, on condition that the light source emits light with a full and continuous spectrum and that our visual system has had time to adapt to the specific light situation.

The mechanisms that make us perceive and determine the lightness of surfaces observed in different situations have been thoroughly considered by professor Alan Gilchrist et.al (1999). They present a number of theories and discuss them in relation to many experiments carried out

1 Parts of the project *Den rymliga gråheten* (*The spacious greyness*), Konstfack 2008) have been presented with two papers at AIC in Sydney 2009 . The subsequent project *Så vitt vi vet* (*White - as you like it),* Konstfack 2009 is currently under publication in Swedish.

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by researchers since the late 19th century. As pioneers they especially emphasize Katz (1935), who is characterised as a phenomenologist, and Koffka and other upholders of the Gestalt theory (Koffka 1935). As a result Gilchrist et al. present a new theory: *The anchoring theory of lightness perception.*

Gilchrist et al. state that it is not the luminance that decides the perceived lightness of a surface. Any luminance level can be perceived light or dark depending on context, and the surface that we perceive as white functions as an "anchor" for perceived lightness of all other surfaces seen simultaneously. Most often our anchor for ”white” is defined as the surface that has the highest luminance in the visual field – *Highest Luminance Rule.* This is, however, not true in all situations, since we also have a tendency to perceive the largest area in the field of vision as anchor for ”white” – *Area rule*. As long as the lightest area also is the largest the two rules coincide, but they come into conflict if the darker one also is the largest. Then we tend to perceive the largest area as white at the same time as the smaller and lighter area also is perceived as white - a paradox that is solved by perceiving the smaller area as luminous.

3. Nominal chromatic colours as anchors for perception

Gilchrist et al. discuss how we perceive lightness in areas that are very near neutral grey, in other words colours with so low chromaticness that you can ignore the hue. In our research we have gone further and studied colours that have nominal hue and chromaticness. We have tried to find out if surfaces with nominally chromatic colours under special circumstances can be perceived as white and thus serve as anchors for perception of other colours in the field of vision. We also have tried to find out if this anchoring may affect also the perceived hue of other colours seen simultaneously.

We have with the help of observers tested how he nominal hues of light colours affect the perceived hues of darker colours in the field of vision. One of these observation series was carried out on a LCD Monitor, where 45 combinations of whitish but just slightly chromatic backgrounds and darker greyish samples were shown to 10 observers who were asked to assess the hue of the darker colour with reference to NCS elementaries. The answers of the observers gave a clear support to the hypothesis that the perceived colour of the sample shifts in the direction of the complementary colour of the nominal background colour. This could be interpreted as a classical simultaneous contrast.

Apart from the answers given, it is, however, interesting to discuss answers to the question never asked; the observers where not asked to describe the whitish background colour. Not a single observer commented on the colour of the background and no one gave any indication that there were any differences between the backgrounds. The French philosopher Maurice Merleau-Ponty discusses how we experience the surrounding world in different ways depending on situation. He makes a distinction between two modes of attention: *the reflective attitude* and *living perception* (Merleau-Ponty 1989). This distinction is significant to our perception of colours. Strictly speaking it is not possible to find out how we perceive colours in *living perception,* since every question that directs our attention towards a colour of necessity gives rise to a *reflective attitude*.

Our interpretation is that, in our test, the observers had a reflective attitude towards the darker greyish samples; these were the subjects of the conscious analyses of colour qualities. The whitish backgrounds were seen as simply ”backgrounds” with a spontaneous living perception. The perceptive shift of hue of the darker greyish samples on the whitish backgrounds could be

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interpreted as a result of adaptation to the surface that spontaneously was perceived as white. Gilchrist et al. have shown that what we perceive as white perceptive anchor and determines the lightness we perceive. Our studies indicate that the acts as a perceived white can be an anchor also for perception of hue. All colours have, at least, a slight chomaticness and a hue. We never experience absolutely neutral – achromatic – colours. With an analogy from music theory white anchoring could be regarded as a ”transposition” where the surface that is perceived as white is the ”keynote” – or ”keycolour” – for perception of both lightness and hue in a given light situation; the ”keycolour” decides all relations between the colours in the field of vision (Fridell Anter and Klarén 2009; Klarén and Fridell Anter 2009).

This may give a new interpretation of the *simultaneous contrast* phenomena (Gelb 1929). In our understanding *simultaneous contrasts* are no specific optical illusions. They can be regarded as isolated *examples* of the function of normal vision in *all* spatial situations. Continuously changing light conditions in the surrounding world are counter- balanced by perception and thereby a continuous and relatively constant experience of colour and light is maintained.

Demonstration of simultaneous contrast is an important – and conspicuous – element in almost all literature about colour theory. Is usually presented two-dimensionally and without intention to be spatially experienced. One important example is the work of Joseph Albers (1963). Thus traditional colour theory has not observed the fundamental connection between simultaneous colour contrast and colour and lightness adaptation.

4. Colour in a spatial whole

When perceiving colours our vision does not react to the absolute spectral distribution of radiation that reaches our retina. Instead distinctions and relations are registered. Hence our visual system is developed for a continuous spectrum of light and gradual changes between different light situations and under these circumstances we perceive colours as more or less constant. But even if we experience that an object has the same colour in different light we can at the same time perceive a slight tone of colour that reveals the character of light. For nominally white surfaces this effect is more obvious than for nominally chromatic surfaces. We experience that the surface is white but we understand at the same time that it is illuminated with a light of a special quality and intensity. This involves not only light coming directly from the light source, but also reflected light from surrounding surfaces. Reflection from chromatic surfaces in a room can give a hue to a nominally neutral or slightly chromatic surface, which is especially evident in neutral light surfaces (Billger 1999).

Dependent on *modes of attention* a nominally white wall lit by a “warm” sunshine can be seen as slightly yellowish (with a reflective attitude) or as pure white – as a lightness anchor – or as the imagined “real” colour of the wall experienced “beyond” the two perceived colours (with living perception). As a suggestion we call this imagined colour *constancy colour* (Figure 1). According to the American philosopher Alva Noë, different kinds of visual appearances can be experienced simultaneously. Noë gives an example from shape perception: When a circular plate is held up in an angle we are able to experience circularity in what we simultaneously perceive as an elliptical shape. In the same way, we can experience a white constancy colour in a surface that we simultaneously perceive as having a hue caused by light (Noë 2004).

All these colour and light interactions are what make us perceive space. Normally we have no difficulties to make distinctions between what is caused by the light and by the qualities of surfaces. Perhaps we do not attend or give interest to the accidental colour of direct light, of

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Figure 1. View from a winter day in Norway: The nominally white snow can be seen as slightly bluish and yellowish as effects of sunlight and shading or as pure white as a lightness anchor. Beyond the perceived colours we experience the constancy colour, the imagined "real" colour of the snow. Photo: Ulf Klarén

reflected light or in shades. But intuitively the logically distributed colour variations caused by light and reflections are indispensable spatial qualities.

Experience of colour in space is both perceptive and cognitive. What we call adaptation is not limited to basic perception (Noë 2004); it is interplay between the individual and the world on many levels. These include the basic level of hereditary basic reactions, the level of perceptive skills based on direct experience of the world and the level of cultural context. To understand and to describe colour phenomena it is necessary to regard colour as an integrated part of the comprehensive and dynamic perceptive process of exploring the appearance of the world as a – spatial – whole.

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La couleur, fille de la lumière: The interaction of colour and light in the monastery of Sainte Marie de la Tourette

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Abstract

This paper investigates the colour- and form*gestalt* of the church of Sainte Marie de La Tourette (1959), linking Le Corbusier's *polychromie architecturale* to his concepts of *visual acoustics* and *ineffable space;* both essential aspects of his post-war architecture. The richness of the painted surfaces and the glowing colour, created through reflections of natural light onto its boldly painted walls and sculpted objects, such as demonstrated in the sacristy and the crypt of the church, stand in stark contrast to the crude, "bare" concrete to create a sense of pureness, akin to his early whitewash ideas seen in his Law of Ripolin. This use of industrial, raw products, such as concrete and cement, paired with a sublime but controlled play of colour and natural light, too, mediates between the profane and the sacred to create a space of poetic lyricism and spiritual asceticism.

1. Polychromie architecturale

Le Corbusier's architectural work, beginning in the early 1920s, reflect his profound research and interest in colour as one of the "fundamental elements in the architectural perception" (FLC J1 (7), 340-342); his essays and writings about colour stress its significance. Transforming his purist concept of *polychromie architectural*, "Colour completely depends on the material form," (Ozenfant and Jeanneret 1918) colour began to emerge in his buildings, after World War II, as an autonomous design feature in the interplay of architectural elements. While his purist buildings share a sophisticated colour palette of muted tones based on the *constructive qualities* of each hue, his post-purist buildings share a colour palette of vibrant, often primary or *pure* hues employed to evoke strong emotional responses. As starting with the purist buildings of the early 1920s, Le Corbusier used colour in direct-relationship to the quality and quantity of light received in his structures enhancing the sculptural, spatial and emotional response potentials of each hue within the space. In his own words, "colour, daughter of light," (Le Corbusier 1931) revealed itself in his works by showing the physical interdependence of colour and light.

Fig. 1: La Tourette, church main nave

Fig.2: La Tourette, crypt

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2. Ineffable space

We have to consider the architectural polychromy of La Tourette in the context of Le Corbusier's demand for a *synthesis of the arts* and his concept of *ineffable space*, both central to his theories and projects of the post-war period (Le Corbusier 1946). Ineffable space describes transformation of space as a transcendental event that lies beyond the physical reality of the space. Moreover, the perfect interplay of all the spatial elements creates an aura evoking an invisible humming and vibration of the space caused by *visual acoustics*, similar to a musical instrument. Visual acoustics, which sometimes also appeared as *plastic acoustics* in his writings, is used as a trope for a spatial phenomenon describing the interactive play of acoustical waves, light waves, spatial effect and emotional energy. In this context the building serves as a sounding board for the surrounding landscape or "visual echo" (Pearson, 1997), and also a work of art, radiating visually into the environment.

As Le Corbusier stated, the phenomenon of the ineffable space became both, a means and a goal of the spatial concept of Sainte Marie de la Tourette:

> *Lorsqu'une œuvre a son maximum d'intensité, de proportion, de qualité d'exécution, de perfection, il se produit un phénomène d'espace indicible : les lieux se mettent à rayonner, physiquement ils rayonnent. Ils déterminent ce que j'appelle « l'espace indicible », c'est-à-dire un choc qui ne dépend pas des dimensions mais de la qualité de perfection. C'est du domaine de l'ineffable. (Le Corbusier 1960)*

3. Colour and light

As a built expression of existential minimalism, the church surprises with its plainness and pureness, emitting a sensation of transcendental solemnity. A large door at the end of the conduit leading to the church opens the view into a dark room illuminated only by a few windows and openings. A simple Cartesian room, bare of any decoration and built out of pure concrete, welcomes the visitor and opens the view to a built, polychrome still life made of boldly painted walls and dazzling light framed in concrete (Fig. 1). Comparable to the white entry hall at La Roche House in Auteuil, built in 1924, the main nave of the church is conceived as a "negative space". The built emptiness turns into a perceptible medium: A space of pure abstraction striped of any decoration, and as such a built expression of the symbolic cleansing of the 1925 *Law of Ripolin* (Le Corbusier 1925)[1]. Colourful window slits in the primary colours red, green, yellow and white barely illuminate the choir area, and the dark nave visually disappears into the black hole of the organ attached to the West wall. This creates a space placed between the constant tension of medieval mysticism and modern architecture, light and darkness, natural materials and expressive colours, evoking with its visual acoustics the architectural tension desired by Le Corbusier.

Boldly painted surfaces (crypt, sacristy and confessional) and coloured light surround the main altar as an aureole emphasising the altar as the focal point of the composition: *"C'est avec les autels que le centre de gravité sera marqué ainsi que la valeur, la hiérarchie des choses. I y a*

1 With the exception of a few *taches de couleurs*, the church and the monastery, though executed in exposed concrete, were originally planned to be painted in *blanc absolu*, a reminiscence of the white monasteries which Le Corbusier experienced during his Voyage to the Orient in 1911. A thought that later was abandoned due to financial constraints (FLC K3 (20), 462).

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en musique une clé, un diapason, un accord. C'est l'autel, lieu sacré par excellence, qui donne cette note-là, qui doit déclencher le rayonnement de l'œuvre." (Le Corbusier 1960: 14 and 16). The main nave is conceived as a spatial unit, mainly through its Cartesian form and material choices, but also emphasised through the unifying darkness and achromatic materials of the main space: a built "inversion of the traditional church" (Kessler 1986). The main nave pushes over the colour space of the sacristy and the crypt; both are linked underneath the nave, but without direct access from it. The contrast of the *colourless* main nave (with the exception of a few colour splashes), built from materials left in its natural state, such as the black slate, grey concrete and white stone for the altars, with the colourful spaces of the transept (sacristy and crypt) creates a space of poetic lyricism built upon the spatial and emotional powers of colour. As Le Corbusier wrote in reference to the spatial dynamics and physiological effects of colour in architecture, *"La couleur c'est de la dynamite"* (Le Corbusier 1936).

Where the dark nave can be seen as a built analogy of monastic life, the exploding colour space of the transept, contrastingly, can be interpreted as a modern version of the medieval representations of the 'new Jerusalem'. The chosen colour scheme of yellow, red, blue and black surfaces of the crypt draws to the colour schemes of the gothic cathedrals, and creates a mystical space of pronounced plastic effect (Fig. 2)." As a representation of the "New Jerusalem" the gothic cathedral was built without windows, but rather with luminous wall infills, walls like glowing crystals and gems, from which the colour schemes of the cathedral are derived: gold-yellow, ruby-red, ultramarine, and emerald-green." (Kessler 1986: 172, translation by author). Bathing the crypt into diffuse and timeless light, the gothic window is transferred into a still-life of glowing walls, emitting radiant energy as both reflected light and visual energy:

> *Et alors le problème d'éclairage est toujours celui-ci, c'est de savoir ce qu'est l'éclairage : ce sont des murs qui reçoivent une lumière. Ce sont des murs éclairés. L'émotion vient de ce que les yeux voient, c'est-à-dire les volumes, de ce que le corps reçoit par l'impression ou pression des murs sur soi-même et ensuite de ce que l'éclairage vous donne soit en intensité, soit en douceur selon les endroits ou ils se produit. (Le Corbusier 1960: 11-12)*

In working with stark light/dark and colour/no colour contrasts Le Corbusier creates a modern chiaroscuro as an *art abstrait*, breaking the boundaries between sculpture, painting and architecture as demanded in his *synthesis of the arts.*

Together with Jean Xenakis, Le Corbusier developed two different types of *canons de lumières* that not only control direction and reflection angle, but also determine exactly the quantity and quality of the light received and reflected from the painted walls. The first is a transformation of the light tower, as depicted in a sketch made during his visit at the Villa Hadriana in 1910. Though developed as an idea for the Basilica in Sainte Baume in order to create a "symphony of light, shadow and semi-shade of extraordinary effect" (Le Corbusier 1953: 28), they are built for the first time in La Tourette. Capturing the light from the North, these conical *canons de lumières* create a mystical constant and diffuse light of extraordinary effect that recall the divine light of the *New Jerusalem*. The cones, painted in red, white, and black, turn into mystical, bodiless openings, a reminiscence of the *true de mystère* in the Villa Hadriana. The second type of *canons de lumières* are placed above the sacristy: seven prismatic light sources positioned to capture the light from the South. In contrast to the crypt, the light here is sharp, almost aggressive, reflecting from the red wall of the sacristy onto the dark room of the nave. The

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choice of red for the wall and yellow for the ceiling emphasises a warm glow created through the reflection of light from the painted surfaces. He uses a similar effect, though less pronounced, in the choir area. White sunlight reflected on painted surfaces in primary colours, enters as a red, yellow and green glow in the darkness of the space.

Le Corbusier masterfully uses the interdependence of colour and light to create an *art abstrait* of poetic lyricism and spiritual asceticism. Light, colour, proportions and dimensions are perfectly arranged creating through their visual acoustics the phenomenon of ineffable space.

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A consideration on mathematical relations between color attributes of Munsell, PCCS, and NCS

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Abstract

This paper concerns mathematical relationships between color attributes of three typical perceptual color systems, Munsell, NCS, and PCCS. Simple and beautiful relations were found between their color attributes. It means that each color attribute is a different representation of one perceptual color, which implies the possibility of unifying perceptual color systems.

1. Introduction

Quantitative representation of perceptual color is useful both for analysis and synthesis of color combination in the field of application of color. Many perceptual color systems, such as Munsell, NCS, PCCS (Practical Color Coordinate System, Natori 1997) and so on, are developed to define color by means of their color attributes. As the attributes of each system are adopted independently, there exist few explicit relations between them.

The aim of this research is to find mathematical relationship between color attributes of above three typical color systems and to reveal a common structure through the perceptual color systems.

2. Color attributes of Munsell, NCS, and PCCS

When a color space is utilized to the analysis or the synthesis of color combination, the color space is expected to have uniformity in hue and to represent a tone directly by its coordinates.

a) Munsell system has three color attributes, hue H, value V, and chroma C, which are said to have uniformity separately, but it is difficult to define a tone by the attributes.

b) NCS has four fundamental attributes, whiteness w, blackness s, chromaticness c, and hue φ. The first three attributes, satisfying the condition $w+s+c=100$, $w \geq 0$, $s \geq 0$, $c \geq 0$, compose a barycentric coordinate system which is illustrated by a color triangle. NCS also has an auxiliary attribute, value v.

c) PCCS has three attributes, hue h, light-ness l, which is equi-valent to Munsell value V, and saturation s. To avoid confusion we use hereafter the notation V, S instead of l, s respectively. A feature of PCCS is to have the concept of tones. Representative color of tone is defined by PCCS attributes and also by Munsell attributes in the docu-ment of PCCS (JCRI 1991). Twelve tones of yellow hue (h=8,

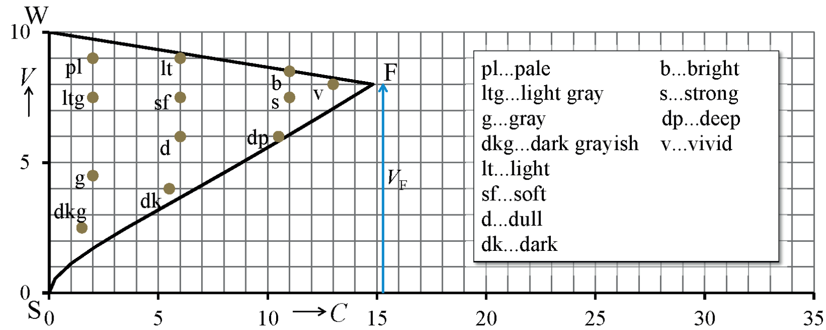

Figure 1. Twelve tones on Munsell C-V plane (H=5R).

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i.e. H=5R) are plotted both in Munsell S-V plane (Figure 1) and PCCS C-V plane (Figure 2). Here W and S denote respectively the points of white and black color. S_∞ is the upper limit of saturation (cf. section 3.3). (Solid lines are explained in section 3.4.)
d)

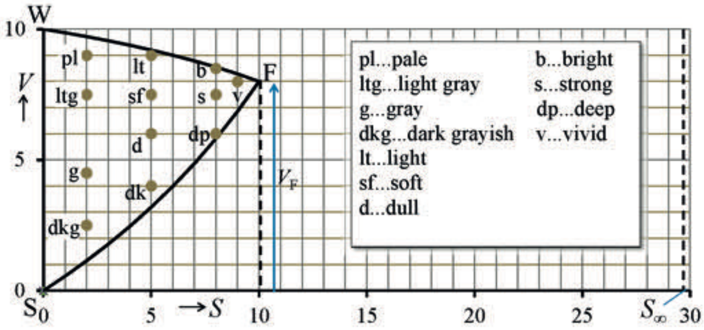

Figure 2. Twelve tones on PCCS S-V plane (h=8, i.e. H=5R).

3. Relations between color attributes

In this paper, hue is always fixed and only other attributes, such as value, chroma, and so on, are considered.

3.1 Color triangle and tone scale of NCS

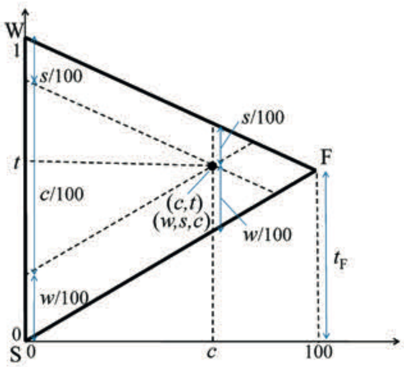

Figure 3. Color triangle and tone coordinate (c, t)

NCS attributes w, s, c are expressed as a point in a color triangle WSF on a plane. Here F represents full saturated color. The edge WS is usually put on the vertical axis with origin S. See Figure 3. Let t denote the ordinate with t=1 at the point W, and c denote the abscissa with c=100 at the point F. Relations between the orthogonal coordinate (c, t) and the barycentric coordinate (w, s, c) are represented by:

$$t = w/100 + t_F\, c/100 = (1\text{-}s/100) - (1\text{-}t_F)\, c/100,$$
$$w = 100t - t_F\, c \text{ and } s = 100(1\text{-}t) - (1\text{-}t_F)\, c,$$

where t_F is an ordinate of full color F. NCS commonly adopts $t_F = 0.5$.

The quantity (1-t) corresponds to Chevreul's tone, that is the degree of increasing depth or intensity of a color (Chevreul 1861). After this the quantity t is called 'tone scale', and coordinate (c, t) is called tone representation of a color.

3.2 NCS auxiliary attribute: value v

Noticing NCS auxiliary attribute, value v, all loci of constant v form a set of lines which converge at one point with abscissa c_∞. The equation of the line is written as

$$t = t_\infty + (1\text{-}\, c/c_\infty)\,(v - t_\infty),$$
$$t_\infty = (c_\infty/100)\,(t_F - v_F) + v_F,$$

where v_F is the value of full color F. Values of v_F and c_∞ for each hue are listed in Swedish standard (SS019100E 1990). The above equation can be interpreted as a transformation from (c, v) to (c, t). The inverse transformation is easily obtained:

$$v = t_\infty + (t\text{-}\, t_\infty) / (1\text{-}c/c_\infty).$$

Figure 4 illustrates color triangle WSF and a set of lines having constant value in c-t plane.

Figure 5 illustrates the transformed figure of color triangle. Here constant value lines are parallel to the horizontal axis in c-v plane.

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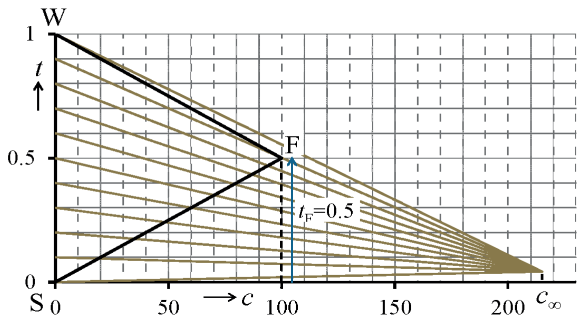

Figure 4. Color triangle and constant v line on NCS c-t plane (ϕ =Y).

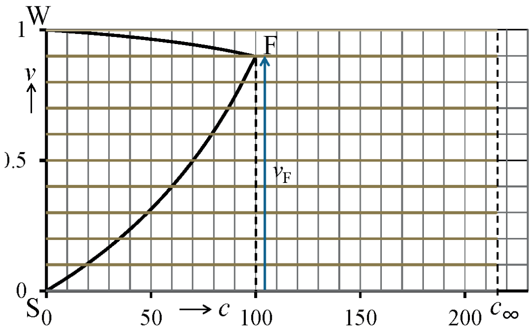

Figure 5. Colr triangle and constant v lline on NCS c-v plane (ϕ =Y).

3.3 Transformation of color attributes between PCCS and Munsell

From our previous research (Kobayasi 2010), Munsell chroma C and PCCS saturation S are mutually transformed by linear fractional functions:

$$C = k\,(1\text{-}e^{-rV})\,S\,/\,(S_\infty - S),$$
$$S = S_\infty C\,/\,(k\,(1\text{-}e^{-rV}) + C),$$

where k, r, and S_∞ are constants depending only on hue (See Table 1). This transformation approximates, with high accuracy, the numerical relation defined in the PCCS document. It is noted that these expressions behave almost independent of V though they include V, because the term of exponential function is nearly zero when V is not very small. It is also noted that saturation S is finite and approaches to S_∞, when chroma C increases infinitely.

Table 1. Coefficient in PCCS-Munsell transformation.

h	2	4	6	8	10	12	14	16	18	20	22	24
k	28.02	29.53	40.49	29.46	28.45	27.34	38.25	42.20	32.86	35.32	33.61	39.05
r	0.85	0.72	0.62	0.57	0.59	0.66	0.77	0.90	1.00	1.05	1.03	0.96
S_∞	30.30	31.75	46.73	29.67	26.25	22.62	33.22	36.90	31.85	34.72	32.57	41.67

3.4 Homomorphism of NCS and PCCS

From the last discussion of section 3.2, homomorphism will hold between NCS and PCCS. If c and v are equated with 10S and V/10 respectively, and if the similar transformation in section 3.2 is applied to (S, V), its tone representation (S, T) can be obtained. (Note that PCCS tone T_F of full color is not 5 but 5.5 because PCCS adopts V=5.5 as the lightness of medium gray.) Figure 6 illustrates the transformed PSSC tones, equi-value lines, and color triangle in S-T plane. The triangle is inversely transformed to the solid line in Figure 2, and transformed again to the solid line in Figure 1 using the fractional function in section 3.3.

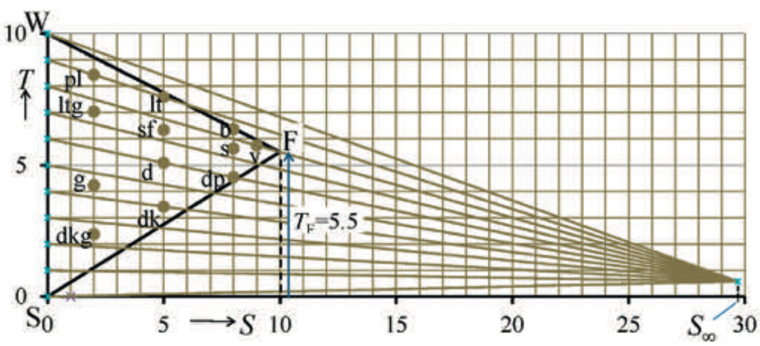

Figure 6. Color triangle and constant V line on PCCS S-T plane (h=8, H=5Y).

PCCS whiteness w' and blackness s' can be easily calculated from tone coordinate (S, T) using the similar relations defined in section 3.1.

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4. Discussion

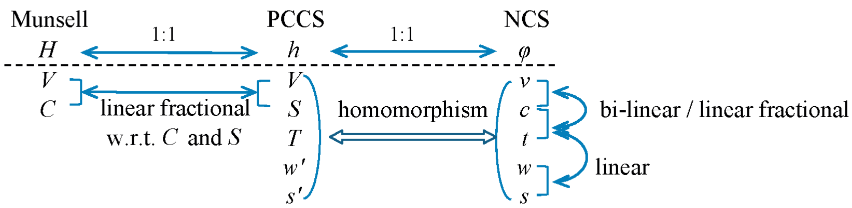
The actual value of c_∞ is less than S_∞ and the scale of v is slightly different from V. How should we consider these facts?

NCS full color is an optimal color, so that the chromaticness c_F of actual full color will be less than 100. As c_∞ is determined compared with c_F, the ideal coordinate of c_∞ may be larger than the existing coordinate. On the other side, PCCS saturation is based on the existing color samples, so that the coordinate of ideal full color will be larger than 10. Thus the ideal coordinate of S_∞ will be smaller than the existing coordinate. This suggests possibility of coincidence of NCS chromaticness and PCCS saturation.

Strictly speaking Munsell value does not represent perceptual lightness. It presents the lightness of color chips. In some visual condition, a color chip marked V=5.5 appears just medium lightness. If V represents perceptual lightness, V should be equal to 5. On the other hand NCS value v determines perceptual lightness, whose relation to stimulus value Y is given only in special visual condition. The difference of value scale would be caused by the difference of visual condition of the target in an image. Once the relation between stimulus color and perceptual color of visual target is determined, perceptual color attributes could be calculated.

5. Summary and conclusion

Simple and beautiful mathematical relations between color attributes of Munsell, PCCS, and NCS are obtained. The relations are summarized in the diagram below:



Moreover, a perceptual color system, NTS (Nayatani 2011) has been considered, which has the concept of tone. Details will be introduced in our next opportunity. Based on our result, design and implementation of a useful and applicable color system will be the next step of future research.

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Factors of a harmonious landscape based on the combination of an accent color and a base color in a building exterior in Japan

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Abstract

In this study, we have examined the factors influencing harmonious landscapes on the basis of combinations of accent and base colours in building exteriors. We pasted colour paper on a building exterior model and conducted simulation experiments based on superficial colours; ten participants evaluated the indicators in terms of prominence, harmony, vigour, and unification. We investigated the influences on townscape evaluations as a result of the colour compositions in building exteriors. The feeling of prominence tends to be strongly influenced by the location of the accent colour, while buildings with value 8 tend to harmonize easily with buildings other than those with value 5. Further, the hue of an accent colour tends to have significant influences on the harmony of townscapes.

1. Introduction

In recent years, in urban design, the range of accent colours in building exteriors has been determined by proportional division, whereas the urban colour design code considers the base and accent colours individually. In addition, many administrative organizations in Japan have not imposed restrictions on accent colours. On the other hand, Chromatictownscape (Cler, M., Cler, F. & Schindler, V.M., 2005) has been considered to be an interesting and extremely effective colour policy that leads to colour communications and cultural identities in urban planning and architecture. However, the primary purpose is not to control but produce colours, and an urban colour design code that uses Chromatictownscape can be regarded as unsuitable since the colour choice is controlled. Moreover, the accent colours in townscapes are so disordered that no urban colour design code can completely control the order of townscapes. Therefore, in order to improve the urban colour design code, an experimental study on the colour evaluations of townscapes (Inagaki, 1993) has been conducted previously by employing experimental architectures based on superficial colours. Since this paper treated superficial colours, the evaluations for colour by employing human data are accurate; however, this study did not focus on restrictions to accent colours.

In our study, we have aimed to collect and analyze fundamental data for building a suitable colour design code. We pasted colour paper on a model of a building exterior and conducted simulation-based experiments on superficial colours. Subsequently, we employed the simulations to investigate the influences of the colour composition in building exteriors on the evaluations of townscapes.

2. Experimental methods

The experimental setup is shown in Fig. 1. First, a building model (Fig. 2) (scale: 1/200) of the area around Kurashiki Station was constructed. The external colour of the building model was prepared by the Japan Colour Research Institute. The lighting conditions were approximately

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5600 luxes and 2500 luxes for the horizontal and vertical luminances, respectively, of the building exterior. Subsequently, the colour composition of the building exterior was simulated by using certain experimental patterns (Table 1); there were a total of 360 experimental patterns. Ten participants were chosen, and they evaluated the indicators in terms of prominence, harmony, vigour, and unification. The total time taken to conduct the experiment was approximately 3 h.

Table 1. Experimental patterns

	Hue	Value	Chroma	Patterns	
Base colour	5R , 5YR , 5GY , 5PB	8 , 5	1 , 3		18
	N	8 , 5	-		
Accent colour	5R/5/13 , 5YR/7/12 , 5GY/7/12 , 5PB/5/12				4
Ratio of base colour and accent colour	1: 10 , 1: 20 , 1: 50 , 1: 100 , 1: 1000				5

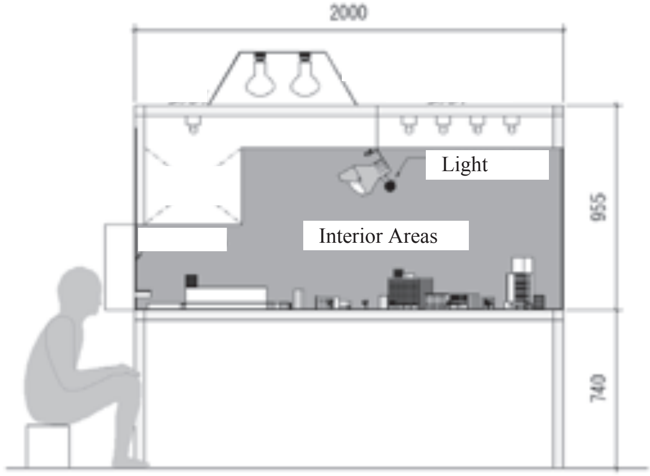

Figure 1. Experimental setup

Figure 2. Experimental area: interiors

3. Results and discussion

3.1 Analysis of variance test

From the results of analysis of variance (ANOVA) tests, the primary effects of prominence were confirmed in the ratio of base colour to accent colour ($F = 200.44$, $p < .000$), chroma of the base colour ($F = 158.69$, $p < .000$), accent colour ($F= 86.39$, $p < .000$), and hue of base colour ($F = 37.14$, $p < .000$). Subsequently, certain interactions were also confirmed. Therefore, although the primary effects cannot be considered to be independent key factors, the “ratio of base colour to accent colour” can be considered a strong impact factor because of the F value and significant probability.

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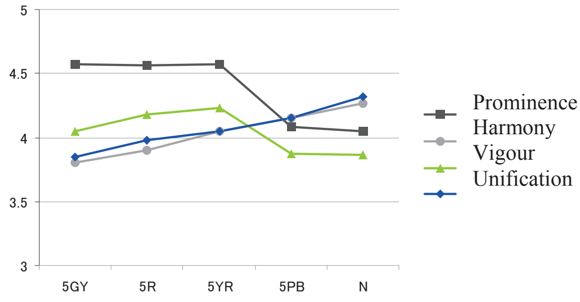

Figure 3. Evaluation for hue of base colour

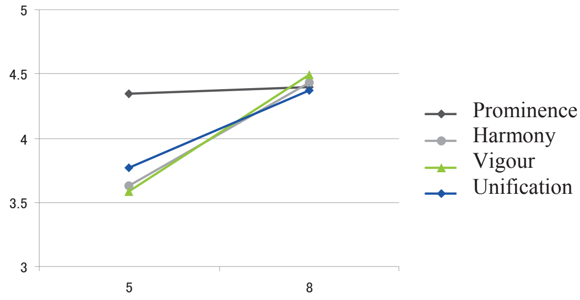

Figure 4. Evaluation for value of base colour

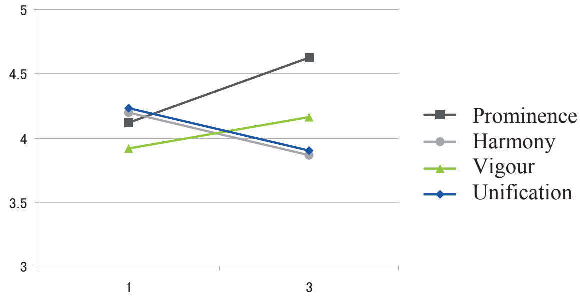

Figure 5. Evaluation for chroma of base colour

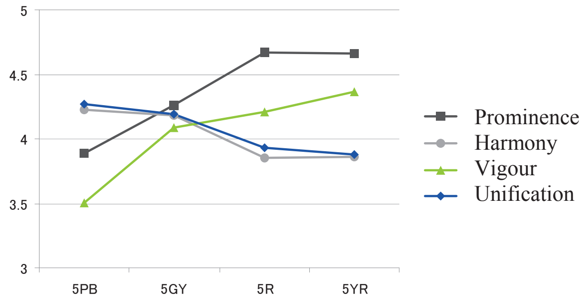

Figure 6. Evaluation for accent colour

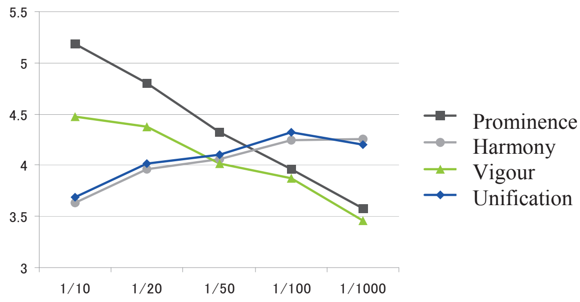

Figure 7. Evaluation for ratio of base colour to accent colour

The primary effects of harmony were confirmed in the value of the base colour (F= 337.38, p < .000), chroma of the base colour (F = 57.67, p < .000), ratio of the base colour to accent colour

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(F = 27.79, p < .000), the accent colour (F= 21.27, p < .000), and hue of the base colour (F = 14.55, p < .000). Similarly, interactions were confirmed in the hue and value of the base colour (F = 14.81, p < .000) and the hue and chroma of the base colour (F = 7.70, p < .000). The primary effects of vigour were confirmed in the value of the base colour (F = 587.12, p < .000), accent colour (F = 102.83, p < .000), ratio of the base colour to accent colour (F = 96.18, p < .000), chroma of the base colour (F = 46.16, p < .000), and the hue of the base colour (F = 16.72, p < .000). Subsequently, certain interactions were confirmed. The primary effects of unification were confirmed in the value of the base colour (F= 183.68, p < .000), chroma of the base colour (F= 55.53, p < .000), ratio of the base colour to accent colour (F = 23.16, p < .000), the accent colour (F = 18.51, p < .000), and the hue of the base colour (F = 12.839, p < .000). Interactions were confirmed in the hue of the base colour (F =17.723, p < .000) and the hue and chroma of the base colour (F = 5.58, p < .000).

3.2 Effects for different values

Figure 3 shows the evaluations for the hue of the base colour. Although 5PB and N exhibit unification and harmony effects, 5GY, 5R, and 5YR have the effect of inducing feelings of prominence, while the effects of inducing harmony and unification are similar. Figure 4 shows the evaluations for the base colour value. The feeling of prominence were similar in the case of values 5 and 8. Value 8 had a stronger effect on harmony, vigor, and unification than value 5, as demonnstrated. Figure 5 shows the evaluations for the chroma of the base colour. As chroma increased, prominence and vigor also increased, whereas, as chroma decreased, harmony and unification decreased. Figure 6 shows the evaluations for the accent colour. When the accent colors were 5PB, vigor decreased, whereas when the accent colors were 5R and 5YR, prominence was confirmed. In figure 7, evaluations for the ratio for base and accent colours are shown. When the accent color is 1/10, the building is not suitable in terms of harmony and unification but is apropriate in terms of prominence. Similarly, when the accent color is 1/50, the building is evaluated over a medium range by the four measures.

4. Conclusions

From our study, we can conclude that prominence feeling tends to be strongly influenced by the area of the accent colour, buildings with value 8 tend to harmonize easily with buildings other than those with value 5, and the hues of accent colours tend to significant influences on the harmony of townscapes. In our next study, we will improve the accuracy by increasing the number of samples. Further, urban colour design codes for accent colours will be investigated in greater detail.

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Research on integration of meteorological landscape and environmental colour changes – a case study of the Yangmingshan National Park, Taiwan

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Abstract

It is consisted of physical and virtual elements in the natural environment. The substance is the form of ecological culvert structure, as physical condition, including mountains, water, rocks, topography and soil, etc; As the biological condition, It is comprised by plants, animals and micro-organisms to build the ecological landscape. The virtual aspects include light, meteorological landscape, smells, colours and other factors.Those elements mentioned above interact with seasonal and daily factors to be shown ever-changing natural colours.

It is a geographical and ecological environment in Taiwan very complex and the environmental colour also varies according to different climate change, different time change and different scales. These differences cause to the landscape and environmental characteristics of Taiwan; Due to its latitude and elevation, it is both subtropical and warm temperate climate zones in the Yangmingshan National Park along with a very apparent monsoon season. The colour change by seasons has become tourist attraction. This study utilized the Colour Geography Theory of French scientist Jean-Philippe Lenclos to explore the colour composition of natural and human geographical conditions in the Yangmingshan National Park, and used survey methods of colour measurement recording, sampling, induction, spectrum compilation and summarization.The daily changes of natural light and shadow for seasonal landscape allow regional characteristics and colours to be recognized and used to illustrate the beauty of the Yangmingshan National Park as well as its environmental colour image.

1. Introduction

Among eight national parks in Taiwan, the most accessibility of the Yangmingshan National Park, located in the northern Taiwan, is due to close to the Taipei metropolitan area. With an area of about 11,455 hectares and an altitude between 200 and 1,120 meters (Figure 1), the park has a unique volcanic terrain, diverse fauna and flora resources and a wealth of historical monuments for its long history of development. Constant variations in micro-climate create an ever-changing meteorological landscape, with spring rains, summer rainbows, autumn sky and winter snows; Moreover, spring cherry blossoms and autumn miscanthus contribute additional colours to the land. With all these different seasonal sceneries, Yangmingshan National Park attracts more than 12 million tourists each year (Figure 2).

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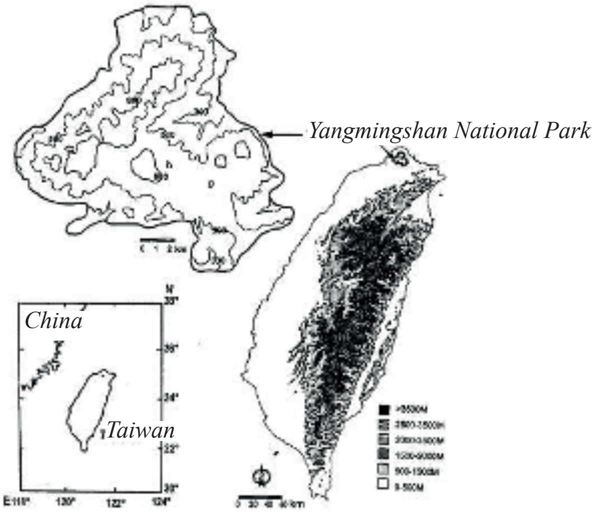

Figure 1. Location map of the Yangmingshan National Park ,Taiwan.

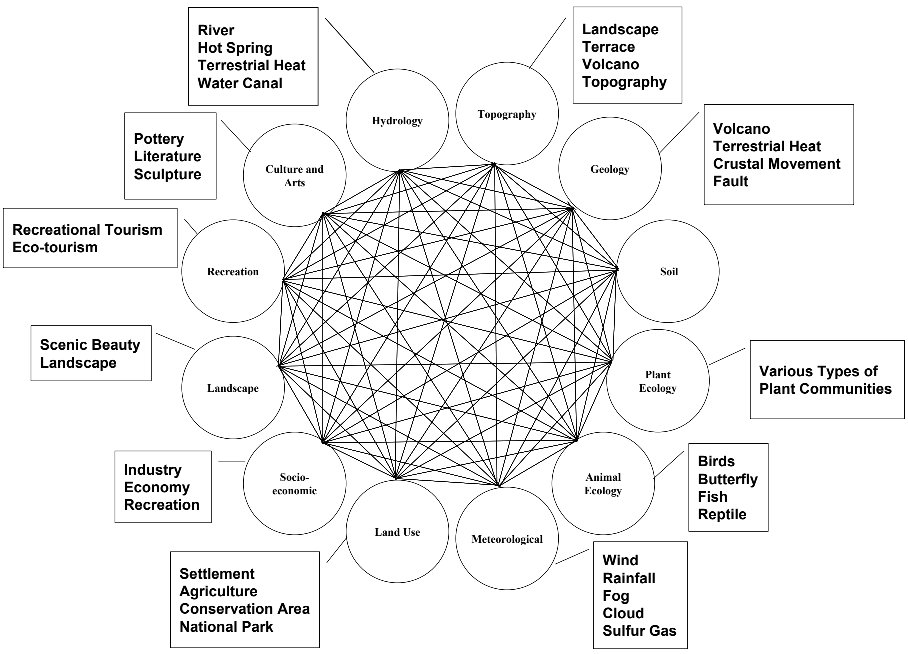

Figure 2. The interaction of environmental resources of the Yangmingshan National Park ,Taiwan.

2. Research methods

"The Colour of Geography" is a colour theory proposed by a 1960's renowned French colourist, Jean-Philippe Lenclos, wherein it is broadly used in urban planning, architecture and environmental/ landscape design practices.The theory suggests protection of local culture by colour surveying, spectrum arrangement, and induction of regional colour expressions. The purpose of the theory is to affirm the "characteristics of landscape colour" and to interpret the colour psychology of the residents in a region.Therefore, our research uses survey, colour determination, recording, sampling, induction,spectrum arrangement and conclusions as methodology to discuss the localization of colour characteristics affected by physical geography and human geography in Yangmingshan National Park (Figure 3).

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Figure 3. The use of environmental color survey method, Yangmingshan National Park to establish the color system of the database environment.

The environmental colour survey of our research is divided into two phases:

- *Phase 1 –Environmental Color Survey and Analysis*: Including all factors that affect the quality of landscape color in our range of investigation and understand the landscape resources as well as the color data in the surrounded environment through a series of methods.The methods of color data surveying are material gathering, color reproduction, material brightness listing, on-site colored drafting, photographing, etc.
- *Phase 2 – Comprehensive Synthesis of Colour Visual Effects*: To analyse, induce and conclude the colour data gathered and reproduce the colour models true to the original colour materials. That is very complex to properly simple the colour composition and finally presents the major colour tones, decoration colours, surrounding colours and the quantitative relationship between each colours through chromatography.

3. Research results

This research tries to find the typical colour composition of the Yangmingshan National Park in order to describe the intimate relationship between environmental colour and localized physical geography and human geography (Table 1). The result of this research is to present the localized chromatography (Figure 4) made by collecting, extracting and inducing local materials. It also encourages visitors to participate in tracing and mapping nature colour and field experience in the Yangmingshan National Park. Through the guidance of nature, it helps make visitors experience for local environmental colours, generate the meaning of colour and the emotion experience in an environment, and accumulate the knowledge of the correct cognitive judgement and projections. The outcome of knowledge accumulation contributes to the understanding of seasonal colour of the elements in a big region and the establishment of scientific data base.

For example, the camellia takes the colour of spring in the Yangmingshan National Park shown different colours; white and off-white, pink to purplish red, from budding to blossom. The magenta of Mountain Cherry compares to Japanese Flowering Cherry's bright tones such as bright red or crimson. Varies native rhododendrons have vivid tones such as white, pink and orange-red; and the soft green of green maple's new leaves usually becomes the focal point of Yangmingshan National Park's spring, which especially stands out from the dark green background of Bird-limetree forest (Figure 5).

The research also describes how geography, landforms and micro-climate interact with light, shadow and colour in time series, which shapes the unique environmental aesthetics in the national park. Through understanding the colour transition in time series, we can increase the depth of the national park's visits, and also manage the need of visitor classification.

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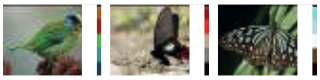
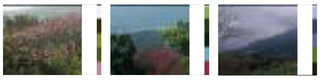
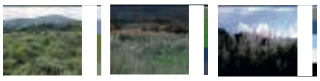
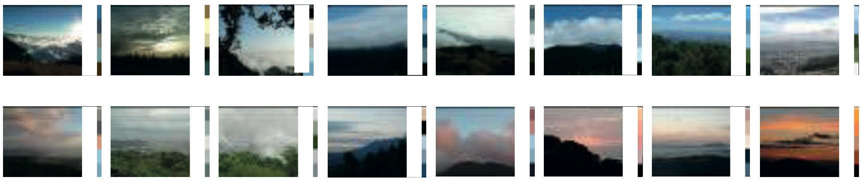
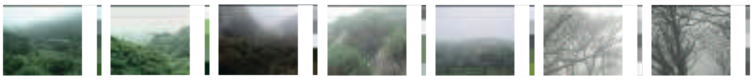
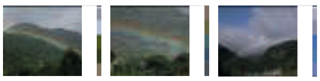
Table 1. Evironmental color survey of the Yangmingshan National Park ,Taiwan.

Spatial Scale	Landscape Resources	Characteristics of Landscape Colours
Macro View	Mountain	
	Water	
	Terrace	
	Sttlement	
Micro View	Plant	
	Animal	
Spatial Scale	**Landscape Resources**	**Characteristics of Landscape Colours**
Seasonal Landscape	Spring	
	Summer	
	Fall	
	Winter	
Meteorological Landscape	Cloud	
	Fog	
	Rainbow	
	Sunset	

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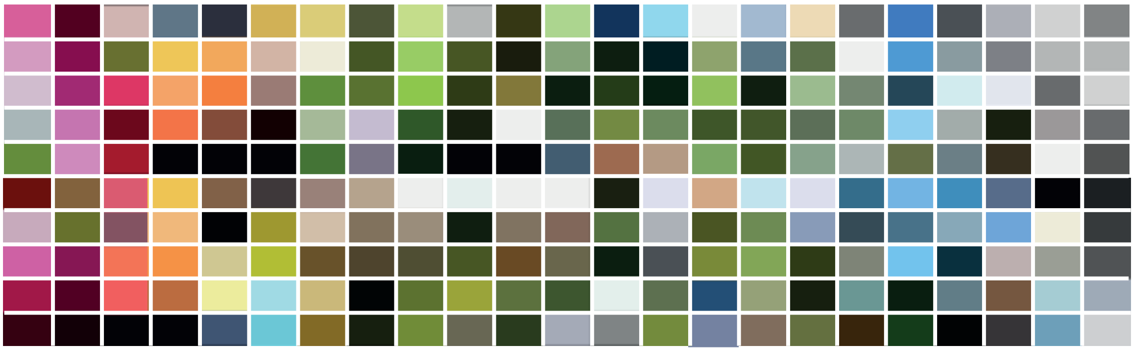

Figure 4. Evironmental chromatography of the Yangmingshan National Park ,Taiwan.

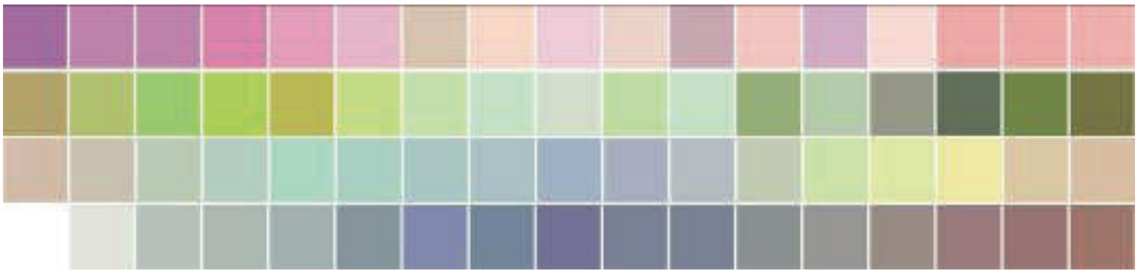

Figure 5.The colors of spring in Yangmingshan National Park ,Taiwan.

4. Discussions and recommendations

It is the unique landforms and the great influence of climate changes which result in varies climate landscape in the Yangmingshan National Park. The seasonal expression locally are more distinct than typical sub-tropical area. The northeast monsoon that interacts with the landforms creates fogs and rainbows, which makes abundant changes of atmosphere in same day. This is the unique aesthetic value owned by the Park, and also the reason why nature experience becomes the major recreation activity in this area. Our research induces the colour changes in different light and time series through surveying and analysing the environmental colours in order to understand the characteristics of local landscape colours. It also suggests the time frame and scenic sites for scenery appreciation arrangement (Figure 6) for future visitors, which increases the charm and value of the tour through visual experiences, and also promotes the intellectuality and sense of beauty of visitors.

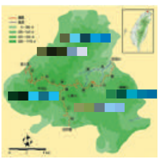

Figure 6. Environmental color map of the Yangmingshan National Park ,Taiwan.

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Robustness of perceived glossiness scale using magnitude estimation method

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Abstract

New sets of glossiness data are obtained using magnitude estimation technique for the polycarbonate (PC) surfaces with the different levels of UV clear coating. By presenting the different number of samples at a time, it is found that the observers can judge a glossiness of a sample without a reference resulting in the similar results with judging glossiness comparing with other samples. It suggests that the glossiness is an intrinsic and absolute visual attribute people use to judge the surface appearance. Also it is confirmed that black samples look glossier than white samples with the same physical gloss value.

1. Introduction

Nowadays, importance of the visual appearance quantification of a surface is growing. However, except color, other attributes such as gloss or texture are relatively less understood. In this study, the effect of the number of test sample shown to the observer at a time is investigated. It was assumed that if the perceived glossiness is an absolute quantity the estimated numbers won't be affected by the neighboring test samples. However, if people tend to judge the glossiness relative to other surfaces, estimating the gloss of an isolated test sample will be more confusing than comparing several samples resulting in the larger variations.

2. Experiments

Eleven black and eleven white samples, which were polycarbonate (PC) surfaces with the different levels of UV clear coating, were prepared. The size of the sample is 4.7cm x 9.8cm. The gloss values measured with BYK micro-gloss glossmeter varied from 3.88GU (@60 degree) to 93.89GU (@60 degree). The average CIELAB L* values for specular component include (SPI) mode using D65, 2-d observer are 94.3 and 26.6 for white and black respectively.

Since the samples used in this study do not contain any effect pigments, the measured gloss will be lower than 100. Therefore, it is decided to confine the glossiness scale to the same range, 0 to 100. Judging the glossiness between 0 and 100 resembles the lightness judgment for color appearance study. Thus it is decided to use the magnitude estimation technique similar with lightness judgment for LUTCHI color appearance data sets collected by Luo et al. (1991).

The samples were displayed inside the viewing booth Judge II illuminated with D65 simulator. The illuminance level was 1163 lux and the correlated color temperature was 6523K at the center of the booth. During the experiment, the observers were asked to assign a number between 0 and 100 corresponding to the perceived glossiness of the sample. The definition of the gloss was not given. The observers were allowed to take hold of the samples for thorough examination and there was no restriction for body and eye movements.

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The test samples were shown to the observers using three different methods. At first, one test sample was shown at a time. Secondly, randomly chosen three samples with the same color (white or black) were shown together. Finally, randomly chosen two black and two white samples were displayed together.

All the experiments were repeated twice. Twelve observers were participated. All the observers were the second year undergraduate students and passed the color blind test using pseudo-chromatic plates and Farnsworth Munsell 100 Hue Test.

3. Data analysis

Applying minimum and maximum values to judge the glossiness makes the observers use a partition technique rather than pure magnitude estimation. Therefore the arithmetic mean values of estimated glossiness were calculated and the standard deviation was also calculated to represent the scattering of the data. According to Stevens (1971), the proper averaging method for magnitude estimation is the geometric mean but the arithmetic mean is adequate for a partition experiment.

Among twelve observers' responses, one of them was excluded because of the extremely low repeatability and oddly different responses from others. After excluding odd responses, all the observers' responses were averaged.

4. Experimental results

Figure 1 summarizes the experimental result. In the case of black samples, it is notable that the number of samples shown at once does not affect the result significantly. The average data and the lengths of the error bars (i.e. standard deviations) are similar to each other. For white samples, as the number of samples shown together increases, the perceived glossiness is slightly increased as well for mid-gloss samples though the size of the standard deviations were similar to each other. However, ANOVA analysis results using MINITAB16 indicate that the difference is not statistically significant.

Such an experimental result that judging the glossiness of one sample at a time has very similar results with other experiments with more samples at a time could be a piece of evidence that the glossiness is an intrinsic and absolute visual attribute we use to judge the surface appearance.

Both glossiness graphs for white and black show the similar trend that the perceived glossiness changes rapidly compare to the measured gloss value for low and high gloss samples while have slower change for mid gloss samples when compared with the measured gloss under 60-degree geometry. This trend is the same with the results of G. Obein et al. (2004) and W. Ji et al.'s studies (2006).

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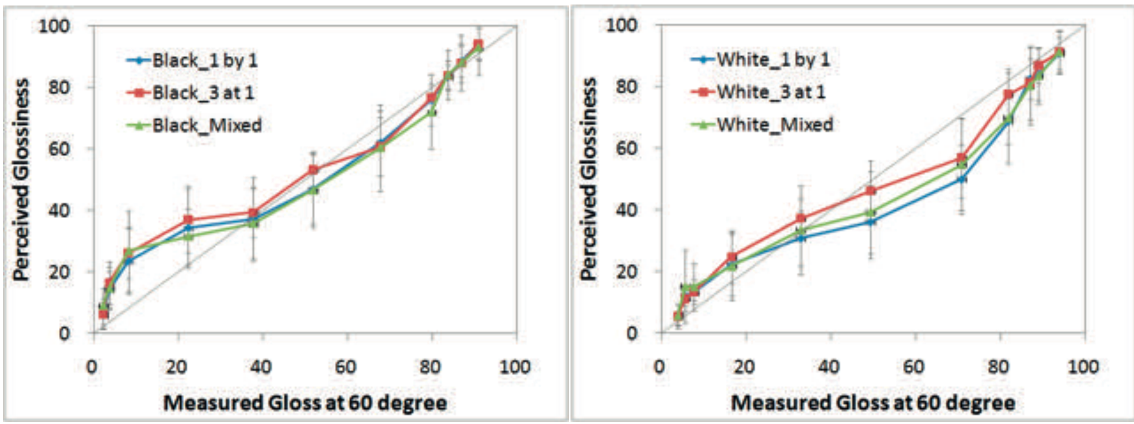

Figure1. Perceived Glossiness vs. Measured Gloss

Since there is little difference between the experimental phases, all the data are averaged and plotted in Figure 2. On the average, the black samples look slightly glossier than the white sample with the same physical gloss as depicted in Figure 2.

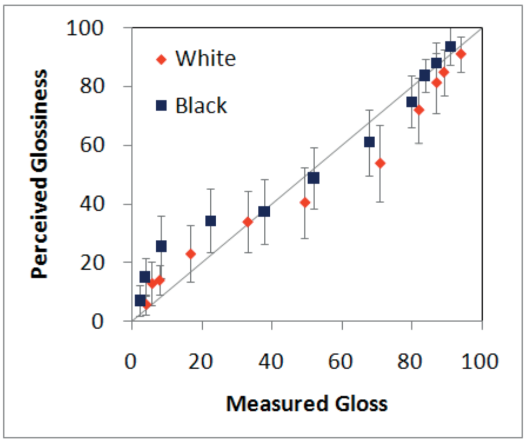

Figure2. Perceived average glossiness difference between black and white

5. Conclusion

The results show that the method presenting the glossy samples does not affect the perceived gloss or the degree of agreement between the observers (i.e. standard deviation) significantly. It could mean that the gloss is an absolute characteristic of a surface not judged relative to other surfaces. Also it is found that the black sample's gloss is easier to judge than that of the white. The experimental results for black were more consistent regardless the experimental method compared to white samples. Finally, it is shown that black samples look glossier than white samples at all gloss levels.

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Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology (2009-0090162).

Also, the authors thank all the experimenters, who were the graduate and intern students of color lab at UNIST for conducting the psychophysical experiments for this research.

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Creating a new world of colour and light by 21st century industrial designers

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Abstract

"Color can bring richness, beauty and ambiguity to design, if it is used well," said Hella Jongerius, a famous Dutch product designer. Colour planning in product design is a process which is crucial for a commercial success. Thanks to the development of new technologies an interaction of colour and light becomes more and more important in product design. New generation paints and light sources enable the changes of surface colours which do not have to be constant any more. LEDs which provide chromatic light with a very high saturation are universally used in devices which are not intended for lighting only. They can have communicative, informational, esthetic, marketing or ergonomic functions.

Colour application in product design

Colour planning can be an important element of a brand strategy, allowing certain products to stand out on the market. Colour decision are also strongly influenced by short or long-term trends, colour forecasting, advertising and visual culture. Through a colour's consistent use by a brand it becomes a part of brand's identity to such extent that when consumer sees the colour, they immediately associate it with the brand. Colour helps to attract a certain group of consumers to a given product and differentiate it in its competitive set. It becomes an important visual discriminator that assumes different levels of importance dependent upon the amount of differentiation being achieved by other elements of the design (Ries 1998). Despite colour draws attention to a product and gives it an extra value the number of available colour choices have been always restricted by the economic issues. In order to find the right colours marketing departments rely on colour forecasting or use typical brand colours. Colour relationships, contrasts and proportions are aspects that need to be considered and they have correspond to the product's structure. The correct colour scheme contributes to order and differentiation. Colour coding helps users to act precisely and quickly, if necessary. Chromatic light can draw attention to the most important elements of an object and may well be the fastest way to convey a simple message. And if colour design is to focus on the needs of the user, a through understanding of the audience's colour perception is also necessary. One must take into consideration a colour-vision deficiency and the aging problems. Not all the aspects of colour in product are clear-cut – it is so strongly connected with the other formal features of on object.

New functions of colour in contemporary design

Although colour was always a crucial element of product image, the number of possible colour choices have always been closely associated with technological capabilities. The history of design shows that natural materials were always the main factor which determined the colours of product categories (furniture, textile, pottery). In line with new materials and synthetic dyes range of possible colours to use expanded significantly. In the second half of the twentieth century in

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connection with the development of plastics technology most of the colours available for human perception has also become possible to apply in design. This enormous amount of possibilities combined with the globalization of the economy and the development of consumer society was the cause of a development of the forecasting industry, international organizations and agencies of colour. Trend forecasting has become a major factor influencing the colours of products - which means that customers have at their disposal in many areas only the scope of the so-called "fashionable" colours, which in many cases do not necessarily coincide with the area of their personal colour preferences. At the same time the development of electronic media means that in many cases, the user can adjust colour of the interface to their specific needs and preferences, in a completely unfettered way or through a use of the available templates. The need for colour customization is also transferred to other classes of consumer products such as: cell phones, MP3 players, netbooks or laptops that get so-called „skins" – adhesive vinyl or gel covers in countless colours and patterns. The development of LED technology also allowed to freely change the colour of light through the RGB controllers. The new generation termochromic, photochromic and electrochromic materials allow you to change colour of a product – what in the past was not possible. Thanks to all these inventions designers can create objects in which colour and light are treated in an unconventional manner.

– Colour customizing – change in colour of an object is performed by a user depending on their colour preference, colour vision, mood or special needs.
– Colour relaxation (chromotherapy) – colour light emitting devices enabling the users to create their own colour scenarios - mono or polychromatic.
– Colour communication – clothing or personal belongings that change colours depending on the physical, mental or emotional state of a user. Colour changes are, as in the world of nature, a mode of transmission of certain information - through an interaction with the observer.
– Colour display – different types of objects become a screen on which various messages are displayed.
– Colour mimicry – object is equipped with receivers for the assimilation of its colour to the environment
– Chameleon objects – objects which colours change depending on external factors such as temperature, light or magnetic field. Variable colour may serve as a source of information or provide the recipient of aesthetic experience.

Examples

1. Gugliemi Water Therapy is a shower head that incorporates 480 individual LED lights and offers 9 mono-chromatic programmes (white: revitalizing, cyan: calming, violet: soothing, blue: purifying, green: relaxing, yellow: stimulating, orange: relieving stress, red: exciting, magenta : energizing) and 2 multi-colour programmes (energizing program: yellow-orange-red-magenta-red-orange-yellow and relaxing program: cyan-blue-green-white-cyan-blue-green-white). The massive rain-effect shower is connected with a relaxing results of chromatic light.
2. Philips Design, a private research organization based in the Netherlands has developed a series of interactive garments as a part of the project known as SKIN (Quinn 2010). The garments can be used to express the emotions of those who wear them – by the changes of light, colour and form. Bubelle, launched in 2007, is a dress constructed from delicate bubble-like textile that illuminate. The bubbles arrange themselves in response to the wearer's

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emotional and physical state and begin to glow individually at the intensity related to the physical contact they sense. The individual glowing areas create abstract pattern that morph into new configurations each time they detect movement or change in surface temperature.

3. French furniture designer Philippe Boulet has integrated a programmable LED lighting system into ornate shaped bed. It enables the continuous changes of colours which can be stopped or programmed by user.
4. Napshell. Capsule intended for short naps in the workplace. RGB lighting can be programmed for a limited time, so as to allow a user to wake up at a certain time.
5. Moritz Waldemeyer is a British/German designer and engineer. He has collaborated with many of the world's top architects and fashion designers including Ron Arad, Zaha Hadid and Hussein Chalayan. His work is a fusion of technology, art, fashion and design. His famous series of chairs respond to the sitter's clothing, changing the atmosphere and space around it. A sensor in the back of the chair reads the colour of the clothing and projects it on to the surface behind using LED lighting. In 2007 Moritz Waldemeyer was commissioned to design performance costumes for the rock band OK Go. When the band appears on stage, LED lights embedded in their jackets run through a sequence that makes up the letters O,K,G,O (McQuaid 2005)
6. Hussain Chalayan and Moritz Waldemeyer worked together in Airborne project, which resulted in a collection of video-dresses capable of projecting moving images. The front of the dress was embellished with 15 600 LEDs and Swarovski crystals, forming screen-like surfaces. The textile's surface acted like hyperscreen, able to construct innumerable colour combinations and communicate through texts and imagery. The effect is mesmerizing in its ambiguity: the loose white fabric covering the LEDS blurs and distorts the images so that they seem to pulsate.
7. Mediamesh is a patented system used for the medialization of large facade surfaces and for displaying videos, graphics, text animations, and changing colour effects. Mediamesh is desingned to provide 60% to 90% transparency and the video display can only be seen from outside of the building, so it doesn't block windows or distract the residence of the building. It is designed for visual information and advertising and works both during day and night time. The Mediamesh display can be operated via the Internet - in a color depth of 36 bit (Addington 2005)
8. Illumesh is designed for large-scale, night-time illumination of façades. It is a metal textile interwoven with LEDs that enable it to be illuminated in a wide spectrum of colours. It is designed to transform a facade in to a lively constantly changing skin. After installation on the building, this system supplies power and data to individual groups of 16 LED profiles. The corresponding control units are installed in the ceilings of the building and are connected to a central server.
9. Karim Rashid is one of the most famous modern designers and he pays a special attention to the colour choices in his work. His collection of household appliances, designed for Gorenje company consists of different kinds of ceramic and glass cooking hobs, a built-in oven and a cooker hood all in white with unique graphics is a minimalist fusion of functionality, technology, interactivity, and purity. Using the MoodLite technology, developed by Gorenje, the vertical LED light stripe allows several colour versions, providing the option to adjust the appearance of the appliance to one's current mood or the other kitchen appliances.
10. Zaha Hadid and Patrik Schumacher VorteXX chandelier was designed in 2005 for Italian lighting brand Sawaya & Moroni and represents an "infinite ribbon of light". The chandelier

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is made from fibreglass and acrylic, finished in car paint with a recessed LED light source which enables a precise colour mixing in RGB mode that can be controlled and programmed by a separate touch-panel user interface.

11. Lolita – a chandelier designed in 2004 by Ron Arad for Swarovski Crystal Palace exploits the omni-directional spiral that may traditionally be associated with the chandelier, and crosses it with technology and lighting in a sophisticated and entertaining way. Lolita is effectively a giant pixel board with 2100 crystals, set with 1500 white LEDs, 1 km of 9-way cable braided shielding and 31 processors, enabling an interactive experience in which people can text their messages via SMS to Lolita and she displays their messages in lights, round and round her spiral form.
12. Gaetano Pesce Mediterraneo chandelier (2006) has 140 strands, each made up of 87 LED-illuminated Swarovski crystals that change in colour and radiance, and it can be remotely instructed to ebb, flow, glow, bulge and balloon. In addition, Mediterraneo emits certain soothing smells and also changes shape before the viewers eyes.
13. Tokujin Yoshioka Star Dust is a futuristic light fitting that combines the luminosity of Swarovski crystals with state of the art technology. It is made up of around 5,000 light sources that send images to the extremities of over 18,000 crystals acting as a kind of television screen. The technical apparatus of the chandelier includes a projector and DVD player.
14. Selected examples of students' works from a Department of Industrial Design of the Academy of Fine Arts in Cracow. The works were performed under the supervision of prof. Piotr Bożyk, prof. Barbara Suszczyńska-Rąpalska and dr Agata Kwiatkowska-Lubańska.

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A prototype of goniophotoscope and its use

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Abstract

The name Goniophotoscope® summarises the core features of the gantry, which primarily was aimed to display the visual directional properties of patterned fabrics (up to 90 cm wide), but may be used for any kind of raw or elaborated material of large dimension, with front and/or back lighting. Beside direct examination, often useful in preliminary phases or for non-scientists or end users, any photo or video-camera may be used, for distant or close pictures (even with a video-microscope), as well as spectrophotometers, thus becoming θ φ 360° gonio-spectrophotometers. While occasional BRDF and BTDF measurements are possible, other devices are better when small samples may be used and there is no pattern or combined materials worth notice, thus making a global measurement efficient. The gantry has a 1.15 m diameter table with triaxial 360° rotation (3D hyperspherical coordinate system), two articulated arms both for 360° oriented and ± 170° incident lights. It may be used with sun as a light source for its spectral or angular diameter properties in direct, indirect or through illumination. Cooperation is asked for improving the specifications and use of a computer-controlled version of this new multipurpose device.

Figures 1-2. Goniophotoscope, the prototype with manual motions, March 2003 (initial project: 2000).

1. Short technical analysis of some available devices

Many systems for BRDF/BTDF measurement are known in computer vision and graphics fields. ELDIM's EZContrast XL88MS (ELDIM) is a multispectral Fourier optics viewing angle system, with a maximum Ø2 mm measuring area, angular accuracy 0.15°, θ ±88°, φ 360°. Other desktop devices, like STIL SA's Reflet, use motorized arms as does the Goniophotoscope. Reflet, has two arms, one for illumination (θ only: 0° to 180°), one for the spectrometer (θ ±90°, φ ±90°), 0.1° angular accuracy. The aim is BRDF/BTDF measurements only, and although the size of the measurement area on the sample is selectable, Ø0.5 mm, Ø1 mm or Ø1.9 mm, these areas are often much too large at the fibers or even at the threads scale (silk satins: up to 15 threads/mm, while jacquard looms have one hook for one thread), and too small at the weave scale even for a

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global characterization (weaves with various metallic threads or compound weaves like twills have a much larger repetition), thus making BRDF characterization inaccurate and anyway inadequate alone for patterned materials. The size of the object platform is also inadequate: we can't cut ancient fabrics, which very often are worth notice, while the Ø115 cm table of the Goniophotoscope is convenient for fabrics in museums collections and sample books.

Much more relevant is the room-sized Stanford Spherical Gantry, a multipurpose 4-DOFs (degrees of freedom) motorized gantry, built for capturing light fields and BRDFs of small stationary objects (Cyberware 1999, Marc Levoy 2002-2010). The geometry was conceived by Marc Levoy and Brian Curless. It is made of a φ 360° object platform with a clear working volume which is 40 cm in diameter, and two arms, the inner with 2 DOFs for sensing device, the outer with 1 DOF for illumination. The RIT Goniometer improved the platform, with 3D translation and 2 DOFs rotation (Lightforce Technology 2007). It has a stationary stand for the sensor, and a 2 DOFs arm for illumination, which is better for studying aspect variation when the light source is mobile, as is the sun for architecture.

2. Goniophotoscope specifications for the computer-controlled version

The computer-controlled version of the Goniophotoscope will have the dimensions and geometry of the prototype with manual motions (Figures 1-2), with 9 main DOFs. It has two arms, each one with 3 DOFs, φ 360° and θ ± 170° rotations for positioning the light source to be used, a third one for its orientation when necessary (polarised light, etc.); payload: 5 kg; accuracy: 0.4°. The triaxial 360° rotation of the Ø115 cm table (accuracy at the center of rotation within 0.1 mm) provides the positioning of the target material in its physical position when in use, which is a core feature both for intuitive use, as often in the arts, and for mechanical reasons when the sample is not rigid; payload: 20 kg. Like in the tribrach of a theodolite, three thumbscrews provide an accurate 3D selection of the relevant plane for the rotation of the sample and compensation of its thickness (± 10 cm). The table has a 60 × 60 cm window with removable glass. Any scale sample may be used, from 6 x 9 mm or less to 60 × 60 cm (glass window) or 75 × 75 cm (square sample) or 60 × 90 cm (rectangular 2/3 sample). Large samples are necessary to take into account the resulting effects in real life. Four rows of holes allow any fixing and positioning devices and any depth samples combination. Two light sources can be used, for front and back lighting, as for curtains, or other combined lighting directions or light sources with different spectrum.

The gantry is intended for direct visual examination, or any camera or video-camera, or spectrophotometer. These devices may be independent on the gantry. When so, use a special device or a ball bearing studio stand like the Cambo UBS with 3.64 m column for a wide range of repeatable incidence, and linear guide rails for its radial translation when a small angle of observation is required for wide samples as when seen at a distance. They also may be mounted on any of the two arms instead of a light source, or, for close or wide angle pictures, on a removable arch (Figures 1-2) with translation for eccentricity and variable distance (max. 50 cm) and incidence, -10° to + 170°; accuracy: 0.1°, 5 kg payload (optional lighting source with semi-transparent mirror for close retro-reflection).

Through an open window or outside, the sun could also be a light source, for spectral and geometrical reasons: when studying shadows or specular reflection, we must take into account the angular diameter of the sun, and the arms may be used for positioning additional shadowing elements and/or various screens, in complex configurations.

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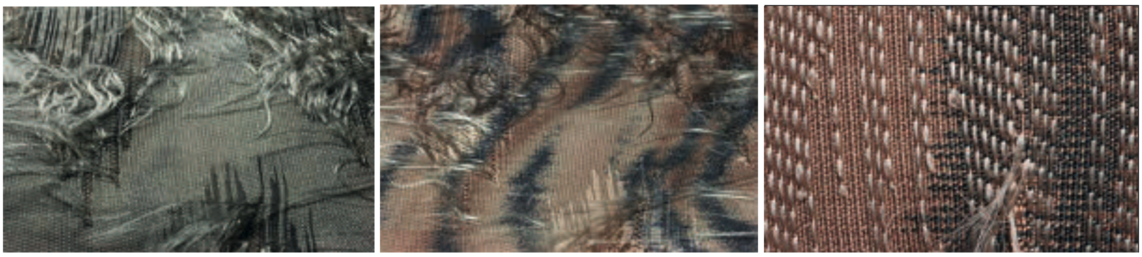
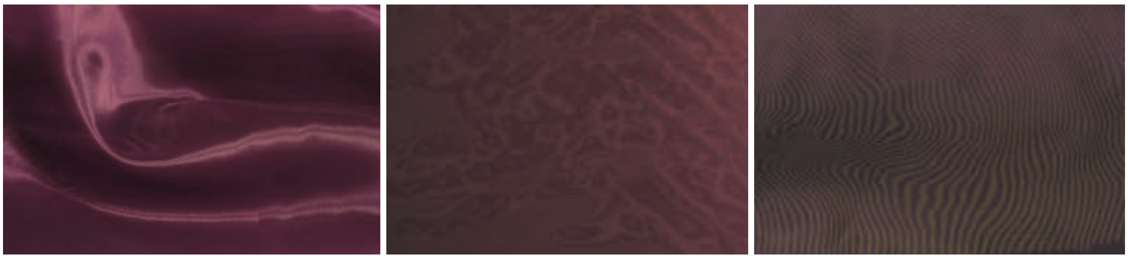
3. Use of a goniophotoscope rather than only gonio-spectrophotometer

The gantry is suitable for any kind of visual properties contributing to the appearance of the pattern, its colours and attributes, among which: apparent geometry; relief or texture, light/shadow, visible/hidden; brilliant/dull, highlighted/invisible; opaque/transparent/ translucent/see-through; background visible/hidden/revealed by its shadow or reflection; shadowing or lighting the background with its properties (Leclercq 2001a-b).



Figures 3-5. A patterned weft printed tabby with cut supplementary shining weft, Bucol, France, 2002. Seen in weft direction: lighting opposite to the viewing point (left, printed warp pattern hidden by reflection on the weft floats towards the camera), in the same direction (middle, printed warp pattern revealed by reflection on the weft floats to the opposite of the camera); right: detail, 14 x 21 mm.



Figures 6-8. Organza, a soft loose plain tabby fabric. Three casual moiré patterns, none being technically moiré or watered: the fabric in relief (left, specular reflection), the fabric on a white paper ground (middle, open network, quite flat only), the fabric folded up (right, extremely mobile networks inteference).

The Goniophotoscope is convenient from the scientist or from the designer to the end user. It provides analysis of directional visual properties of existing materials through direct visual examination, as well as through videos or photographs and use of spectrophotometers or other scientific devices, thus matching the requirements of designers as well as of scientists, for accurate use or reverse engineering. It provides images for visual modelling and control of the modelling. It allows conception of new materials through combination of samples; control of the properties of new materials which must match requirements; photographs and videos for scientific and commercial presentations; presentation to the end user of the visual effects of materials in his own architectural environment, taking into account the orientation of natural light due to the building and the latitude, the season, the hour, the viewing points, the view angle, the direction of the artificial lights, and the spectra of natural and artificial light sources with evaluation of metamerism properties. The aim is contributing to start a more accurate design and to facilitate the diversification of architectural design depending on climate, latitude, and cultural trends. Hence a lot of specifications to be stated or improved in cooperation.

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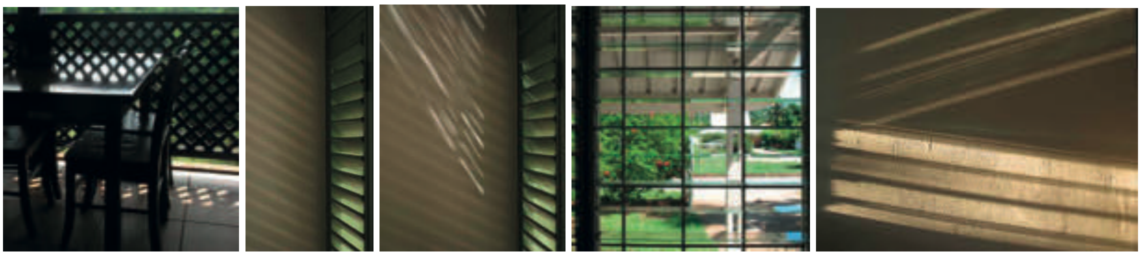
Figures 9-10. Two sheets of the same expanded metal mesh, with slight angular variation. Light to the front side (9): the upper grid only is visible. Light to the back side (10): moiré effect, with a brilliancy of leaded glass due to multiple reflections and thickness resulting from the superposed grids. – Figures11-13. Brushed stainless steel design, Raphael Seretti, 2003-2004, door of Saint-Antoine church, Cayenne, French Guyana. The contrast results from the brushing direction, oblique on the background, parallel to the direction of the square tubes on the cross. The effect varies with the viewing point (11-12), the view angle (13) and the direction of the sun, which depends on the orientation of the wall, the latitude, the season and the hour.



French Guyana. Figure 14. Ground: shadow of the grating, depending on the position of the sun. Table: mobile specular reflection depending on the viewing point. – Figures 15-16. Fixed blinds, sunlight to a tiled floor outside: dry/after a shower. – Figures 17-18. Glass blinds. 17. Up, reflection of grass; down, reflection of the sky. 18. Direct sunlight and reflected sunlight, with green stripes where reflected through the glass.

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The effect of color contrast between text and background on human comfort – psychological and physiological investigations

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Abstract

In this study, we focused on the affective effect of color contrast between text and the background when humans read the text on a LED display. We recorded subjects' brainwaves while they were reading a given text for one minute and asked them about the cognitive as well as emotional quality of the text stimuli. The results showed that the subject felt most comfortable when they were reading the text in dark gray (60% grayscale) against a white background. The subjects later read the text in chromatic colors and gave poor ratings to the text-background combinations of complementary colors. However, the subjects' physiological reaction, as measured by their brainwaves, did not vary across the chromatic text stimuli ($p>0.05$).

1. Background and goal of research

People nowadays receive text information more through screen-based displays rather than via paper. As setting various text and background color combinations is easy on a screen-based display, the choice of a more suitable color combination psychologically and physiologically is necessary. Song (2009) and other researchers typically focused on comparisons with traditional media such as paper. Moreover, Jung (2006) and others have used subjective surveys to measure human emotional responses. In this study, we focused on the affective effect including both psychological and physiological response of color contrast between text and the background when humans read the text on a LED-based display.

2. Plan for the experiment

2.1 Environment settings

The text and background color contrast was presented on an all-in-one LED display computer, a Samsung DM-U200, to the subjects. The distance between the screen and the subject was maintained uniformly for all subjects.

Figure 1. Experiment environment and subject wearing the EEG head set

2.2 Measuring the emotional response

In order to measure the comfortable state of the subjects, their brainwaves were recorded using a 14-channel EEG headset (Emotiv EPOC, research edition). The fourteen receptors were placed based on international 10-20 location system. From the collected EEG data, the ratio of the alpha frequency (7.5~13Hz) to entire range (0.5~50Hz) was calculated as the alpha ratio was used as the comfort level. The Telescan program (Laxha Co.) was used to extract

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these ratio values. The psychological emotional response was measured by questionnaires on a five-point scale (-2~2) regarding the readability (good to read) and preference for each stimulus.

3. Experiment 1

The purpose of experiment 1 was to investigate the emotional response, especially the level of comfort, by collecting and analyzing EEG information and subjective survey data pertaining to various brightness differences between the text and the background. After an orientation session regarding the experiment, the subjects read presented text for one minute and then completed two questionnaires about the stimuli for 15 seconds. These two steps were repeated 20 times. There were twelve subjects, consisted of seven male students and five female students. They were not color-blind and their eyesight level exceeded 0.7. Their native language was Korean. Their average age was 26.08 (*SD*=3.45).

3.1 Stimuli

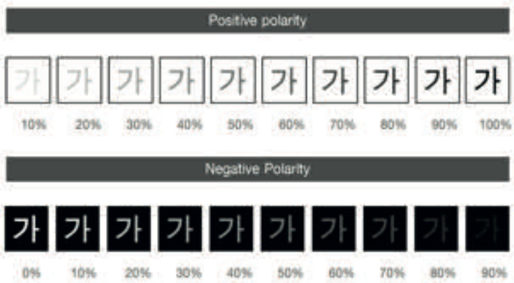

Figure 2. The 20 stimuli for experiment 1

There were 10 levels of stimuli with positive polarity and other 10 levels of stimuli with negative polarity. The brightness difference of one level was 10% grayscale. As the positive polarity stimuli, the background color was fixed as white (0% grayscale), and ten different text colors, from 10% to 100% grayscale, were provided. As the negative polarity stimuli, the background color was black (100% grayscale) and grayscale text from 0% to 90% was provided. The text material was easy to read and easily understandable content.

3.2 Result and analysis

Figure 3 displays the ratio of alphawaves for the ten positive polarity stimuli. Stimulus' label pN indicates positive stimulus that combined with white background and N% grayscale text. Among the positive polarity stimuli, there is the tendency that from p10 to p60 the ratio of alphawaves is increasing except p30. Self-reporting result also shows that p60 get the highest score about readability (1.29) and preference (1.21) from participants.*(Figure 4)* There seems to be positive correlation between physiological response indicating comfortness and psychological response indicating readability [r=.58, p=.08] and preference level [r=.53, p=.12]. The lack of statistical significant result is perhaps caused by the limited number of compared items, as the mean values were taken for the analysis. Both physiological response and psychological response indicates that p100 is better for reading a context than p90. It does not match the general pattern that proves it to be getting worse above p70.

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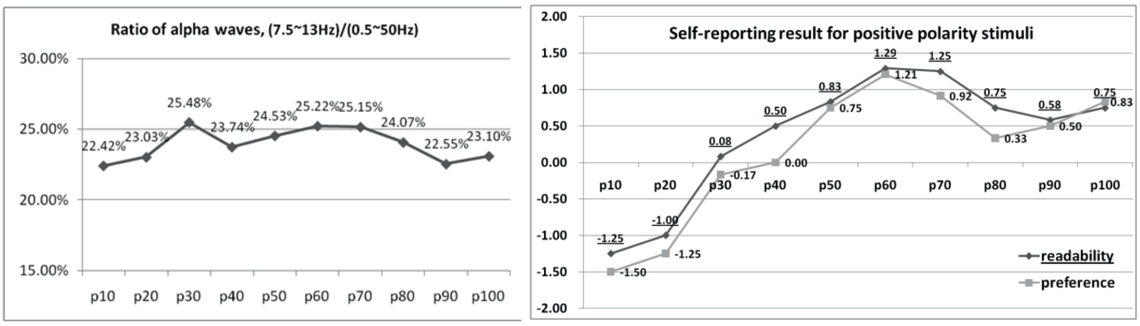

Figure 3,4. The ratio of alphawaves (left) and the score of legibility and preference (right) for positive polarity stimuli. Ratio of alphawaves = (7.5~13Hz)/(0.5~50Hz. p10 indicates positive polarity stimulus that combined with white background and 10% grayscale text.

Regarding the negative polarity stimuli, there is no significant finding or tendency from the brainwaves response *(Figure 5)*. However, in the self-assessment result, n60 receives the highest readability (0.88/2.00)and preference score. (0.71/2.00) *(Figure 6)* Moreover, there is no significant relationship between response of brainwaves and self-reporting result.

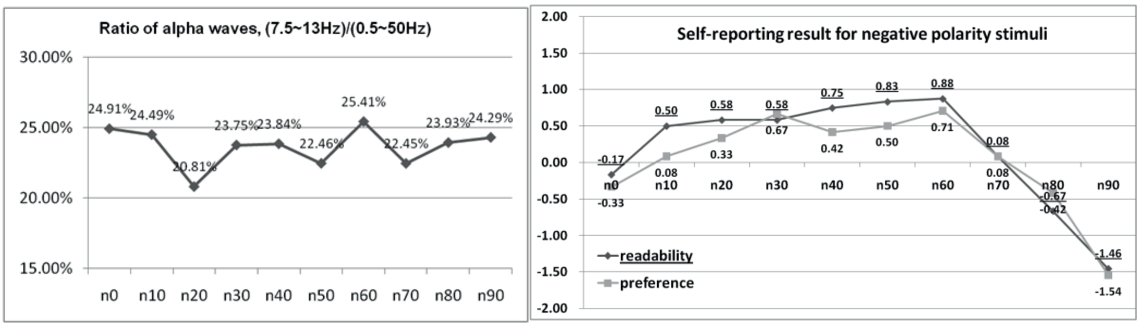

Figure 5,6. The ratio of alphawaves (left) and the score of readability and preference (right) for negative polarity stimuli. Ratio of alphawaves = (7.5~13Hz)/(0.5~50Hz. n10 indicates negative polarity stimulus that combined with black background and 10% grayscale text.

4. Experiment 2

The purpose of experiment 2 was to investigate the emotional response about various hue differences between the text and the background with the same brightness difference (60%). The experiment procedure was identical to the experiment 1. There were thirteen subjects for experiment 2, comprised of seven male students and six female students. Their characteristics are identical to those in experiment 1. Their average age was 25.15 (*SD*=3.95).

4.1 Stimuli

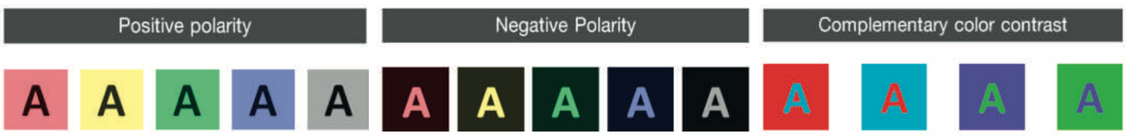

Figure 7. 14 Stimuli for experiment 2

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There were 5 different hues (red, yellow, green, blue and black) that consisted of the positive polarity stimuli with a 80% brightness contrast, 5 negative polarity stimuli, and 4 complementary color contrast stimuli. The complementary colors were defined based on the HSB color system (Red / Cyan, Green/Purple).

4.2 Result and analysis

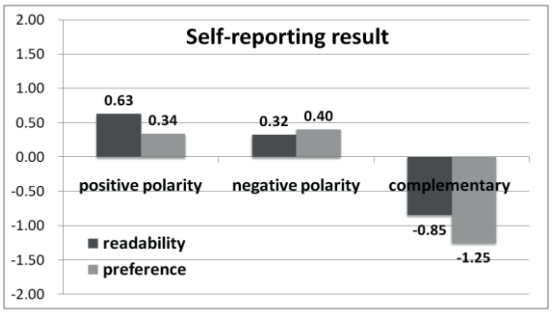

Figure 8. Self-reporting result of experiment 2

According to the EEG data, there were no significant differences between the stimuli. As proven in the self-assessment result, there were significant difference among three contrast types for readability level (repeated measures one-way ANOVA, $F(2,13) = 12.98$, $p<.01$, eta-squared = .52) and preference level (repeated measures one-way ANOVA, $F(2,13) = 50.73$, $p<.01$, eta-squared = .81). Post-hoc test indicated that the mean score of readability and preference level for complementary color contrast was significantly different from both positive polarity and negative polarity.

Conclusion

Among positive polarity stimuli, white background and 60% grayscale text combination is the best for reading context like Lee et al. (2007). Otherwise, the black background and 60% grayscale text combination is the best. Moreover, complementary color contrast should be avoided for the reading task. It can be also concluded that brightness difference between text and background is more influential to people than hue difference. However, hue contrast affected physiological context intensely, so that designer should concern difference in hue as well as difference in brightness. This study can be applied to practical design work with objective and convincing data.

Acknowledgments

This research was supported by following programs: 1) BK21 Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (MEST), 2) Woman Scientist Program through the NRF funded by MEST (NRF 2010-0006319).

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Road safety sign color scheme for the color blindness

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Abstract

Universal design is a design concept that design should be convenient for everybody, regardless of disabilities or any other obstacles. It is becoming more common with developed countries. Locally the application of the concept of universal design is getting increased in public design. Most of the designs consider convenience of the senior citizens, pregnant women, disabled people and ordinary people, but not of the color-blind people. The public designers in welfare state such as America, England and Japan are under obligation of color planning for the color-blind people and such obligation is required domestically too. The precedent studies deal with the color improvement for color blind people, but without the proposal of specific color schemes. In this paper, the problems for color-blind people are analyzed in order to propose the specific color scheme of the road safety for color-blind people.

1. Introduction

1.1 Background and object

Presently, the color-blind people are approximately 8% of the entire population of the world. The color-blind people in Korea are approximately 5.9% of the population of Korea and approximately 0.4% of them are women. Even though that is a considerable amount, the social considerations for them are insufficient.

The color-blind people have all kinds of trouble in their daily lives. And now the concept of the universal design is becoming common and all the designers should consider color-blind people when they plan colors. An area of public design where the concept of universal design must be applied is 'road safety sign' because it is directly related to people's lives and safety. Designers should provide the proper elements to the road users to help them perceive the road signs easily in a complicated environment.

This paper, analyzes the color differences caused from the contrasting visions of the ordinary and color-blind people and the designers can utilize the suggested color schemes in the conclusion when planning colors for the color-blind people.

2. Present condition ofcolor-blind people

2.1 Types of Color-Blindness and Their Causes

The cause of color blindness can be divided into two. The first one is genetic nature but may also occur because of illness or accident. It is most often genetic nature and is caused by cone defect or absence and when one or more of the cone pigments, which is responsible for distinguish colors in human eye, are missing. The types of color blindness can be divided into three. Figure 1 shows kind and ratio of color blindness.

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	Category	Ratio
Anomalous trichromacy	Protanomaly	1%
	Deuteranomaly	24~45%
	Tritanomaly	0.005%
Dichromacy	Protanopia	1%
	Deuteranopia	1%
	Tritanopia	0.005%
Monochromacy	Monochromacy	0.005%

Figure 1. Kinds of color blindness

As the figure 1 shows, the most common cause for color blindness is genetic nature, and especially deuteranomaly constitutes big part among them. Therefore, this study focuses on deuteranomaly and hereafter color blindness refers to deuteranomaly.

2.2 Color perception of color-blind people

To make the research go smoothly, inconveniences of the color-blind people are collected from the web sites for exchanging information between color-blind people. We could find big and small inconveniences which they experience in their lives, for example, they cannot distinguish documents marked with different colors of the highlighters.

After researches, we found that the application of new color scheme for color-blind people is the absolutely necessary in road safety sign.

	Ordinary person	Color-blind person	References in text
Restrict			▪ Color-blind person perceive vivid red as low chromatic yellow color ▪ It cannot function as a road sign

Figure 2. Comparative analysis of road safety sign simulation

3. NCS simulation using Vischeck

To compare how color-blind people perceive colors differently from the ordinary people depend on ratio of each colors (Y, R, B, G), set Y, Y50R, R, R50B, B, B50G, G, G50Y as target colors and start simulation. To create specific color scheme for color-blind people, the analysis of the color difference compared to the ordinary people's sight was necessary. After comparative analysis of 8 NCS colors, two at a time, total 28 comparisons, we could find recommendable and non-recommendable color schemes.

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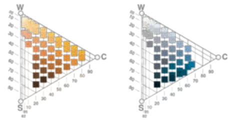
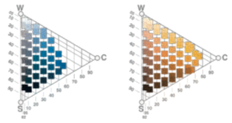
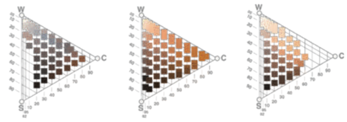
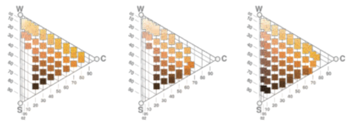
	Caption	References in text
Recommendable		Y& B are complementary colors and not perceived differently to the ordinary people and color-blind people
		R50B& G50Y are complementary colors and color-blind people also perceive them as Blue & Yellow in complementary colors
Non-recommendable		Strong Grayish YR color with low chromaticness and YR color with low value, medium level of chromaticness are similar
		Generally color, value, chromaticness are almost the same

Figure 3. recommendable & non-recommendable color scheme

4. Road Safety Sign and Color Functions

Road safety sign is a plate which conveys a message with picture or letters that indicates caution, restriction, direction and information to road users. By using colors, the road users can perceive the road signs easily and properly understand the meaning of them, therefore there is a need to decide which color function should be applied to road safety sign and which method to analyze color arrangements.

Table 1. Suitable color arranging method for color functions of road safety sign

Color Function	Method of color arrangement	Color guideline
Identification **Safety** **Symbolic** **Aesthetic**	▪ Same chromaticness, Big different value ▪ Same value, Different chromaticness (complementary colors) (Apply low chromaticness colors in large space and high chromaticness colors in small space) ▪ Big different value colors when apply the same colors ▪ High chromatic strong colors (arouse attention)	▪ Yellow color with high value, high chromaticness and blue color with low value, high chromaticness ▪ Neutral color with high value, low chromaticness and blue color with high chromaticness ▪ GY color with high value, high Chromaticness and blue color with low value, high chromaticness

5. Road safety sign color scheme proposal

Presently, the standard color of domestic road safety sign has approximately more than 70 Eab color difference. Therefore, if the colors have approximately 70 Eab color difference or more, the colors ared considered to be suitable for the sign. Refer to the previously analyzed color selection guide to select the colors for color scheme and calculate the value of color difference to make sure the colors are suitable for the road safety sign.

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To find the most suitable colors for color-blind people, among the selected color schemes, select the color scheme that has a bigger color difference in color-blind people's vision than in the ordinary people's vision.

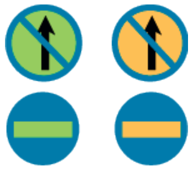
	1	2	3
ordinary person vs. color-blind person's view	 S1080-Y S4050-R50B	 S4050-R50B S1050-G50Y	 S2565-B S1050-G50Y
Color difference	116.2ΔEab 114.9ΔEab	93.59ΔEab 114.87ΔEab	83.41ΔEab111.56ΔEab

Figure 4. color selection of color scheme

Final result of analyzing color scheme suggests that arranging vivid RB affiliated colors with low value and high chromaticness are the most desirable.

6. Conclusion

In this paper, we have presented a color scheme for the color planning of the road safety signs, which can be well perceived by color-blind people.

By combining the NCS's color-blindness simulation and the color functions related to the road safety sign, it is analyzed that ideal combinations for the color scheme of the road safety sign are the combination of vivid RB affiliated colors and colors with low-value and high-chromaticness.

In future, this research is expected to help the designers plan the color schemes of the road safety signs for color-blind people more easily based on the concept of universal design as well as enhancement the efficiency of the color scheme.

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Investigating the psychological and physiological effects of human exposure to color light

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Abstract
This study explores whether colors will influence peoples' feelings when they are exposed to light of different chromaticity and illuminance. A survey was conducted in a controlled environment in order to find out peoples' psychological and physiological response to different light settings. Results of the experiment show a trend of some settings being perceived as more beautiful and comfortable than others, and lighter colors often receiving higher ratings than non-chromatic or darker colors.

1. Introduction
Color lighting can influence mental and physical activity, as was shown by research in the past. However, past discussions have centered more on physical than psychological effects. It had been found that the color temperature of room lights can affect peoples' mental and physical activity. An early study of Kruithof (1941) on peoples' psychological response to room light suggested that there was a range of color temperature and illuminance which can induce a most comfortable feeling about the room. Mukae & Sato (1992) have further tested specifically the heart rate variability (HRV) as an index of autonomic nervous system response under different color temperature setting. They found that the HRV response was higher under the setting of a color temperature of 6700K, when compared against those of 3000K.

Deguchi & Sato (1992) likewise discovered that room light of a color temperature under 7500K, compared to the one of 3000K, can activate contingent negative variation (CNV), which is an index of activity of the central nervous system. Noguchi and Sakaguchi (1996) investigating the influence of color temperature and illluminance on physical activity in a leisure time environment found that color temperature affects the central nervous system, but few discussions have questioned the psychological effects so far. Although a lot of information on the influence of room light on physical activities has already been discussed in the past, these only concentrated on the color temperature aspect. Until now, not much attention has been paid to the question of how the color of the room light influences people psychologically and physically. Will different light intensity affect people? Do people experience different feelings when exposed to different color lighting? If yes, how do their feelings change? And how do people feel in different color environments?

2. Method
This research is based on an experimental survey conducted to examine peoples' psychological and physiological response to lights of different chromaticity. The experiment took place in a laboratory equipped with adjustable LED light (non-directional illumination) of nine chromaticity and illuminance settings (Y, x, y) for color stimulus: red (47.2, 0.693, 0.305), green (46.9, 0.178,

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0.717), and blue (47.0, 0.137, 0.048), yellow (47.1, 0.448, 0.503), cyan (47.3, 0.144, 0.169), magenta (47.4, 0.245, 0.098), white (230, 0.306, 0.312), gray (47.0, 0.304, 0.309), and black (0.0, 0.447, 0.368). Every participant sat comfortably in a chair with armrests which was placed in a closed cubicle-shaped room with white walls. Lighting was fixed in the center of the ceiling directly above the subject's head.

2.1 Subjects

Subjects were ten graduate students of the Master Degree Program at the Department of Information Communications of Chinese Culture University aged between 22 and 25.

2.2 Apparatus and stimulus

Facing the white wall at the front, every participant was exposed to a lighting sequence of the nine settings for four minutes each. During each exposure, subjects were instructed to open their eyes during the first minute and then close them for another minute, repeatedly. The sequence of lighting was conducted in randomized order. During each exposure, the cubicle walls took the color of the respective setting (Figure 1a).

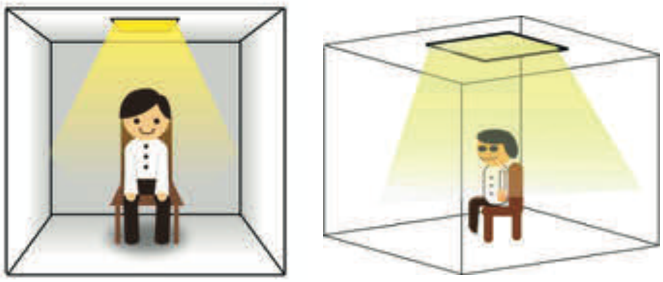
2.3 Semantic survey

After each color exposure, subjects gave their psychological response by sixteen bipolar semantic word pairs based on a five-point-Likert scale: relaxed-agitated, feeling of lightness-feeling of heaviness, calm-excited, comfortable-uncomfortable, refreshed-gloomy, tired-vivid, cool-warm, sleepy-awake, sharpness of mind-dullness of mind, beautiful-ugly, soft-hard, elegant-vulgar, feminine-masculine, loud-discreet, pleasant-unpleasant, and like-dislike.

2.4 Biofeedback measurement

Bio-feedback receptors were measuring four modes of physical response: electrocardiogram (ECG), skin temperature (SKT), galvanic skin reflex (GSR), and electroencephalogram (EEG).

1a



1b

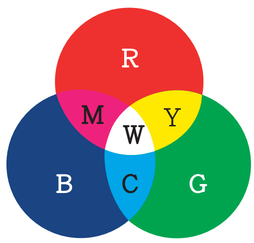


Figure 1a. Experimental setting. 1b. Primary and secondary colors.

3. Results

Results have been clustered into four figures, each one combining two primary colors and one secondary color (Figure 1b), showing subjects' semantic response to light exposure (Figure 2 and 3). From the general chart it becomes clearer that darker light and darker colors make people feel more tired and sleepier: Dark light is perceived as most discreet, heavy, and feeling sleepy. Dark and blue light are most sensed for feeling gloomy. Colored light makes people feel refreshed,

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mostly bright light and yellow. The more reddish the color lighting, the more it is perceived as warmer, more awakening, agitating, and more exciting. Blue appears cooler than dark or bright light and shares the calming perception with cyan. Blue light seems to be the most masculine, hard, cool and - together with red - most uncomfortable color lighting. Yellow appears as the most pleasant and - like bright light - most comfortable color lighting, while magenta is felt as most feminine and -with dim light - the softest. Cyan and yellow appear most liked and elegant. Dim light, followed by bright light (and blue or cyan respectively) makes people feel most calm and relaxed (Figure 4).

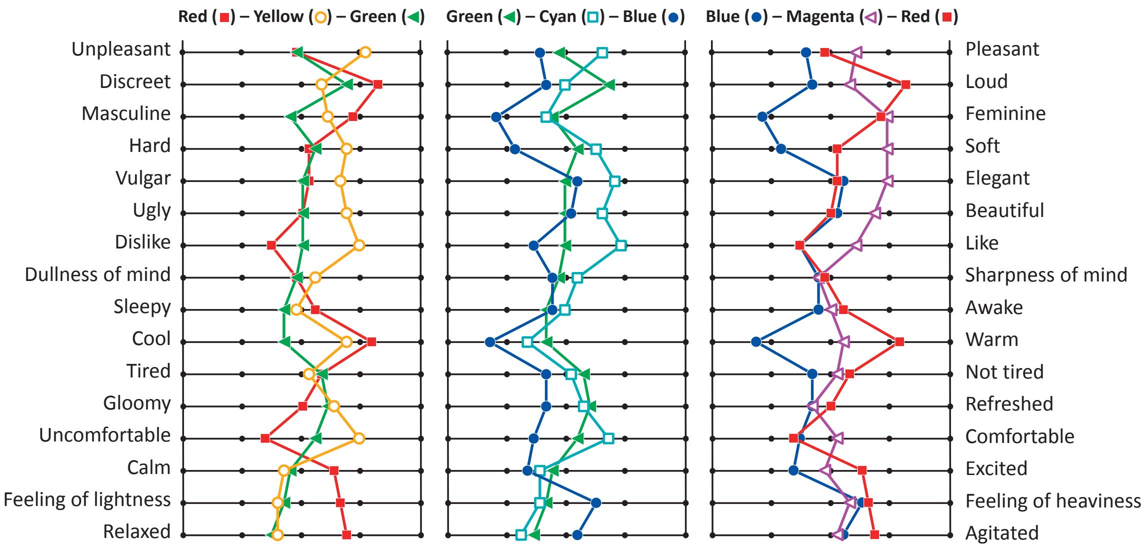

Figure 2. Wavelength-based semantic ratings of R-Y-G lighting, G-C-B lighting, and B-M-R lighting.

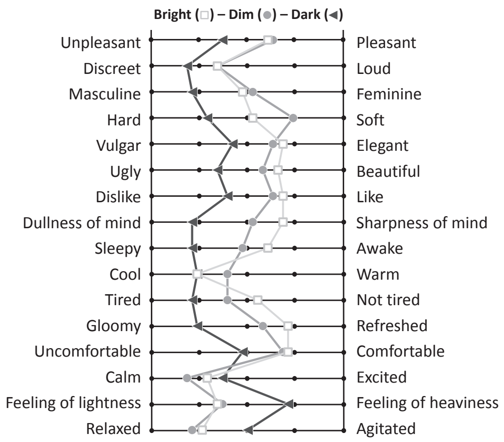

Figure 3. Semantic ratings of illuminous lighting.

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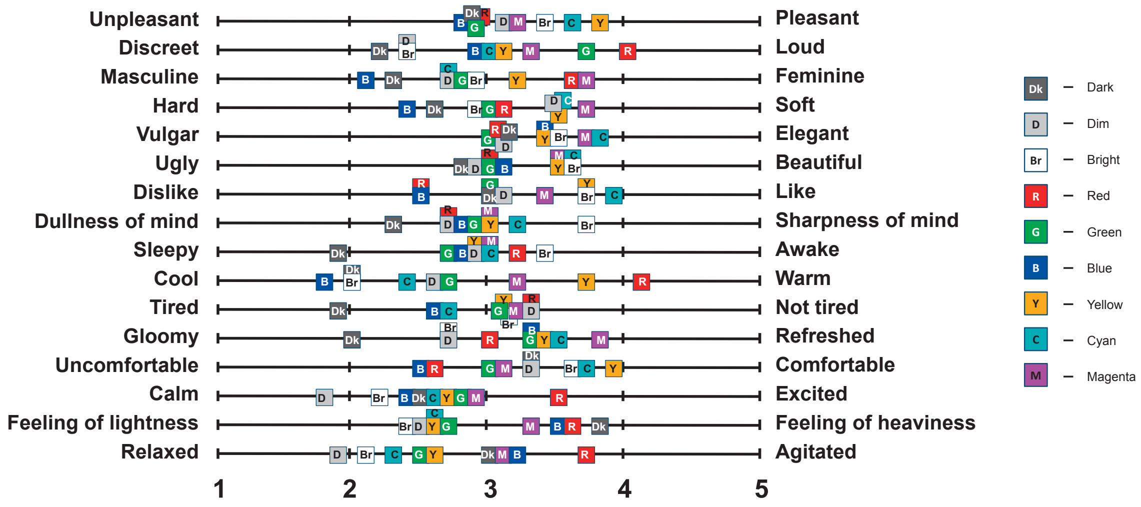

Figure 4. Semantic ratings of color lighting (General).

4. Conclusion

It was shown that colors can affect people differently according to their evaluative factors, potency, and activity. Chromatic colors often received higher scores than non-chromatic ones, and lighter colors were more liked than darker colors: Cyan, yellow, and white were liked most and perceived as pleasant, elegant and comfortable, while red, blue and black appeared as heavy and agitating. Blue and darkness were found as masculine, while magenta and red were considered as feminine. Therefore, a trend can be watched of people preferring colors of greater chromaticity for their environment, especially brighter colors. There also seems to be a basic pattern in the response to different luminance: scores don't vary significantly regarding the semantic feeling, but in the grades that are given, so the ratings reflect quite parallel perceptions given by the subjects.

However, as the results are limited by the low number of participants in this experiment, more research needs to be conducted for confirming this trend. It is further assumed that color lighting induces physiological reactions: results of the biofeedback measurements will be reported in a subsequent paper.

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Using the camera as a paintbrush for non-photorealistic renderings (NPR)

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Abstract

From the ultra-real to the surreal, from stillness to movements, the camera, digital or otherwise, is used as an image capturing device for photography (*phos*, Gk, light; *Graphis*, Gk, stylus or paintbrush) since 1861. It is a known process, since March 14, 1839. To date, the camera remains as a recording device, as man directs the beam in the precise way accord in inhibited spaces – a rigidity that confines human exuberance.

While camera records, light is color -- a complex relationship with its surrounding bodies and surfaces. In response to this interesting notion and sensibility, light source influences the result of the captured visage qualitatively. This paper presents the possibilities and demonstrates the results of this intrinsic characteristics and capabilities of light by combining the hyper relation of camera movements and the light source. At a click, the sum of movements of this camera offers infinite generative in-camera paintings, of various styles and effects, without any post-possessing, independent of subject, anytime, anywhere. Based on this phenomenon, non-photorealistic renderings (NPR) can be composed where the light-movement-based variables ramify and manifest itself with infinite possibilities. Through the syntheses of light, this paper redefines photography and visual expressions, it reinforces the notion of light is color.

1. Introduction

From the ultra-real to the surreal, from stillness to movements, the camera, digital or otherwise, is used as an image capturing device for photography (phos, Gk, light; Graphis, Gk, stylus or paintbrush) since 1861. Indeed, it is a known process, an activity and expression using light as a medium based on a selected subject.

Visible or invisible to the human eyes, light is color, it establishes a complex relationship with its surroundings bodies and surfaces, the camera is used as a device to record a selected subject using light as a medium. In response to this interesting notion and sensibility, light source influences the result of the captured visage qualitatively. To date, the camera is aimed at attaining the utmost image sharpness and accuracy in recording. Occasionally, some photographers spend hours setting up, or rather "incubating" light to compose and achieve a desired effects over a chosen subject. Nevertheless, the camera remains as an enhanced recording device, as man directs the beam in the precise way accord in inhibited spaces – a rigidity that confines human exuberance.

2. The approach

As light source contributes to a phenomenon causing dispersion, light as a medium is formidable, it allows us to experience the dissolution of light whereby it attests the original meaning of photography. This paper presents and demonstrates the possibilities and results of this intrinsic characteristics and capabilities of light by combining the hyper relation of camera movements and the light source. In which, this relationship depicts and expresses the nature or disposition of the

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hand gesture that determines, designs, choreographs and orientates light, thus produces non-photorealistic renderings (NPR), as manifested in "non-light" painting mediums such as pencil, charcoal, pastel, crayon, watercolor and oil. The sum of movements of this camera offers infinite generative in-camera paintings without any post-possessing.

3. The concept

Fundamentally, a brush stroke is the result of a combination of: brush properties, brush hair properties, brush handle, brush size, media properties. method of execution and the artist's skills at time t. Accordingly, a brush stroke is a manifestation of the artist's control of the painting tool, such as a paintbrush.

Conventionally, a camera person controls the camera and lens to "expose" the light recording material to the required amount of light to form a "latent image" or "raw file". By using an electronic image sensor based on light-sensitive electronics such as charge-coupled device (CCD) or complementary metal-oxide-semiconductor (CMOS) technology, a digital camera is able to place the sharpest focus, "sense" and capture the subject at a click.

The motion of the camera person, velocity of the subject, the shutter speed, the adjustment of the lens opening -- the f-number which controls the amount of light passing through the lens, the aperture that measures the depth of field and diffraction, and hence the effective aperture diameter (focal length/f-number) are parameters that measure the image sharpness. In other words, the f-number, which is inversely proportional to the aperture controls the diffraction blur.

By translating the amount of light into a selected aperture and shutter speed, in fractions of seconds, the camera person controls the amount of time during which the imaging medium is exposed to light for each exposure in accordance to the law of luminance. Hence to control the degree of image blurring of the subject whereby the direction of the emitting luminance are derived by using the geometric optics equations. As such, one can alter this equation with different parameters and variables such that it can demonstrate the result that "equates" to a painting. Thus, with the principle of the altered equation in mind, be it a static or moving subject, it is possible to choreograph the camera movement: using the relative velocity of the camera and the color of the subject "as if" one is holding a paintbrush to achieve a desired painting style or effect (§ 4.1)

4. Light as a medium

4.1 The offerings

Even with the explosion of the plethora of non-photorealistic effects in image-editing software, basically, there is a lack of understanding of the primitives: the notion and motion of sketch, draw, paint and creating so-called "effects". Apart from using the two-button mechanical mouse to achieve these effects from source, using camera as a paintbrush

a) presents itself as different drawing and painting tools which self-embeds the painting medium: pigments and solvents. Amongst, chalks (Figure 1), charcoals, crayons (Figure 2), graphites, pens, pencils and brushes simulating different animal hair and sable for different painting mediums such as pigments, acrylic, oil, ink and watercolor (Figure 3).
b) displays rich color fabric in full (16.7 million colors), broken, toned, blended and buildup color hues and tones.

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c) configures and defines different brush types (pointed, dome-shaped, round, filbert, airbrush, roller), (Figure 4) and hence it enables the execution of various types of brush strokes that include: dots and planes, fine lines (Figure 5), broad sweep or splashes, impasto or even, discrete or continuous curvilinear lines (Figure 6, Figure 7).
d) offers a gamut of instantly achievable effects and styles. It includes: Cubism, Divisionism (Figure 8), Pointillism, Delaunay effects, Diebenkorn effects (Figure 9) , Malevich effects, Monet effects (Figure 10), stipple effects (Figure 11), striated effects (Figure 12), Van Gogh effects and beyond.

4.2 The results – In-Camera Paintings (ICP)

Based on the method herewith, the author has created more than a thousand in-camera paintings in a short space of time since August 2010. These ICPs can be categorized by painting techniques, medium (§ 4.1) and themes. Presented herewith are exemplification of the said method whereby the evocation of light becomes colors in hues and shades manifested in various compositions of different dimensions, brush strokes, textures and mediums, completely incognito from the original subject, remote from material reality. Based on this phenomenon, by varying the choreography, the same subject can be transformed into different compositions with different textures, each unique.

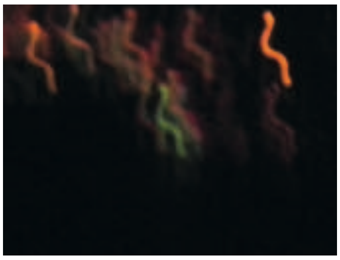

Figure 1 say pleaz...
Artist: Lin Hsin Hsin, Year: 2010
Medium: light, painted by camera only
Camera Data: t_e:0.25 (1/4), f/5.9
©Lin Hsin Hsin. All Rights Reserved.

Figure 2 we come in lights
Artist: Lin Hsin Hsin, Year:2010
Medium: light, painted by camera only
Camera Data: t_e:0.125 (1/8), f/2.6
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Figure 3 doodling
Artist: Lin Hsin Hsin, Year:2010
Medium: light, painted by camera only
Camera Data: t_e:0.25 (1/4), f/4.7
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Figure 4 Different types of paint brushes
Artist: Lin Hsin Hsin, Year: 2010
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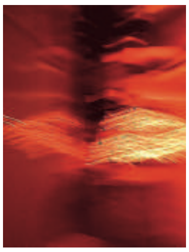

Figure 5 long tail, moving
Artist: Lin Hsin Hsin, Year:2010
Medium: light, painted by camera only
Camera Data: t_e:0.2 (1/5), f/2.6
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Figure 6 arcticulate
Artist: Lin Hsin Hsin, Year:2010
Medium: light, painted by camera
Camera Data: t_e:0.2 (1/5), f/2.6
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Figure 7 fancy net (details)
Artist: Lin Hsin Hsin, Year: 2010
Medium: light, painted by camera only
Camera Data: t_e:0.167 (1/6), f/5.4
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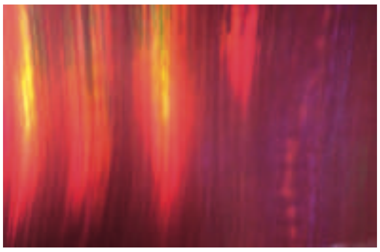

Figure 8 burning desires
Artist: Lin Hsin Hsin, Year: 2010
Medium: light, painted by camera only
Camera Data: t_e:0.100 (1/10), f/2.6
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Figure 9 plane pleasure
Artist: Lin Hsin Hsin, Year: 2010
Medium: light, painted by camera
Camera Data: t_e:0.033 (1/30), f/2.6
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Figure 10 in full bloom (Monet Series)
Artist: Lin Hsin Hsin, Year: 2010
Medium: light, painted by camera only
Camera Data: t_e:0.25 (1/4), f/2.6
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served.

Figure 11 glittering glory
Artist: Lin Hsin Hsin, Year: 2010
Medium: light, painted by camera only
Camera Data: t_e:0.100 (1/10), f/2.6
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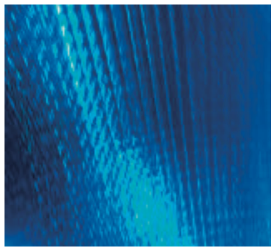

Figure 12 outshine
Artist: Lin Hsin Hsin, Year: 2010
Medium: light, painted by camera only
Camera Data: t_e:0.50 (1/20), f/2.6
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5. Benefits

Using the camera as a paintbrush is a cost-effective, chemical-free, ecologically and user friendly one-step, single device, end-to-end solution for creating digital painting without any personal computers and/or tablets: from instant conceptualization to visualization to the finished product. Herein, the camera screen is the digital canvas, our environment is our subject and color palettes, be it an open or enclosed space. Regardless of the light source, form, shape, size, movements of the subject, this approach offers an infinite amount of opportunities to create NPR paintings of our choice, anywhere, anytime. As such, it bridges the gap between desire, creative thinking and realization in the age of mobile lifestyle that reigns.

6. Conclusions

As such, this lighting performance ensues a new aesthetic experience being established with innovative potentials. The assembly of calculated movements that transforms the spatial experience of light defines a new portrait and a new identity of light -- a new semantic of light. The multiplicity of light is only a distance away from our thoughts, appropriating us in experiencing light in an unprecedented way.

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Experimental evidence for the formula for saturation

Eva LÜBBE
Privat scientist

Abstract

There is more than one definition of the saturation of colour. In 2008 the author proposed a new formula for the saturation and in this presentation the experimental verification is shown by means of the Japanese Colour system PCCS.

The distances in the lines of equal saturation have three maxima and three minima. We can make a connection to neurology and to the colour sensation.

Making a new colour space with the saturation, the LSh-colour space, we get a space much more symmetrically than the LCh-colour space. This is of interest for calculating colour differences.

1. Question

In the field of physiology the terms of saturation and chroma are not used correct. Many of the physiologists only use the term saturation. First the difference between Chroma and Saturation has to be explained. For this we consider a hue triangle (fig. 1).

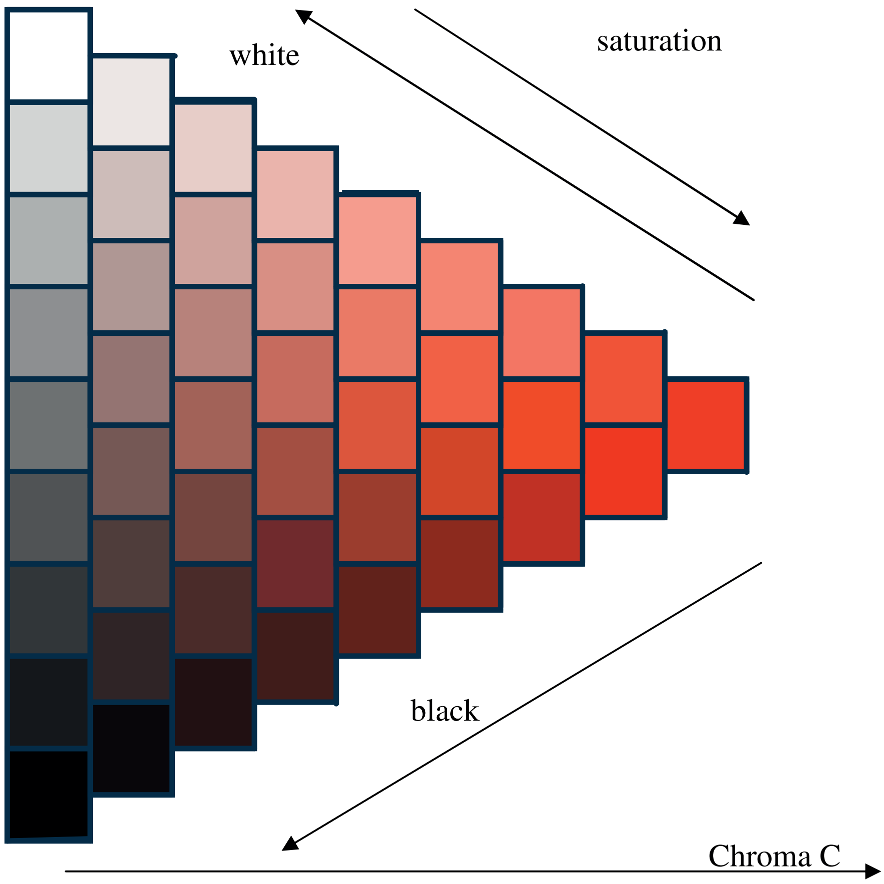

Fig. 1 Hue triangle

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Such a triangle goes back to Ewald Hering. After him Wilhelm Ostwald and many others worked with this triangle and today we find the hue triangle in the Natural Colour System (NCS). On the right corner of this triangle we find the pure colour. This colour is the colour with the greatest chroma. We can add the triangle with lines for the mixtures of white or black with the pure colour.

If we add black to a colour the saturation changes only a little, but if we add white to a colour the saturation decreases. After adding more black to a colour the saturation also decreases and we arrive at a point where we have a coloured black.

The direction which shows the saturation in figure 1 is only an approximation. We cannot draw an exact straight line of saturation in the triangle.

In 2007 the author proposed the following formula to describe saturation (Lübbe 2008, 2010).

$$S^{+} = \frac{C_{ab}}{\sqrt{C_{ab}^{*\,2} + L^{*2}}} 100\% \qquad (1)$$

In this formula C_{ab}* and L* are chroma and lightness of a colour measured in the CIELAB-System.

This formula differs from the following

$$S = \frac{C}{L} \qquad (2),$$

which is used in many models of colour appearance (Fairchild 2005). The formula proposed by the author is in agreement with the verbal definition of Manfred Richter: Saturation is the proportion of pure chromatic colour in the total colour sensation (Richter 1981). Therefore the research question is to find experimental evidence for the formula (1).

2. Methodology

For the experimental verification we need visual scaling data of saturation assessed by persons. Because good scaling data could not be found in the literature a new investigation has been accomplished. For this the Japanese colour system PCCS has been used. Unlike the German system after DIN 6164 the PCCS system has charts of different saturation but with visually equal hues (Fig.2). The DIN system has been constructed with inadequate straight lines in the CIE 1931 xy chromaticity diagram.

The PCCS has a colour circle with 24 hues, 12 of them in steps which can be used for the scaling experiment. For each hue there are 14 saturation steps. Therefore, each person had to position 12 * 14 = 168 colour charts on a given scaling area.

At first the people who had to scale were introduced between the difference between chroma and saturation.

For visual scaling lines were drawn on a middle grey background. So we get a scale from 0 to 100 % from the left to the right.

On the top left we put the white chart as 0 %. This is the zero point of the scale. Under the white chart we place some grey and at least the black chart. The person now has to put the charts of the first hue on the grey paper. He has to imagine that it is possible we can have charts with more saturation as the charts in his hand.

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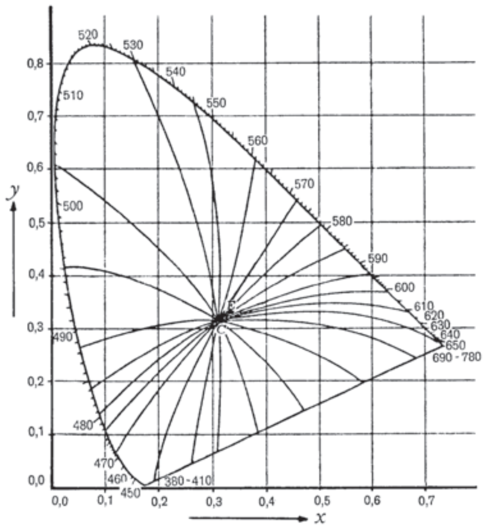

Fig. 2 Lines of equal hue in the CIE 1931 xy chromaticity diagram.

That means that the chart with the highest value of saturation is probably to be placed on a point under 100 %. The next step is that he puts charts with white in the colour on the scale. This was easy to do for the most people. Finally the charts with grey and black had to be put on the scale. This was not easy in all cases. We get a picture like figure 3.

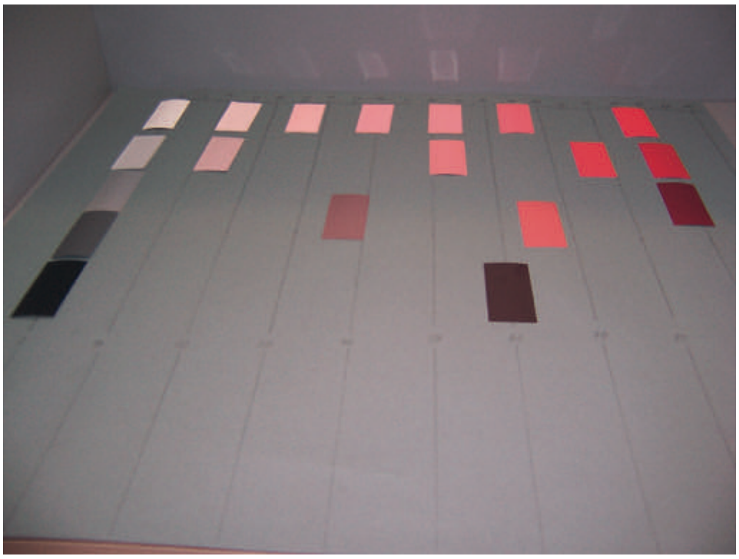

Fig.3.Visual scaling of the Charts of the first hue in the lightening cabin with D50

After putting all charts of the first hue on the grey scale, we finally looked on which lines they lay and write down the values in a table.
Only the first chart from of the first hue stays on the scaling paper and the test person makes the same with the next hue and so on.
The visual test was done after ISO 3664 for graphic industry with day light D50 and 2000 lux.
Fig. 3 shows the cabin Highlight 2000 with D50 and with the charts of the hue nr. 2.
Such a visual scaling takes between 1.5 to 2 hours.
The 14 persons (6 women and 8 men) who did the scaling had normal visual senses.

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3. Results

The results of the experiment are shown in figure 4. The figure also shows the saturation in CIECAM02. For CIECAM02 see Fairchild (2005).

The line of saturation in CIECAM02 does not go through the zero-point. The line of S^+ is in a better agreement with the visual values.

The correlation coefficient for S^+ is r = 0,97 (R^2 = 0,94) and for the saturation after CIECAM02 we have r = 0,95 (R^2 = 0,90).

If we had drawn the line CIECAM02 through zero, the correlation coefficient would become worse.

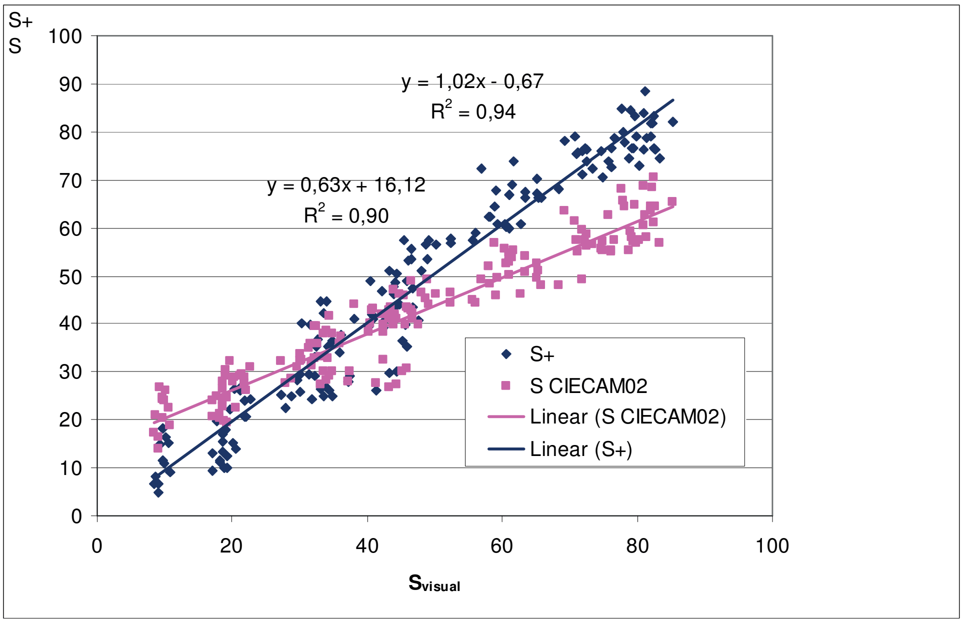
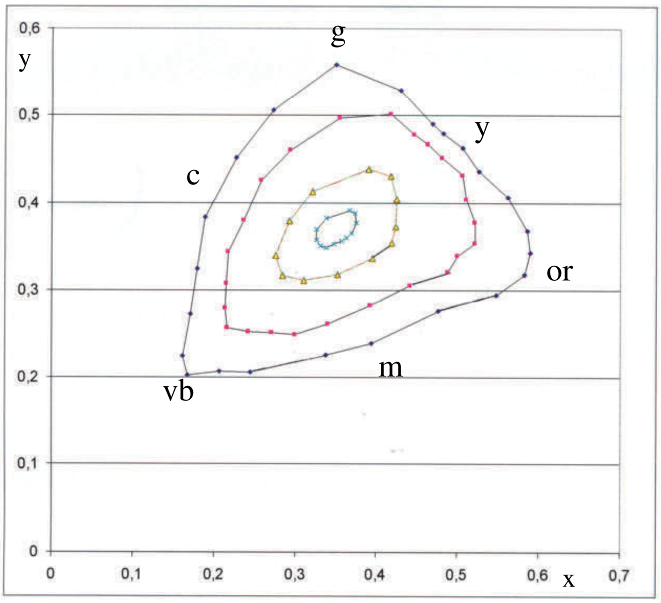


Fig. 4 Results of the visual experiment with the PCCS; S+ was calculated from the measured values of the charts and S in the CIECAM02.



green	M-L
yellow	M-S
orange red	L-M
magenta	(L+M)-S
violet blue	S-L
cyan	S-(M+L)

Fig. 5 Lines of equal saturation. We see large distances of these lines by orange red, green and violet blue and smaller distances by magenta, yellow and cyan.

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In figure 5 we see the lines of equal saturation. These lines of equal saturation have different distances. We find large distances by orange red, green and violet blue and smaller distances by yellow, magenta and cyan (Lübbe 2010, 2011).

4. Conclusion

If we take the Rösch colour space (space of the "optimal colours") and transform it into a new space with the axes L,S^+ and h, we get a nearly symmetrical space. It is much more symmetrical than the LCh-space. You can see this in fig.6.

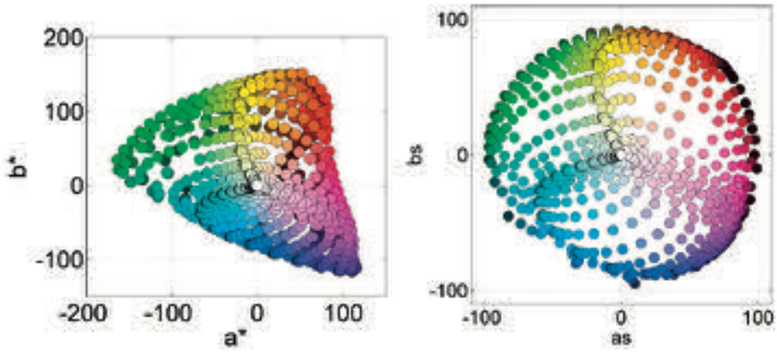

Fig. 6 Rösch's colour space in CIELab system and in LS^+h system; as = $S^+cos(h)$ and bs= $S^+sin(h)$.

The experiment shows that the proposed formula (1) can be used for calculating saturation from the measured values C_{ab} and L*.
In practice this could be very useful for physiologists, designers and for controlling printing.
The LS^+h colour space also is of interest for calculating colour differences.
We can bring together the distances in the lines of equal saturation with the colour opponent cells (fig.5) and the six colours yellow, orange red, magenta, violet blue, cyan and green. In this way we get symmetry in the colour circle (Lübbe 2010, 2011).

Acknowledgments

I want to thank Prof. Schierz from the TU Ilmenau for supervising my habilitation and also the HTWK Leipzig, Berufsförderungswerk Leipzig and the Sächsisches Institut für Druckindustrie for supporting this work. I thank Prof. Hartmann from TU Dresden for given to me fig. 1 and Prof. Meichsner from TU Darmstadt for making fig 5.

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Colour harmony for fashion design

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Abstract

The study was aimed to investigate the observer response to colour harmony in fashion designs and to quantify the response using CIELAB system. To achieve this, a psychophysical experiment was carried out using 36 observers, 20 Chinese and 16 British, each assessing colour harmony of 90 fashion images using force-choice 10-point categorical judgement method. The 90 images consisted of three fashion styles, each containing the same set of 30 colour schemes. The experimental results show that fashion style and colour scheme both have a significant impact on harmony response. However the two factors may be independent of each other. The results also demonstrate that the images with high-chroma values were seen as more harmonious than those with low chroma values, while the opposite trend was found in harmony response to colour patches.

1. Introduction

Empirical studies of colour harmony have conventionally relied on the use of colour patches as the stimuli in an attempt to simplify experimental conditions (Ou and Luo 2006; Nayatani and Sakai 2009; Szabó et al. 2010). Such settings have led to question marks as to whether or not the findings can apply to real world applications. A new study of colour harmony (Ou et al. 2011), due to be published in Color Research and Application, used both colour patches and interior images as the stimuli, with results showing that colour harmony responses for the two types of stimuli were in close agreement. While this might suggest a strong link between contextless colour patch and contextualised colour image in terms of the harmony response, whether this can be generalised to other design areas still remains to be discovered.

Fashion design is another area where colour is seen as a crucial design element. While the fashion colour trends may vary rapidly due to cultural, economical or political changes, it is essential for the designer to ensure each colour scheme looks harmonious and thus appealing to the buyer. By looking into the harmony response for fashion designs, the present study attempted to address the context issue for colour harmony.

2. Methods

Thirty-six observers participated in this study, including 20 Chinese and 16 British, each assessing colour harmony of 90 fashion images using force-choice 10-point categorical judgement method (Torgerson 1958). The images were presented individually in random order on a calibrated cathode ray tube display. The 90 images consisted of three fashion styles, spring, summer and winter, each containing the same set of 30 colour schemes, as demonstrated in Figure 1. The colour schemes were selected from the CIELAB space to cover a reasonably wide range of hue, lightness and chroma.

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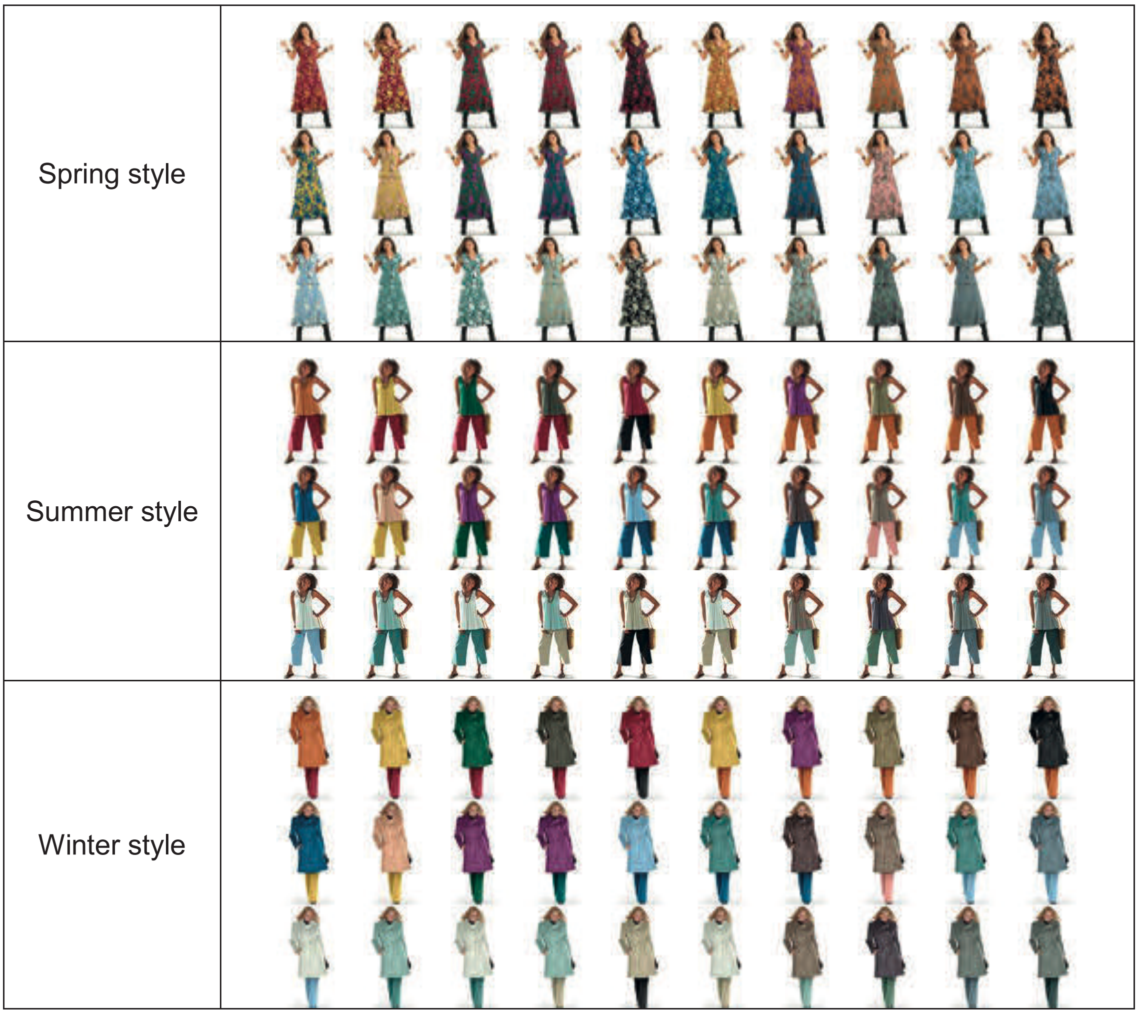

Figure 1. Experimental stimuli divided into three fashion styles: spring, summer and winter

3. Results

The experimental data of the two observer groups, Chinese and British, were combined for the following data analysis, as the colour harmony responses of the two groups were found to agree well, with a correlation coefficient of 0.74. The harmony values for the three fashion styles were first compared by plotting the values for one fashion style against those for another. As shown in Figures 2 (a)-(c), the three sets of harmony values are correlated closely, with a correlation coefficient of 0.78 for comparison of spring vs. summer, 0.78 for summer vs. winter, and 0.68 for winter vs. spring.

The results seem to imply there was little interaction between colour scheme and fashion style. To see whether this was the case, the ANOVA test was performed. As a result, significant differences were found between the three fashion styles in terms of mean harmony values for each style ($p < 0.001$); little interaction was shown between fashion style and colour scheme in terms of harmony response ($p = 0.312$). These test results suggest that the colour harmony response is influenced by both fashion style and colour scheme, but the two factors may be independent of each other.

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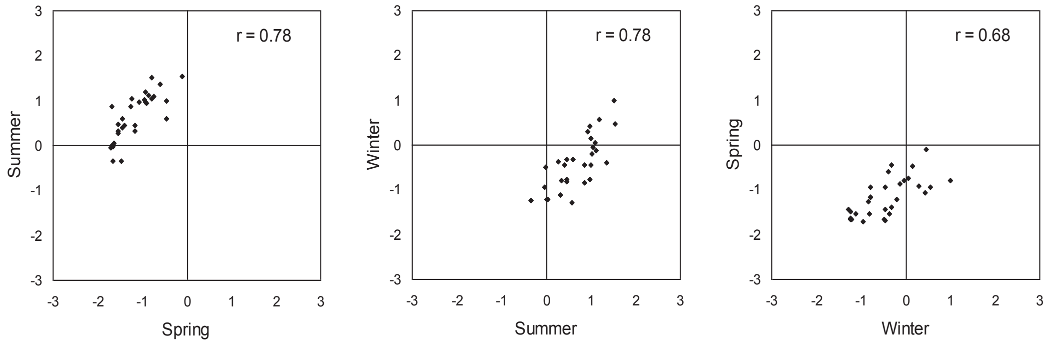

Figure 2. Colour harmony responses for the three styles plotted against each other: (a) spring vs. summer, (b) summer vs. winter and (c) winter vs. spring

From the results, a new colour harmony model for fashion design was derived using techniques similar to those for the authors' original model of colour harmony (Ou and Luo 2006).

$$CH_{fashion} = H_C + H_L + H_H \quad (1)$$

in which

$$H_C = -0.86 + 0.012\left(C^*_{ab,1} + C^*_{ab,2}\right)$$

$$H_L = H_{Lsum} + H_{\Delta L}$$

$$H_{Lsum} = -0.72 + 0.01\left(L^*_1 + L^*_2\right)$$

$$H_{\Delta L} = -0.24 + 0.12\tanh\left(-2 + 0.2\left|L^*_1 - L^*_2\right|\right)$$

$$H_H = H_{SY1} + H_{SY2}$$

$$H_{SY} = E_C \times H_S$$

$$E_C = 0.5 + 0.5\tanh\left(-2 + 0.5C^*_{ab}\right)$$

$$H_S = -0.22 - 0.10\sin(h_{ab} + 50°) + 0.05\sin(2h_{ab} + 90°)$$

Here, L^*, C^*_{ab} and h_{ab} represent lightness, chroma and hue angle in CIELAB, respectively. The model can be summarised by the "principles" below:

- High chroma/lightness. The higher the chroma or lightness of each constituent colour in a fashion design, the more harmonious the design will appear.
- Unequal lightness values. Small lightness variations between the constituent colours in a fashion design may reduce the harmony.
- Hue preference. Cool colours are more likely than warm ones to create harmony.

To compare the difference in harmony value between fashion design and colour patch, two sets of harmony data for the 30 colour schemes used in this study were examined – one the mean harmony response obtained in this study (i.e. the average of the three fashion styles), and the other the predicted harmony value by a colour harmony model derived on the basis of colour patches (Ou and Luo 2006). The result shows low correlation for the two sets of harmony values (r = 0.18). To examine further as to what the differences were, scatter graphs of harmony values were made against each harmony predictor used in the original colour harmony model [1], including the mean or difference values in lightness, chroma and hue. The result shows that the main factor for

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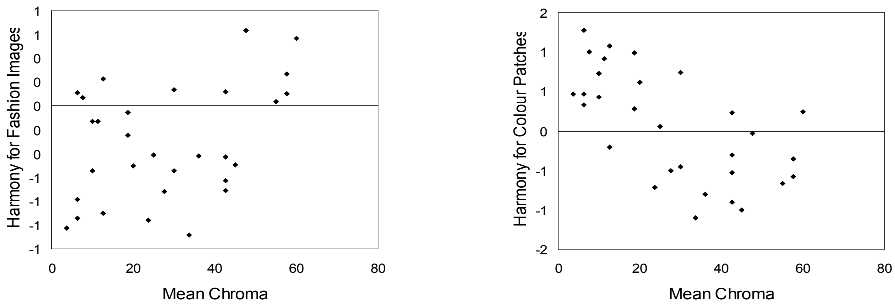
the difference between colour patches and fashion images was the mean chroma value of constituent colours in a colour combination. Figure 3 (a) demonstrates that the harmony value for fashion images increases as mean chroma gets higher and higher, whereas the harmony value for colour patches tends to decrease as mean chroma increases (Figure 3b).



(a) *(b)*

Figure 3. Colour harmony value plotted against mean chroma for (a) fashion images and (b) colour patches

4. Conclusion

The experimental results show that while fashion style and colour scheme both have a significant impact on harmony response, the two factors may be independent of each other. Note that the sample size for fashion style was small; to establish whether or not there is any interaction between the two factors, a more comprehensive study with larger sample size will be required. The present work also demonstrates that the high-chroma fashion images were seen as more harmonious than those with low chroma values, whereas the opposite trend was found for colour patches (Ou and Luo 2006; Szabó et al. 2010). It will be interesting to investigate further as to why chroma plays such a significant role in differentiating the two colour harmony models.

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The choice of colours in graphic design in relation to the children's preference. Aspects transferred to the colour appearance of printed media

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Abstract

The aim of this paper is directed at the observation of colour preference of children to the printed media products. The two objectives of this paper have been defined. The first one is directed at the choice of colours for different kinds of children printed products. It is based on the fact that the choice of colour used for children printed media toys belongs to the graphic designer (adult) and that the chosen colour is the result of his creativity and knowledge of children psychology. The second objective is based on the fact that children colour preference may differ according to their nature, temper, different lightening and atmospheres during the daylight. The results have shown that designers' choice of colour is in correlation with the main children preferences. Majority of designers would choose red and yellow for girls, and blue for boys. On the other hand, the results have shown that there were no particular differences between boys' and girls' preference of presented colours or graphics. Exposure to different light surroundings showed that in the afternoon children chose blue rather than warm colours. This paper has given an interesting perspective for graphic designers that are involved with children printed media industry.

1. Introduction

It is well known that extensive studies have been done on colour appearance. Some of these studies deal with the emotional effects of colour on people in general. The others show which colours children are attracted to in relation to those which adults are attracted to. Never the less, it is very difficult to define the psychological aspects of colour for two reasons (Fehrman and Fehrman, 2004). First one is that psychological measurements are mostly highly subjective and submissive to completely individual interpretation. The second one is related to the atmosphere conditions, i.e. colour and light interactions, in which are hardly to separate them even in the defined surroundings (Hårleman, 2007; Davidoff, 1991; Garo 1999).

On the other hand, children preference of different colour is even more difficult to define. They are particularly sensitive and receptive to stimuli that surround them. The visual stimuli generate different reactions in the body, and the colours, especially, that not only stimulates them visually, but also affects their humour and emotional feelings. Small children (about three to five years) have different preference to the colours according to their emotional state and behaviour during the day. In the morning they are full of energy, in the noon they could be sleepy, in the evening more sensitive, etc. All of these feelings could have influence on their perception of colours and their preference of different colours. Based on those facts two objectives of this paper have been defined. The first one is directed at the choice of colours for different kinds of children products: picture books, birthday invitation cards and toy catalogues. It is based on the fact that the choice of colour used for children printed media toys belongs to the graphic designer (adult) and that the chosen colour is the result of his creativity and knowledge of children psychology. The knowledge of the psychology of perception allows them, through the concept of reading, to

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search for the new forms responding the supporting levels and the effects of these on children behaviour. Within this field, colour plays a fundamental role, as highly important variable for visual communication. Though, graphic designers must be adequately formed and educated to be able to develop and articulate specific knowledge in order to deliver an appropriate creation for a competitive product.

The second objective is based on the fact that children colour preference may differ according to their nature, temper, different lightening and atmospheres during the daylight.

2. Methods

The same methods were used for detecting the preference of colours and graphics of adults (designers) and of children (kindergarten, age three to five years). Three different graphics were used in the study (named *a girl (1)*, *a party (2)* and *a dog(3)*) and each was coloured in different background: *yellow (A), red (B) and blue (C),* (Figure 1).

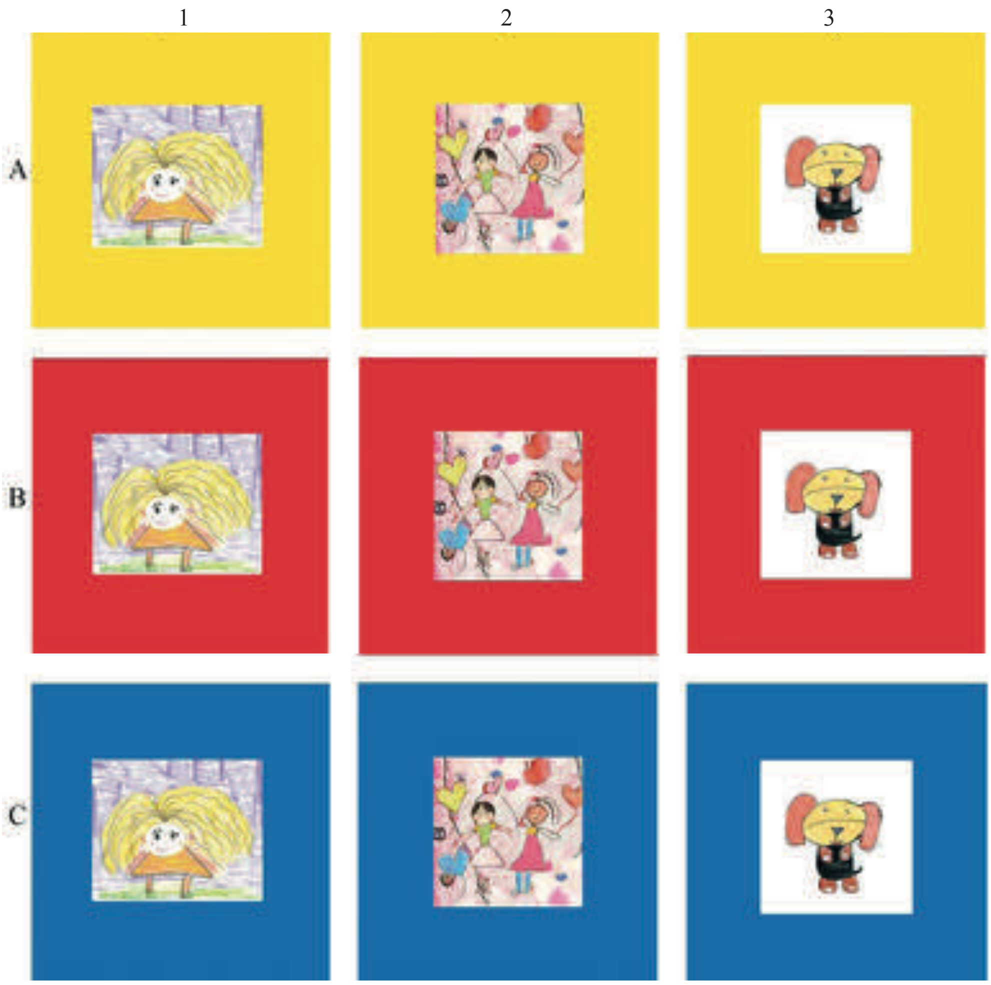

Figure 1. Colours and graphics used in evaluation (L.M. 10 years).

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The colours were chosen according to the study that children prefer primary colours (Halse, 1978). The graphics were held up for five seconds and the interviewees were asked about their preference. Only five seconds were allowed for the viewing of the graphic because a quick glance is aimed at provoking purely emotional reactions. The children and the designer had to decide which graphic and background they prefer according to the presented printed media.

In the study twenty adult persons, involved in graphic design and twenty children (ten boys and girls) were interweaved. The adults were interwoven during the daylight with presumption that their preference would not be changed throughout the day. The children were asked the same questions in the morning by early daylight, in the noon and in the afternoon. The test was repeated a few times and throughout few days to get more concrete results. Designers and children were asked the same question: Which of those colours / graphic will they prefer for designing / choosing the three different printed products: picture books, birthday invitation cards and toy catalogues. The selection of these products was based on the fact that it should be a printed media material. On the other hand, motives were selected according to the assumption that preferred colour will be defined by the object in which it is associated (McCamy, 2003). According to the study published earlier (Fehrman and Fehrman, 2004), this relation is probably the product of cultural norms and expectations or subjective colour bias.

3. Results and discussion

The results of the paper include: analysis of mostly used colours in design of printed media products; children preference of used colours for specific purposes; analysis of children preference of colours in different light surroundings. By walking through the supermarket's toy department one can see that products are mainly coloured with primary colour, i.e. colours are used to attract children's attention and sell the products. Little children are attracted to bright colours. Numerous academic researches show that the age changes children's preferences. Many children under ten call red (or pink) and yellow their favourite colours. But having grown above ten they start preferring blue. It is considered to be with the process of growing up and appearance of ability to perceive different hues of mood.

Results of this study performed in the morning by early daylight and in the noon are presented in Table 1. The results have shown that designers' choice of colour is in correlation with the main children preferences. One can say that designers thought mostly that girls prefer red and yellow, and boys prefer blue. On the other hand, the results have shown that there were no particular differences between boys' and girls' preference of presented colours or graphics.

Table 1. Results of the colour / graphic preference (in the morning by early daylight and in the noon)

Preferred graphic / colour	**Children (20 persons)**		**Graphic disigners (20 persons)**
	Girls	**Boys**	
Picture book	1B (48%)	3B (41%)	1A (88%)
Birthday's invitation cards	2B (78%)	2A (65%)	2B (81%)
Toy catalogue	1A (65%)	3B (70%)	3C (65%)

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Table 2. Results of the colour / graphic preference (in the afternoon)

Preferred graphic / colour	Children (20 persons)		Graphic disigners (20 persons)
	Girls	Boys	
Picture book	1B (40%)	3B (48%)	1A (88%)
Birthday's invitation cards	2B (51%)	2C (55%)	2B (81%)
Toy catalogue	3C (45%)	3C (60%)	3C (65%)

Results of the children's colour and graphic preference performed in the afternoon are presented in Table 2. One can see, according to the average results that in the afternoon children chose blue rather than warm colours. Colour preferences are closely connected with the gender. Numerous researches show that most little girls prefer red, pink, lavender or violet. Little boys like dark colours more than girls. The question has arisen if those preferences are innate or acquired. Adults accustom little girls and boys to like certain colours choosing their clothes and toys. It‘s hard to give the exact answer but we are inclined to consider colour preferences to be innate. It is an interesting fact and hard to be solved in future.

4. Conclusion

This paper has given some new findings about the influence of atmosphere and daylight conditions on colour preferences of children. It has given an interesting perspective for graphic designers involved with children printed media industry. The results have shown that designers' choice of colour is in relative correlation with the main children preferences. One can say that designers mostly thought that girls prefer red and yellow, and boys prefer blue. On the other hand, the results have shown that there were no particular differences between boys' and girls' preference of presented colours or graphics.

Results have shown that it is very difficult to define the children's preference of colour because of their highly subjective interpretation. Complexity of the research could give the contradictory results of psychological aspects and colour preferences studies can be often. But, from the other side, different studies, conditions under which studies have been performed and their results can be often intriguing and interesting especially for graphic designers involved with children printed media industry.

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Comparative analysis of electrophotographic prints with the standard magenta and cyan in relation to the prints in which light magenta and light cyan are added

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Abstract

The satellite machine construction enables the positioning of greater number printing units which can print greater number of colours. They are most often Pantone inks and in recent times the clear varnish as well. EP machines which use the liquid EP inks (Digital Colour Offset) can contain up to 7 printing units. In this work the spectrophotometric analysis of magenta and cyan prints has been done (4 colour print) in relation to the 6 colour print (the added light cyan and light magenta). With it the continuous wedge is reproduced, containing 9 specific screen patches. The addition of lighter inks in screen reproduction does not achieve considerable visual changes in tone (ΔE_{max}=3,00). But they are more expressed in magenta ΔE_{mean}=2,16 in relation to cyan ΔE_{mean}=1.18. On prints, the light screen elements are applied up to 40% of screen value, after which they change into the full tone. Medium and dark areas contain 100% of the applied light ink to which the screen elements of the darker inks are added. With it the diameters of the screen elements range from 56,5 µm up to 96,02 µm, while diameters of the dark screen elements range from 37,64 µm up to 135,91 µm.

1. Theoretical part

For achieving the prints which have the photographic quality it is not enough to use the standard process inks only. Such inks must be transparent, which means that they must contain a transparent substance which must not change the index of refraction of the incident light beams (Thompson 2004: 480). In order to get the halftones during the application of the process inks, it is necessary to perform the screening process (changing the continuous tones of the original into the halftone screen image which will contain the numerous screen elements). With different methods of the digital screening as well as by the application of the new algorithms, printing of the intermediate tones is considerably improved (Goldmann, 2004). Improving the reproduction quality is the printing of the additional inks. Nevertheless, for the further quality increase it is necessary to eliminate the screen elements and to replace them by continuous tones. In this process the light inks are printed (light magenta= LM and light cyan=LC). (Eldred and Scarlett, 1994)

In colour prints the share of cyan (C) and magenta (M) is very high and the application of the LM and LC improve the contrast of the whole reproduction. In order to produce the LC and the LM, white pigments are added to the standard C (copper phtalocyanines) and to the standard M (dimethylquinachrydon). The most universal white pigment is titanium dioxide. It is added in 80% white inks because of the opacity which is very high. In order to get different grades of whiteness during the production it is often mixed with Zn, Al, Zr and SiO (silica). The basic parts of the components in such inks is TiO_2 (80-99,8%), while Al, Zn, Zr or SiO are in relation of 0-20% (Leach and Pierce, 1999). In the electrophotographic printing technology the application of greater number of inks has been solved effectively by the satellite machine construction. HP Indigo machines can have up to 7 BIDs which are activated during each separation and which

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apply the corresponding ink (Kiphan 1997:11). BKT cylinder is covered by a special rubber blanket which conducts electricity, which completely transfers the ink on the printing substrate during the printing process. The important detail is the warm offset blanket (T=125°C) which eliminates the liquid inking carrier (Isopar). Depending on the laser diodes power IR light (λ=830 nm) formed with varying beams diameter. The developing process is responsible for formation of ink layer on paper, in which the greater negative voltage is caused by the thicker layer of ink. The continuous tonal gradation is achieved by the combination of printing the lighter and darker screen elements. Landa et al (1988).

2. Experimental parts

For this experiment the HP Indigo form was used by which the printed native RGB image. In order to achieve the colorimetrical controlled printing, the printing form was done in two specific screen forms: in the image containing only the basic CMYK separations (method 1) and the image containing CMYK separations + LM and LC (method 2). Harlequine RIP software version 7.2 was used with the application of ICC profile ISO coated. Prints was done with the HP Indigo S 5500 with the built in 6 colours. Gloss fine art paper (130 g/m^2) was used as supstrate. For the analysis was used X-rite DTP 20 (geometry of the optics 0/45^o). The colour difference (CIE LAB ΔE_{2000}) was calculated from L*a*b* values. Image analysis of the samples was performed where the dimension of the reproduced screen elements (Δd). Different coverage some diameters were especially noticeable: the diameters of the light screen elements (d_L), diameters of the dark screen elements (d_D) and the diameters of the white screen elements d_W. Roldan et al. (2001).

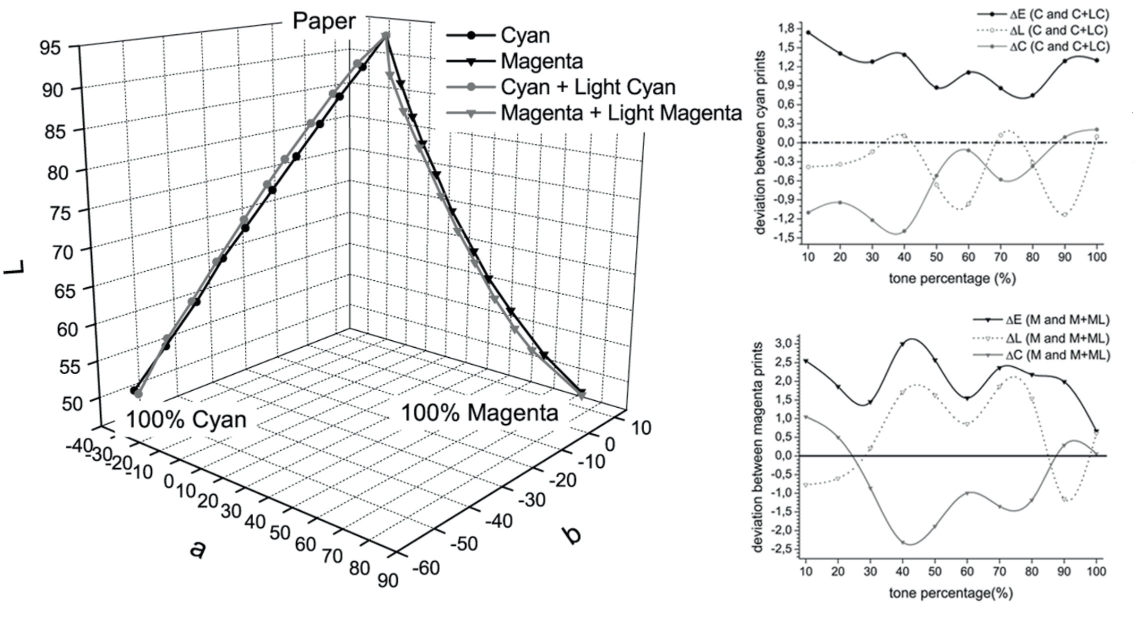

Figure1. CIE LAB differences ΔE_{2000} between C+M prints and C +M +LC +LM

Comparing the prints of C with C+LC, the greatest ΔE appears in the light area ($\Delta E_{C10\%}$=1,74) while the smallest ΔE appears in the tonal value between 50% and 80% ($\Delta E_{C80\%}$=0,75). The solid patches have considerably change in tone ($\Delta E_{C100\%}$=1.30). This is the result of trapping. Important aberration between ΔL and ΔC is noticed only in some screen areas. They are the areas of 40%, 60%, 70% and 90% of the screen value. The formed ΔE is mainly influenced by the changes in

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chroma (areas of 10%, 20%, 30% 40% and 70%). Magenta prints (M and M+ML) have greater ΔE. There are visible in all the tonal areas in which the area between 40% and 50% screen value ($\Delta E_{M50\%}$=3,00) and the area between 70 and 80% of the screen value have higher values ($\Delta E_{M50\%}$=2,36). Greater aberrations between the ΔL and the ΔC are noticed in some screen areas. They are the areas of 10%, 40%, 70% and 90% of the screen value. By the image analysis of prints created with C and M is noticed the linear growth of the screen dots up to 60% screen value. Because of the amplitude screening in the areas above 60% screen value, the dark screen elements merge, after which it is possible to follow unprinted area (figure 2a).

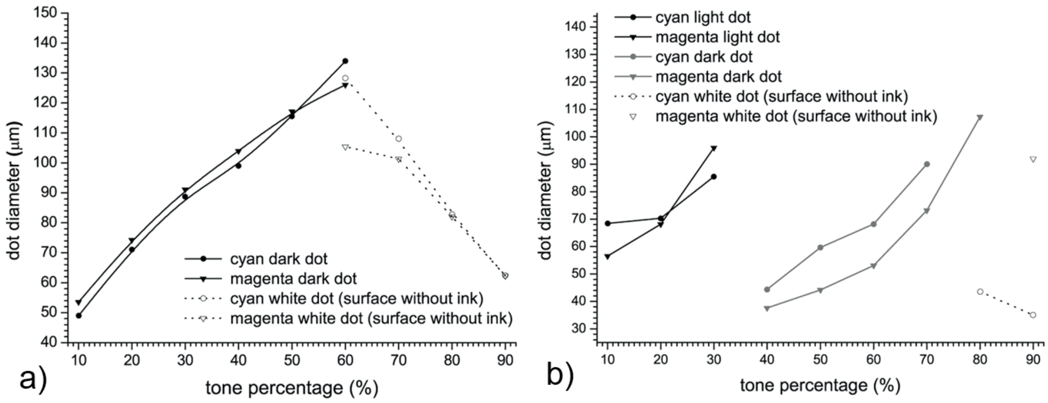

Figure 2. Results of the image analysis: a) change of the dark screen elements and the white non printed surfaces b) change of the dark screen elements, light screen elements and white non printed surfaces

The C screen elements (dark dots) have the smallest diameter of $d_{10\%=}$48,97 µm while the greatest diameter is $d_{D60\%}$=133,93 µm. The screen area of 60% screen value is the boundary one and the formation of the white dots $d_{W60\%}$=128,32 µm. By the increase of the screen value the number of the white screen dots increases and their diameter decreases d_{Wmin}=62,35 µm. The dark M dots have the smallest diameter $d_{10\%}$=53,52 µm, while the greatest diameter is $d_{D60\%}$=126,03 µm. In the boundary screen area there are more white elements ($d_{W60\%}$=105,46µm). Prints with two different light inks, except d_D and d_W, in the reproduction has to be monitored d_L. The light screen elements are possible to be noticed up to 30% screen value (figure 2b). Reproduction of the dark dots begins at 40% screen value and it is possible to be monitored up to the area of 70% screen value.

The prints with LC was reproduce smaller diameter than $d_{10\%}$=68,4 µm while the greatest diameter is $d_{L30\%}$=85,55 µm. Circularity of the elements disappeared and screen dots merge into linear chains of the average height of $h_{L30\%}$=524,75 µm. Dark dots start in 40% of the screen field ($d_{D40\%}$=44,42) and stop in 60% screen field ($d_{D60\%}$=68,19). In the screen field of 70% the elements have lost all their circularity forming the line screen with the width of $d_{D70\%}$=68,19µm; and the high $h_{D70\%}$=233,94µm. The white linear elements are formed in the area of 80% (width $d_{w80\%}$=43,54 and the height of $h_{w80\%}$=120,7), while in the area of 90% screen value, the white elements of the circular form are formed ($d_{w90\%}$ = 35,05 µm). Surfaces in which is LM reproduced have the smallest dot diameter ($d_{L10\%=}$56,5 µm), while the greatest width of the elements is $d_{L30\%=}$96,02 µm. The elements in 30% screen area are merged into the vertical chains which stretch over the whole selected image $h_{L30\%}$=2540 µm. The dark M elements start to form in 40% screen patch ($d_{D40\%}$=37,64) and they stop in 90% screen patch ($d_{D90\%}$=135,91). The dark elements lose their circularity in the 70% screen value. In higher tonal areas stretch on the whole analyzed surface ($h_{D90\%}$=2540 µm). The laser head has the greatest influence on these results. In the article Majnarić et. al. (2009) it is presented that the application of the laser head power (of 1µW/mA to 12 µW/

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mA) influences the size of the reproduced printing elements. In the calibration area (50% screen value) it is $\Delta d_{50\%C}$= 10,16 µm for cyan; and $\Delta d_{50\%M}$=16,51 µm for magenta.

4. Conclusion

Addition of the light inks (LC, LM) does not consequently have considerable visual changes in tone (ΔE_{max}=3,00). They are more expressed in M ΔE_{mean}=2,16 in relation to cyan ΔE_{mean}=1.18. The addition of light inks considerably increases the chromaticy in the area between 30 and 40% screen value ($\Delta C_{40\%M}$=2,31; $\Delta C_{40\%C}$=1,39) which is problematic for realization, because of the optical dot gain (the paper surface is completely covered with light ink which decreases the reflection of the white light from the surface). In this way the prints have greater contrast and tone of C and M is better visible.

The light screen elements on prints are applied up to 40% screen value, after which they become the full tone. Medium and dark areas contain 100% of the applied light inks to which the screen elements of the dark inks are added. The diameters range from 56,5 µm to 96,02 µm, while the diameters of the dark screen elements range from 37,64 µm to 135,91 µm. Such tone difference is visible in reproducing the high quality photos which are recommended to be made on fine art paper. The 50% higher price of prints (6 colour separations in relation to the 4 colour separations) does not give the 50% higher print quality, especially not in the case of the reproductions printed on rough papers where the difference in prints is almost unnoticeable. Because of that it is recommended to avoid the usage of the additional light inks for the graphic products of lower quality.

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Color modification of signboard suitable for streetscapes without significant loss of visibility and logo identity

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Abstract
Two experiments were carried out to determine signboard color modification rules for a harmonized streetscape in which signboards are visible and the identity of logos is clear. Various color-modified logos were displayed in the first experiment. Streetscapes containing a color-modified signboard were displayed in the second experiment. Twenty-two subjects rated their impression of the samples in each experiment on 8 scales. In the first experiment, it was found that it is preferable to maintain the hue of the logos similar to that of the original logos. Red-white and blue-white combinations were found to be the most visible. It is suggested that retaining the original hue of logos on signboards improves their visibility and makes the streetscape aesthetically appealing from experiment 2.

1. Introduction
Color modification of signboards is sometimes carried out in a traditional or green area in Japan. In such cases, the color would mostly be changed to a less saturated color, especially brown or achromatic colors (Figure 1).

However, color modifications of logos on signboards would adversely affect the recognition of the corporate identity and brand recall. Moreover, the visibility of the signboards would decrease.

The author carried out two experiments to find signboard color combinations that contribute to high visibility, suit the streetscape, and facilitate the recognition of the logo identity.

Figure 1. Examples of color modification of signboards in Japan

2. Method
The first experiment dealt with logos on signboards. A total of 186 samples (14 unsuitable samples were removed from the 200 samples obtained by considering all combinations of ten color patterns (Figure 2) and twenty logos (Figure 3) were displayed on a screen by using a liquid crystal projector. Twenty-two women students rated their impression of each sample using eight 7-step semantic differential scales.

In the second experiment, signboards with logos displayed in the first experiment were introduced in three streetscapes—a traditional street of Japan, a street in a commercial district, and a green street in a suburb (Figure 4). A total of 126 samples (six samples were removed from the 132 samples obtained by considering all combinations of the three streetscapes, four signboards, and eleven color patterns were displayed in the experiment. Twenty-two women students rated their impression of each sample using eight 7-step semantic differential scales.

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<1> Original image
<2> Exchange between figure color and background color
<3> Reduce background color area by introducing brown frame
<4> Reduce brightness of background color
<5> Reduce brightness and saturation range
<6> Modify background color to white and figure color to black
<7> Modify background color to white and figure color to brown
<8> Modify background color to brown and figure color to black
<9> Modify background color to red and figure color to white
<10> Modify background color to blue and figure color to white
<11> Reduce overall saturation (only in experiment 2)

Figure 2. Color patterns for logos in experiment 1 and 2

Figure 4. Samples of streetscapes displayed in experiment 2

3. Results

3-1. Experiment 1

Three factors are identified by factor analysis (principal component solution, varimax rotation) of the mean values of the ratings (Table 1). They are preference, visibility, and warmth. The scale "Similarity to the original logo" has a comparative large coefficient for factor 1, preference.

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Table 1. Factor coefficients (experiment 1)

Scales	Fac. 1	Fac. 2	Fac. 3	Communality
Preferred - Not preferred	0.90	-0.03	0.08	0.82
Beautiful - Not beautiful	0.88	0.08	0.01	0.78
Familiar - Unfamiliar	0.85	0.06	0.28	0.81
Similar to the original logo - Unsimilar to the original logo	0.76	0.21	0.23	0.68
Composed - Uncomposed	0.45	-0.74	0.09	0.76
Visible - Invisible	0.28	0.88	0.06	0.86
Loud - Conservative	0.21	0.90	0.15	0.88
Warm - Cool	0.21	0.08	0.96	0.98
Factor contribution (%)	40.7	27.6	13.7	82.0

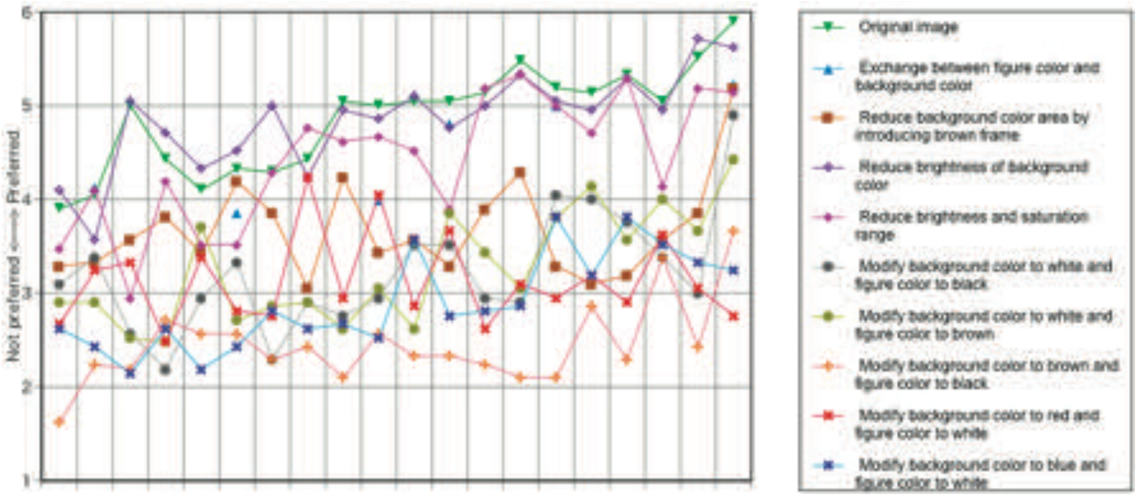

Figure 5. Mean ratings of preference on the 7-step scales (experiment 1)

The mean ratings of preference are shown in Figure 5. Modification patterns that retain the original colors, such as the cases “Exchange between figure color and background color,” “Original,” and “Reduce brightness of background color,” show relatively higher values. The ratings of the scale “similarity to the original” are also relatively higher in these cases, even though the influence of figure design is small. These results suggest the importance of retaining a logo’s hue.

The perception of visibility is defined predominantly by the color combination. A white logo against a blue or red background is the most visible.

3-2. Experiment 2

Three factors—composedness, visibility, and warmth—are derived by factor analysis of the mean values of the ratings. Preference is a complex factor of factors 1 and 2. This is the main difference in comparison to experiment 1, and it suggests the availability of color modification rules that make the signboard harmonious with the streetscape, and visible.

Composedness feeling received a high rating for less-saturated-color patterns, “white background and black figure,” “brown background and white figure,” etc. Visibility feeling received a rating similar to the feeling of composedness, but it differed in some ways; for example, while the originals had highly visibility, brown background and black figures had low visibility. Highly composed and visible feelings were obtained for the original patterns and for low background brightness, small difference between the brightness and saturation of the logo and the background colors, overall low saturation, exchange between figure color and background

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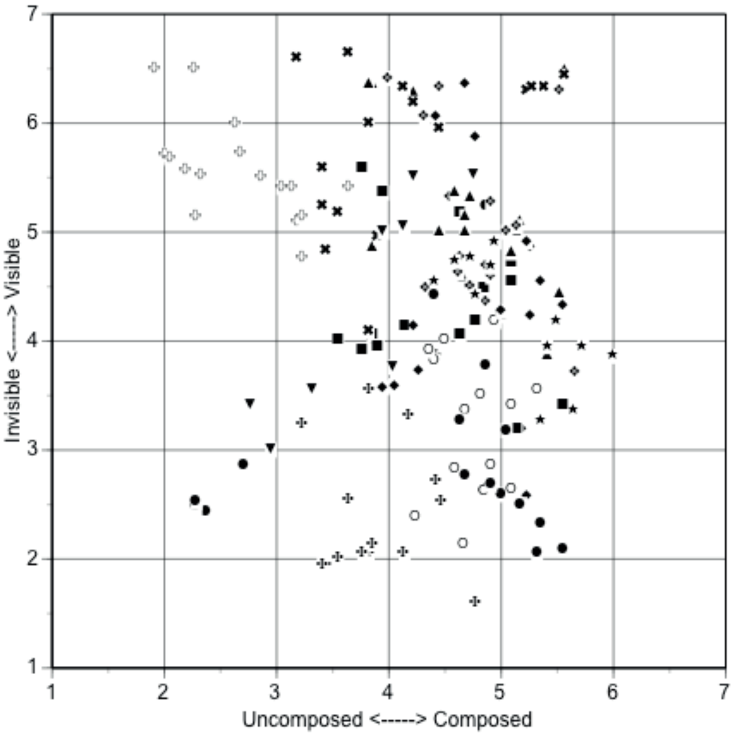
color, red and white combination in the case where the original logo colors are warm colors, etc. (Figure 6).



Color modification type	symbol
1 Original image	▲
2 Exchange between figure color and background color	▼
3 Reduce background color area by introducing brown frame	■
4 Reduce brightness of background color	❖
5 Reduce brightness and saturation range	◆
6 Modify background color to white and figure color to black	●
7 Modify background color to white and figure color to brown	○
8 Modify background color to brown and figure color to black	✣
9 Modify background color to red and figure color to white	✖
10 Modify background color to blue and figure color to white	✧
11 Reduce overall saturation	★

Figure 6. Mean values of composedness and visibility in experiment 2

4. Discussion

The experimental results suggest that three types of color modifications can be used in a signboard to provide composedness to a streetscape and for high visibility of a signboard. They are tone change with retention of the original hue, exchange between figure color and background color, and the use of a red-white color combination in cases where the original logo colors are warm colors.

To confirm the validity of these color modification rules, it is necessary to carry out an experiment evaluating streetscape images when there are many signboards; a line of signboards would require another aspect to be considered: the harmony among the signboards. I intend performing such an experiment.

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Representation of texture and interreflection using spherical mirror for mixed reality

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Abstract

This paper proposes a method to keep optical consistency between the real environment and virtual objects in Mixed Reality (MR) by representing texture and interreflection. A condition of interreflection determines appearance of virtual objects. This paper proposes a method to represent interreflection and material properties using spherical mirror. The proposed method is capable of rendering not only reflected real environment onto virtual objects but also reflected virtual objects onto real environment. In addition, it is capable of rendering material properties including intensity of interreflection and surface roughness. The interactive application with combination of the proposed methods can display MR representation with low computation cost.

1. Introduction

Representation of texture and interreflection to keep optical consistency between the real environment and virtual objects is important in Mixed Reality (MR). Debevec (1998) has represented the interreflection using a projected a part of spherical mirror in a captured image to a modelled space. Powell et al. (2001) has proposed an estimating method of light sources position with the use of two spherical mirrors in order to realize a realistic rendering. Sato et al. (1999) estimated light sources position using two cameras with fish-eye lens. In these methods, however, the area of representation of the virtual object has been limited because the position of the camera and spherical mirror was fixed.

This paper proposes a real-time representation method of interreflection and material property of a virtual object using spherical mirror using 3D marker consisted of 2D markers and spherical mirror (Yasumuro et. al 2003).

2. Proposed method

The proposed method is capable of rendering reflected real environment onto virtual objects using Sphere Mapping that is one of methods of environment mapping. Then the method represents local interreflection onto the virtual object by blending the color of the object with color in image of spherical mirror while changing the ratio of each color. Moreover the method represents surface roughness by means of changing the resolution of image of spherical mirror.

This paper uses Torrance-Sparrow reflection model that is one of Bidirectional Reflectance Distribution Function (BRDF) in order to represent material properties of a virtual object. Equation 1 is the formulation of Torrance-Sparrow reflection model.

$$I = K_d \cos\theta + K_s \exp(-(\sigma \cdot \theta/2)^2)/\cos\theta \qquad (1)$$

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Material property of a virtual object depends on the appearance of gloss on the object. If gloss is strong, we feel the object has smooth surface. An appearance of local interreflection on an object is also affected by gloss. So the proposed method represents the local interreflection onto the virtual object by blending the color of the virtual object with color in image of spherical mirror based on the ratio α of the diffuse reflectance and specular reflectance of the virtual object. When the ratio α is 1.0, strong gloss appears on the object. Then it looks like a metal. When the ratio α is 0.0, gloss doesn't appear on the object. So it looks like a mat ceramic. Figure 1 shows three rendering results of teapot with different value of the ration α (1.0, 0.2 and 0.0). The results show the proposed method can represent different material properties by controlling the ratio α.

(a) α = 1.0 *(b) α = 0.2* *(c) α = 0.0*

Figure 1. Rendering results of local interreflection on virtual object

The spread of specular reflection that shows surface roughness can be described by parameter σ in equation 1. To represent surface roughness of a virtual object, the several spreads of specular reflection are simulated for a sphere while changing the parameter σ. Then an area that shows the spread of specular reflection in the simulated image is extracted, and mask image for conversion of the resolution of image is prepared. When we represent a virtual object with arbitrary surface property, the image of spherical mirror is blurred by this mask image that matches the surface property. Figure 2 is an extracted image that shows an area of spread of specular reflection in a simulated image with σ = 60, and figure 3 shows the prepared mask image.

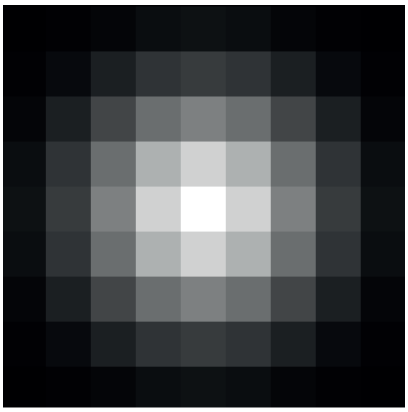

Figure 2. Extracted image of specular area

0.0	0.1	0.2	0.2	0.2	0.1	0.0
0.1	0.3	0.4	0.6	0.4	0.3	0.1
0.2	0.4	0.8	0.9	0.8	0.4	0.2
0.2	0.6	0.9	1	0.9	0.6	0.2
0.2	0.4	0.8	0.9	0.8	0.4	0.2
0.1	0.3	0.4	0.6	0.4	0.3	0.1
0.0	0.1	0.2	0.2	0.2	0.1	0.0

Figure 3. Mask image

Figure 4 is a graph of relationship between value of σ and size of mask that is obtained from simulated images. Using this graph, we can represent a virtual object with arbitrary parameter of surface roughness.

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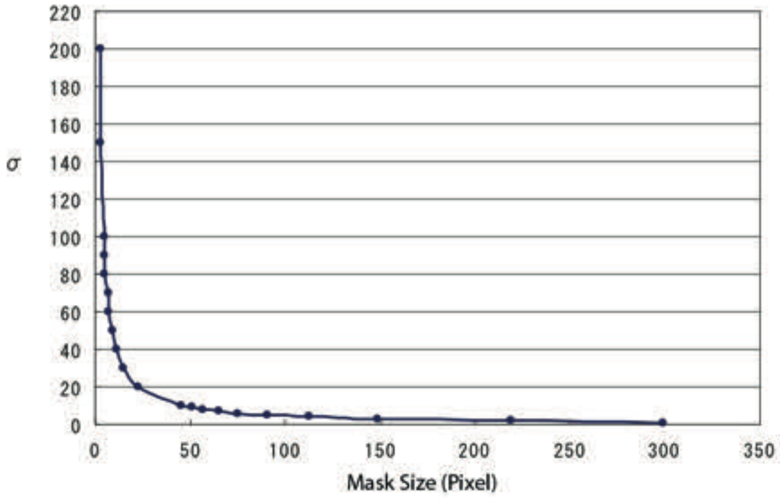
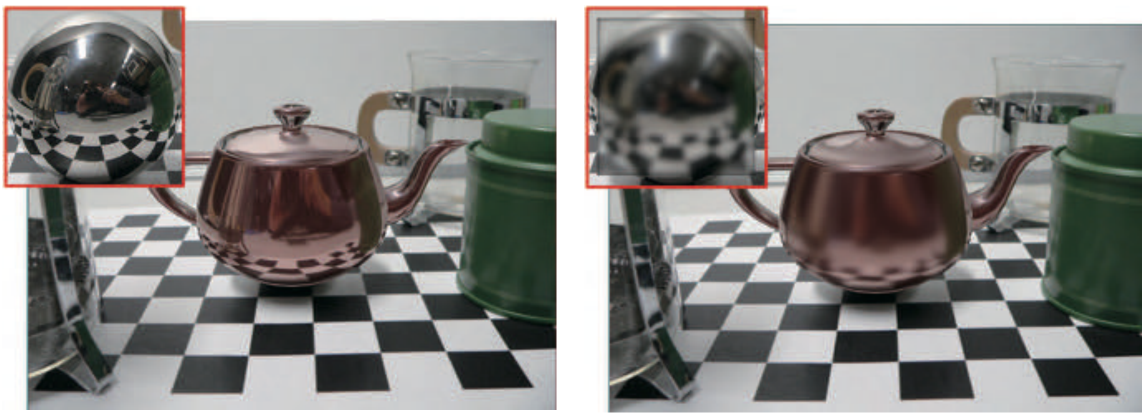


Figure 4. Relationship between σ and mask size

3. Experiments

Figure 5 shows experimental results. Fig. 5 (a) is a picture of Sphere Mapping before the conversion of the resolution of image. In figure, red metallic teapot is virtual object. Figure 5 (b) is a picture of representation image that includes a teapot with rough surface (σ = 20) by the converted resolution of spherical mirror image using the mask image. Fig. 5 (a) can represent the smooth metallic surface. On the other hand, fig. 5 (b) can represent the mat surface.



(a) Before conversion of resolution *(b) After conversion of resolution (σ = 20)*

Figure 5. Results of representation of surface roughness

Next, we made an interactive application based on our proposed method. The application uses a Laptop computer, USB camera and 3D marker, and can move a virtual object and change the material properties as texture interactively. Figure 6 shows a result using the system. Fig. 6 (a) is a captured image of a scene with 3D marker, and (b) is rendering result of the virtual teapot in the scene. Moreover the optical and geometry consistency are kept by representation of the reflected virtual objects onto real environment. This result shows that our proposed method enables realistic rendering of virtual object that reflected the light source environment interactively.

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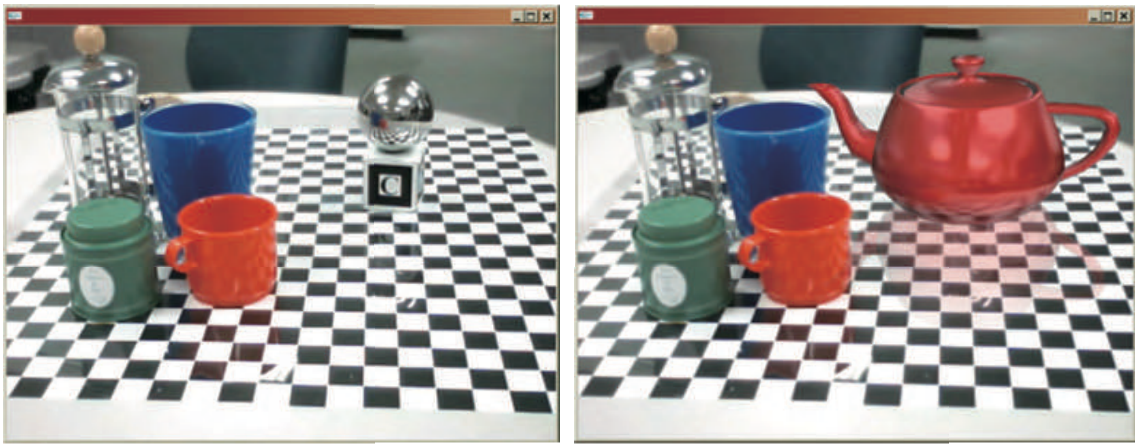

(a) Captured Scene with 3D Marker *(b) Rendering Result*

Figure 6. Example of Application

3. Conclusions

This paper has proposed a real-time representation method of interreflection and material property of a virtual object using 3D marker. Interreflection is expressed by estimating light source environment based on the captured image of spherical mirror. Also material property is expressed by controlling parameters of Torrance-Sparrow reflection model. We made an interactive application with combination of the proposed methods, and the application can display MR representation with low computation cost.

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Monocromatism and the architecture of industrial landscapes

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Abstract

When a colour range mixes with acromatic colours, it loses saturation to the extent that it can be even mistaken for monocromatism and absence of colour. In the evolutionary process of monocromatism, the attempt to replace colour-matter by the energy of colour-light appears as an essential step in the arts in the twentieth century. The possibilities of architectonical perception are maximized by giving both the surrounding environment, as well as the spectator, an active role in the creative process. Monocromatism, initially related to the expression of atemporality and autonomy, eventually becomes the basis of the temporal change of human gaze. We understand the architecture of industrial landscapes as a dialectical game of oppositions, representing both the permanent tension between fullness and vacuum; between heavy machinery and thick walls, and light and mobile industrial mechanisms. It moreover represents an opposition between time and change. The possibility of considering industrial architecture focusing on the concept of "ruin" associated to it is built upon an interest in minimally intervening in those industrial settings by inserting a sole essential form that, in its turn, becomes the backbone of the existing spatial forces with the view to turning the perception of material remains into mental spaces.

1. The architectural forms of the industrial landscapes as a dialectical game of opposition.

An industrial location has a permanent tension between fullness and vacuum, a formation, permanently unfinished, of containers, thick walls, that accommodate light and mobile elements related with the industrial mechanics. The visual thought denotes a clear opposition between materials, their different reflexive characters show the viewer the light transformed in diverse textures. We can observe a whole game of relations between the belonging to land, from the most stony to the most viscous, from the rock to the clay, from the stone to the mortar, and the metal world, that receive pieces of big size and gears more precise.

Also it represents an opposition between time and change. In the end it is an opposition to movement. When words like abandonment, obsolete, or cost-effectiveness appears, and stop the activity in these factories, occurs an imbalance, a distension which unleash these characteristic landscapes of stopped time. That perception of the past of industrialization as distension of stopped time makes the perception easier, enabling the immersion in a stabilized sequence of plans and perspectives of material and colour.

The possibility of considering industrial architecture focusing on the concept of "ruin" associated to it is built upon an interest in minimally intervening in those industrial settings by inserting a sole essential form that, in its turn, becomes the backbone of the existing spatial forces with the view to turning the perception of material remains into mental spaces. For this action line, the beginning of the process of project must to detect the main point able to regenerate the cultural perception of landscape.

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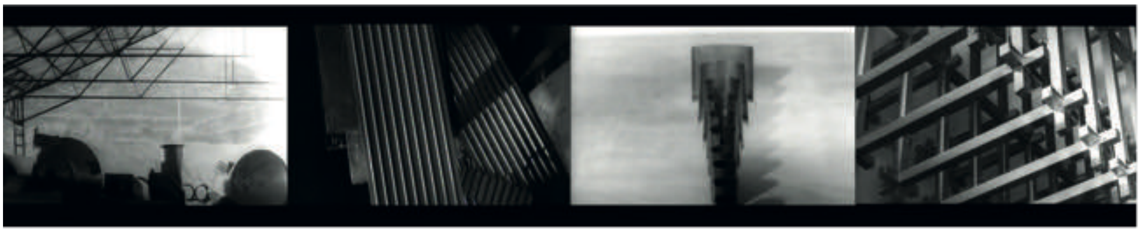

Figure 1.Frame from Operación H, Néstor Basterretxea and Jorge Oteiza

2. Intervention in industrial landscapes

2.1 Visitor center in a cement factory, Atarfe

The old cement factory from Atarfe, is one of the pieces that make up the great landscapes of the Vega from Granada, with characteristic forms of ocupation, old industrial installations, rural buildings and agricultural exploitations. In this location, the whole group of buildings is form by aggregation of new containers built with thick walls. This growth has created a group of volumes out of order.

We look for a characterist form able to regenerate the place and to mark the perception an the memory. The special nature of the great hoppers will form the axle for the new complex entry (Figure 2).

Figure 2. New entry

Around this amazing entry, which sculptural and oppressive character will impress the visitors, we propose a composition by the dialectic between fullness and vacuum, between the solid and the emptiness, using light materials like perforated steel, which reflects the colour of the landscape.

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In that case, the colour study (Figure 3) was made four times, in diffefent moments of day.

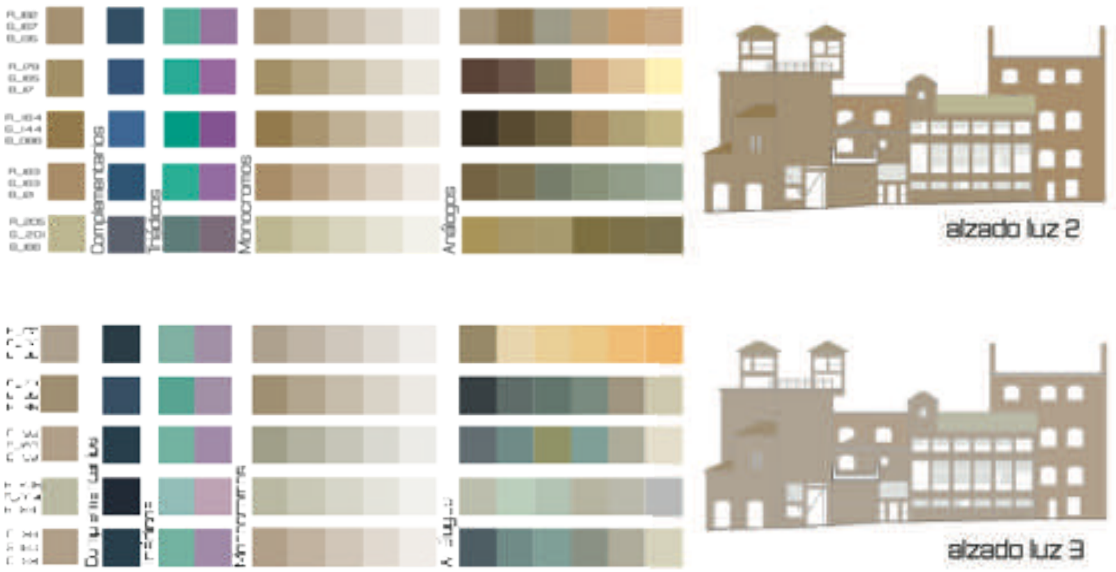

Figure 3. Colour study from cement factory

2.2 Visitor Center in a Gold Mine, Rodalquilar

The old cement gold mine from Rodalquilar form a landscapes that seems to be uniform. However this apparent sameness hides a wide range of colours that increases the extraordinary capacity of seduction on this place, largely based in the extrange combination of the formal singularity and the expressive atmosphere. In Rodalquilar it has no sense the discussion of the priority between line and colour.

In this case, the colour study (Figure 4) pays special attention to the diversity of materials that make up the buildings.

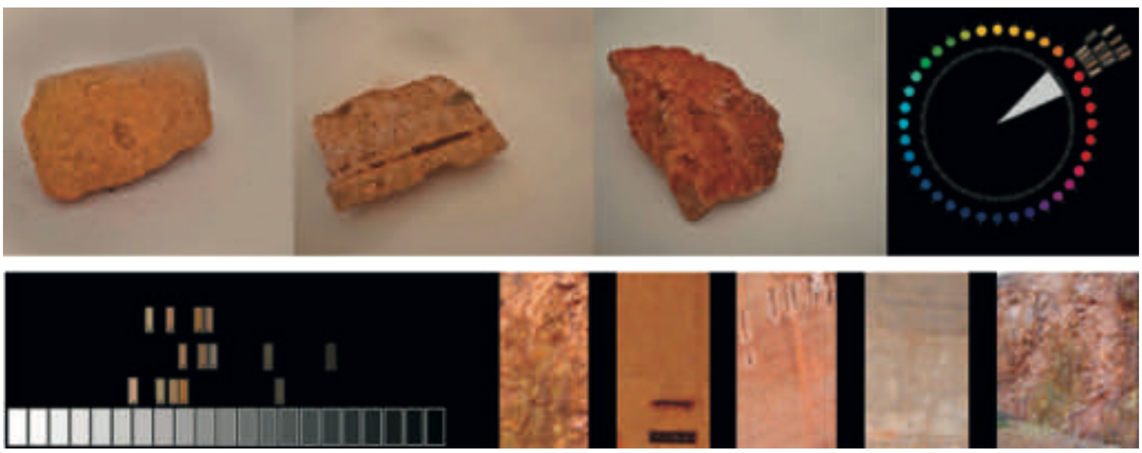

Figure 4. Colour study from the gold mine

The project, despite it punctual character, is a trajectrory from the materiality of the mineral to the sight of Cabo de Gata. It looks from the digged heart in the mine to the see and the sun.

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The plan proposes to cover a volume from the group of buildings, that proves a key for the understanding and the control of thewhole project, with a double skin (Figure 5), formed by a material with refletive and tactile qualities, completely opposite to the other existing materials.

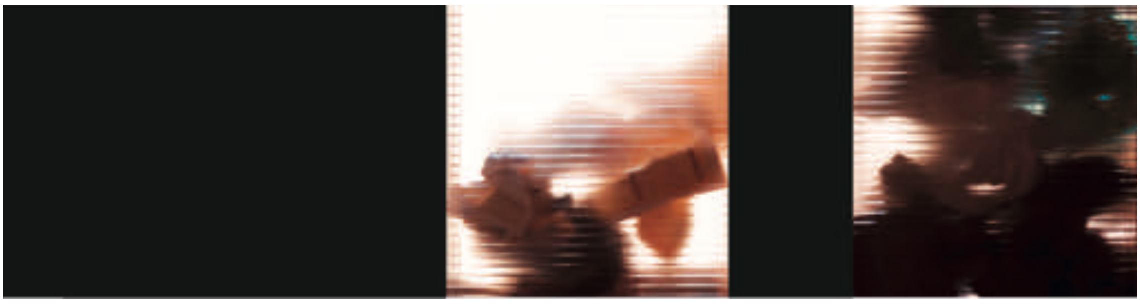

Figure 5. Photography from the double skin

3. Acknowledgments

Research Group "CO3. Arquitectura y color en Andalucía"
Supported by Consejería de Obras Públicas y Vivienda, Government Regional of Junta de Andalucía (Spain).

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Contribution of colour and texture information to the recognition of natural objects

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Abstract

Various visual attributes i.e. shape, colour, and texture etc, contribute to the recognition of natural objects. The colours of natural objects which we memorize are known as the memory colours of the object. It is well known that memory colours have higher saturation than the colours of the real natural objects have. In most of the past studies about memory colour, uniformly-coloured patches were used as stimuli, and the interaction between texture and memory colour wasn't investigated. In this study, we investigated whether texture information of a natural object had an influence on memory colour of the object or not. We measured the plausibility of colour with or without texture information of a cabbage and a piece of a watermelon. The results showed that the most plausible colour for the coloured textured patch had lower saturation than that for the uniform patch had. The colour region which provided high plausibility evaluations was smaller for the coloured textured patch than for the uniformly-coloured patch. These results suggest the addition of texture information restricts the colour region which provides high plausibility as the colour of the natural object.

1. Introduction

When we recognize a natural object, we use memory of the visual attributes, i.e. shape, colour, and texture etc, as cues (e.g. Snowden et al. 2006). However it is unclear how these attributes interact each other. The colour of a natural object which we memorize is well known as a memory colour. We tend to memorize the colour of a natural object as a colour with higher saturation than the actual colour (e.g. Bartleson 1960). There are a lot of studies about memory colour (e.g. Fisher et al. 1956). However, in most of them, uniformly-coloured patches were used as stimuli (e.g. Carpinell et al. 1998), and the interaction of memory colour and texture has not been examined. In this study, we investigated how texture information influences on memory colour. In addition to uniformly-coloured patches, the coloured patches including a texture based on surface of a natural object were used as stimuli. We named the patches the coloured textured patches. We compared the evaluation of the memory colour for the object between in the uniformly-coloured patch and in the coloured textured patch. Then, we investigated how texture information had an influence on memory colour.

There are four hypotheses for the influence of texture information on memory colour. The first hypothesis is that the texture information impairs the memory colour. This means that by adding a texture to chromatic information, it is possible that only texture information establishes the recognition of the object. Thus even with uncertain or ambiguous colour information, recognition of the object can be fully established. This hypothesis would make the colour region, which is plausible as the colour of a certain natural object, to be wider when the coloured patch is textured rather than when the patch is uniform. The second hypothesis is that the texture information restricts the memory colour. In contrast to the first hypothesis, this hypothesis suggests

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that the colour region that is plausible as the colour of a certain natural object is smaller with texture information than without texture information. The third hypothesis is that by texture information we do not imagine the memory colour of a certain object but judge whether the colour is plausible as the object's colour or not. This would bring to the result that the characteristic of memory colour which has higher saturation than colour of real natural objects disappears. Finally, we hypothesized that memory colour and texture information are independent each other. In this case, both the colour region and the most plausible colour will not change regardless of whether the stimulus contains texture information or not. We examined which hypothesis of the four is appropriate.

2. Method

2.1 Observers

Seven undergraduate or graduate students participated in the experiment. They were between 20 and 24 years old. Four were male, and three were female. They had normal or corrected-to-normal acuity, and had normal color vision which was assessed by a Farnsworth-Munsell 100-hue test.

2.2 Apparatus

We used a 19-inch colour monitor (Sony Trinitron Multiscan CPD-G420) controlled by a computer (Dell Vostro 200). The monitor was set with a refresh rate of 75 Hz and a resolution of 1280 x 960 pixels. The gamma characteristics of the monitor were corrected to be linear after measurement by a spectral radiometer (Konica Minolta CS-2000). The monitor was placed in a darkened room. The stimulus was presented at an average height of observers' eyes and was viewed by observers from a distance of 70cm. We didn't use a chin rest.

2.3 Stimulus

We used a cabbage and a piece of a watermelon as natural objects. The stimulus was a uniformly-coloured patch, or a coloured textured patch with the texture information based on surface of them. The texture pattern used for the coloured textured patch was obtained from an image of the object's surface taken by a digital camera (Konica Minolta αSweet DIGITAL DG-5D) under the

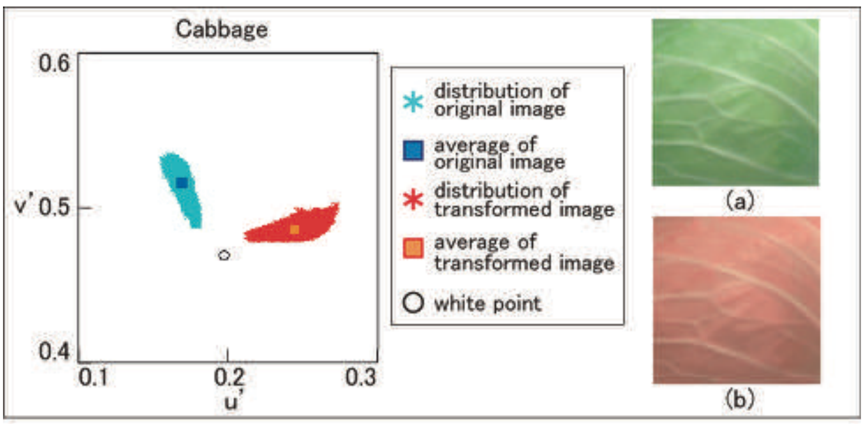

Figure 1. The example of coloured texture patches and the distributions of them.In the left panel, the asterisks indicate the chromaticities of each pixel of the coloured texture patches, and the filled squares indicate the averages of them. (a) The original image. (b) The transformed image.

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D65 illumination. We named this image the original image. We measured the histograms of the chromaticity distribution on the CIE1976u'v' UCS and the luminance distribution of the original image. Then we made many coloured textured patches by shifting the average chromaticity to the direction of hue and saturation while maintaining the luminance and the relative hue angle and saturation of each pixel of the original image to the average chromaticity (Figure1, Hansen et al. 2006). Further, we prepared uniformly-coloured patches whose chromaticity and luminance were the same as the average chromaticity and luminance of the coloured textured patches. The size of the patch was 5.3 × 5.3 deg. Each patch surrounded by a grey background of 20.14 cd/m^2 was presented on the colour CRT display. The numbers of uniformly-coloured patches and coloured textured patches were 91 and 60 for the cabbage stimuli, and 87 and 63 for the watermelon stimuli, respectively.

2.4 Procedure

The experimental session was conducted after we instructed observers to imagine the colour of a cabbage in the cabbage task or the colour of a piece of a watermelon in the watermelon task. The observers' task was to evaluate how similar the colour of the presented patch was to the colour which they imagined as the colour of the object, by using four grades; "very similar (3 point)", "similar (2 point)", "different (1 point)", "very different (0 point)". The observers performed 10 trials for each stimulus. Each stimulus was kept being presented until the observers finished evaluating its plausibility. We calculated total scores of each patch and called the total score *'the plausibility score'*. So, the range of the plausibility score was between 0 point and 30 point.

3. Results and discussion

Figure 2 shows example of the results both in the cabbage task and in the watermelon task on the CIE1976u'v' chromaticity diagram. The each chromaticity of a real cabbage and a piece of a real watermelon under the D65 illumination is also shown in Figure 2. First, we compared the colour of the real cabbage and the most plausible colours for two types of stimuli: the uniformly-coloured patch and the coloured textured patch. The most plausible colours both for the uniformly-coloured patch and for the coloured textured patch were more greenish than the real colour of the cabbage. The most plausible colour for the uniformly-coloured patch had higher saturation than the colour of the real cabbage. This result corresponds to the past studies (e.g. Bartleson 1960). On the other hand, the most plausible colour for the coloured textured patch was less saturated than that of the uniformly-coloured patch, that is, the most plausible colour shifted to the direction of the colour of the real cabbage by adding texture information. This finding is quite new.

Next, we defined the plausibility score of 15 points out of 30 points as a threshold for the chromaticity of the colour which was judged the plausible colour as the colour of natural objects. Then, we compared the colour region providing the plausibility score above the threshold in between the uniformly-coloured patch and the coloured textured patch. The colour region providing high plausibility evaluations was smaller for the coloured textured patch than for the uniformly-coloured patch. Namely, texture information restricted the colour region providing high plausibility evaluations. In the watermelon task, the same tendency was observed as in the cabbage task. Therefore, texture information may contribute to increasing both the precision and the accuracy in the recollection of natural objects' colour.

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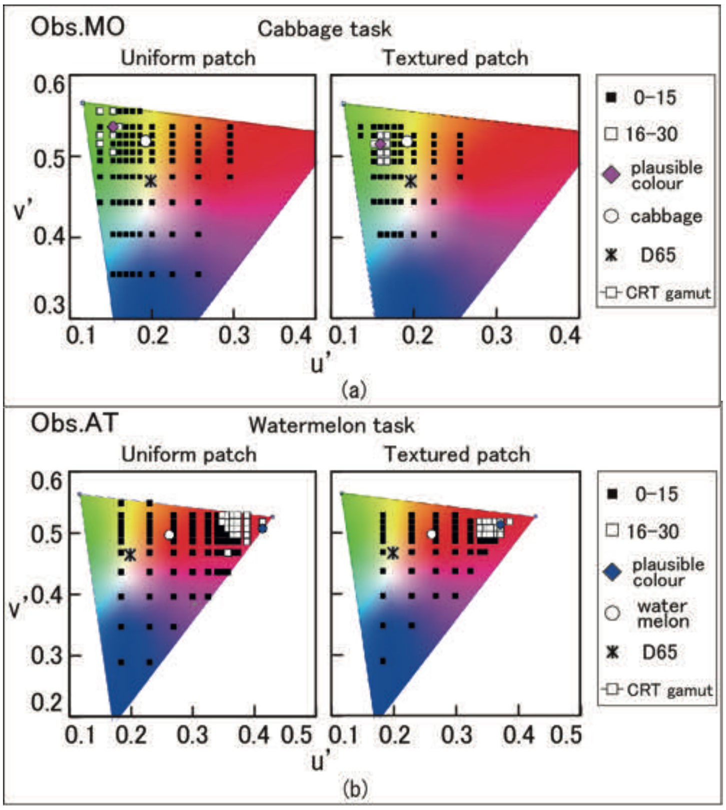

Figure 2. Examples of the results. The upper panels (a) shows the results of observer MO in the cabbage task. The bottom panels (b) shows the results of observer AT in the watermelon task. The left panels show the results of the uniformly-coloured patches, and the right panels show those of the coloured texture patches. The filled squares indicate the plausibility scores of between 0 and 15 points, and the open squares indicate those of between 16 to 30 points. The diamond indicates the most plausible colour for each patch. The open circle indicates the average of chromaticity distribution of real objects.

4. Conclusion

We investigated how texture information influences memory colour. We found that texture information restricts the colour region which provided plausible colour as the colour of real natural objects. Further, the most plausible colour for the coloured textured patch tended to shift toward the colour of real natural objects. These results indicate that texture information influences memory colour.

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PERCIFAL method in use: Visual evaluation of three spaces

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Abstract

In this paper we describe the use of PERCIFAL method for visual registration and evaluation of three architectural spaces in Trondheim: an atrium, a skylight room and a room lit by electrical light. A group of subjects visited those three rooms in August 2010. They were asked to make a spontaneous verbal evaluation as well as evaluation with the help of quality descriptor differentials developed in the PERCIFAL project. Despite differences between subjects, it was possible to find a strong correlation between surface illuminances, the score at *Light level* scale and the impression of openness/spaciousness versus darkness/gloominess. Furthermore, it was possible to find a correlation between the occurrence/absence of chromatic colors in the room and the impression of the room being serious and severe versus lively and playful.

1. Background

PERCIFAL *Perceptive Spatial Analysis of Colour and Light* is a subproject within the Nordic research project *SYN-TES: Human colour and light synthesis; towards a coherent field of knowledge*. SYN-TES is funded by the Knowledge Foundation, Sweden. The project grew from a need to share knowledge and to find better ways of communication across disciplines and research areas that deal with the human experience of light and colour in space. For further presentation of the PERCIFAL method see Arnkil et al.

2. Method

Three architectural spaces in Trondheim, Norway, were chosen for evaluation: 1. Atrium, 2. Skylight room and 3. Electrical light room. The Atrium is a part of the hotel building situated in Trondheim Centrum and called Porthuset. The courtyard is nearly square in plan (11 x 12m) and has a height of 5 storeys. The courtyard is the secondary daylight source for apartment rooms adjacent to it. The glazed roof covers the whole courtyard, some of the window panes at the roof are made of coloured glass; this contributes to a nice play of coloured and uncoloured daylight at the facades of the courtyard, especially during sunshine hours. Daylighting is supplemented by an artificial lighting system that consists of evenly distributed, spherical lamps with compact fluorescent light bulbs, hanging about 3m over the floor. The room is also characterized by a strident colour composition with strong colour contrasts, see figures 1 and 2.

The Skylight room is the largest and most spectacular room in Kunstmuseum, the Art Museum in Trondheim. There is a linear, large and elegantly designed skylight in the room that nearly dominates the visual environment in the room. It has a specially designed internal sun shading device fastened to a steel construction that has a similar shape to the skylight, but is oriented downwards. Different types of lamps (spots and wall-washers) are fastened around the

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skylight, but they were not switched on during the visit. The colours chosen on the room surfaces are solely nuances of grey, see figure 3.

The Electrical light room is a part of the exhibition area in the Nordenfieldske Kunstindustrimuseum, a museum of applied arts in Trondheim. The room has some high and narrow windows that are covered by sun-proof textile roller blinds. However, there are gaps between the blinds and the walls, which became very bright during the visit. The room is lit by halogen light spots distributed over the space and giving light precisely where it is needed. The color composition in the room consists of wooden floor, dark gray ceiling and white walls, except for one that is painted in green. (See figure 4).


Figure 1and 2. Atrium in the Porthuset, photos Kine Angelo.


Figure 3. Skylight room and 4. Electrical light room, photos B. M.

A group of 30 subjects visited those three rooms in August 2010. The participants were: master students of architecture (n=15), a group of electrical engineers (n=13) and architects (n=2). They were asked to make a spontaneous verbal evaluation as well as evaluations with the help of quality descriptor differentials developed within PERCIFAL: *Light level, Light distribution, Shadows and light spots, Glare and specular reflections, Light colour, Surface colour, Interaction between space, objects and people.* During the same visit the illuminance was measured in a few places in the room and colour sample matching was carried out.

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3. Results

Spontaneous linguistic description:

1. Atrium: comfortable/relaxing (13), colourful (9), open (8), playful/alive (7), high/tall (7), contrast variety (4), exciting (3), modern (3), warm (2), flat (2).
2. Skylight room: spacious/open (15), light/aerial (14), comfortable/comf. lit (13), large/high (9), sacred/serious (4), exciting (3), cold (3), calm (2), relaxing (2)
3. Electrical light room: dark/gloomy (30), calm/quiet (12), cosy/comfortable (6), uncomfortable (5), mysterious (4), solemn (4), exciting (3), disordered/messy (2), quiet (2), feels small (2), artificial (2)

The colours in the respective rooms registered by colour matching with NCS samples are:

1. Atrium: dark gray stone S 8500-N and red carpet S 3560-Y80R on the floor, dark palisander S 8010-Y70R (-Y80R), white plaster S 0500-N and green painted walls S4050-G70Y on one side and S2030-G70Y on the opposite side of the room.
2. Skylight room: white plaster walls S 0500-N, light blue marble tiles on the floor S 2002-B and around doors: S 1002-B
3. El. light room: wooden floor S 4502-Y, gray ceiling S 6000-N, plaster walls painted white S 1500-N, one painted green S 7020-G, black curtains S 9000-N.

The illuminance measured during the visit was:

1. Atrium: 1750 – 2300 lux on walls, 1300 – 6800 at tables, 920 lux at the counter
2. Skylight room: 1200 – 1650 lux on walls, 1350 – 2550 on the floor
3. El. light room: on white walls 150-200 lux, 800 – 1050 lux at the center of light spots and objects, 50 lux on the green wall, 300 – 800 lux on the table 1500 – 2000 lux on the daylighted reveals.

The evaluation results for some of quality descriptors used in the PERCIFAL project are presented in figures 5 and 6; 7 steps differential.

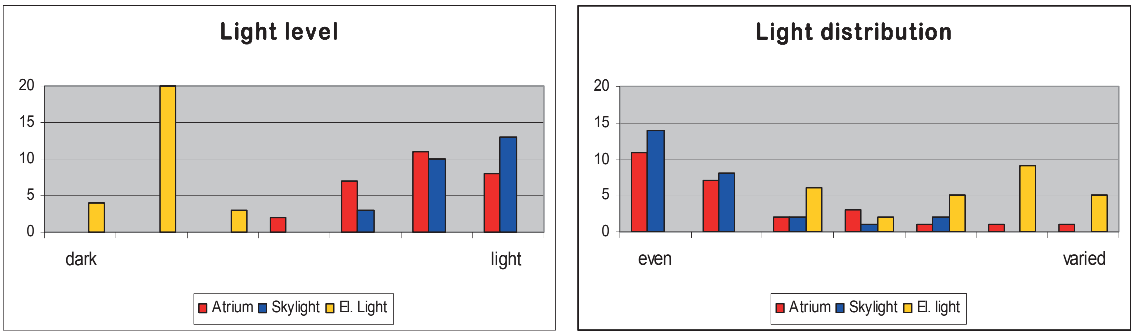

Figure 5. Evaluation results for Light level and Light distribution.

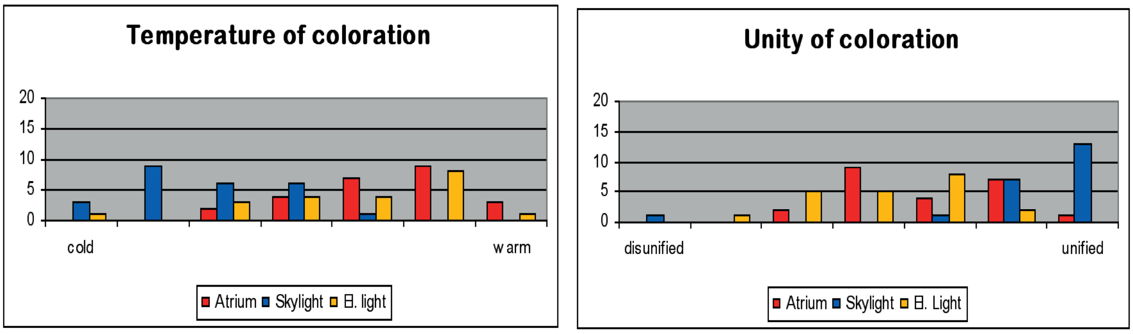

Figure 6. Evaluation results for Temperature and Unity of coloration

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4. Conclusions and discussion

The Atrium was described as most colourful, open and playful/alive of all rooms but also as the most comfortable. The colour composition was most vigorous of all rooms. Both, the chromatic red-green contrast and the luminance contrast between walls and window frames are strong. The coloured glass on the roof appearing as reflections on the window glass contributed probably to the impression of the space being playful/joyful. Since it was the only room having strongly chromatic, warm and bright colours, there is an indication about the coherence between the occurrence/absence of such colors and the impression of the room being respectively serious/severe versus lively/playful.

The Skylight room was described as lightest, most spacious, and most serious/ascetic of all rooms. At the *Light level* differential it was evaluated as the lightest one despite of the fact that the measured illuminance was somewhat lower than in the Atrium. Since the room has the coldest and the most uniform colouration, with nearly no colour or luminance contrasts, it is very probable that the clear impression of lightness and spaciousness is strengthened by this faint, cold and uniform coloration.

The Electrical Light room was liked least of all. It was described as most dark/gloomy, most calm/quiet and most intimate of all rooms. The room was evaluated as darkest in *Light level* and most varied in *Light distribution,* something that is in agreement with measured illuminance values. The very high illuminances at window reveals, caused by sunlight, were evaluated as glary by 7 subjects and gave an important reference.

The PERCIFAL method was evaluated as a very useful tool for helping to observe, analyse and better understand spontaneous evaluation of visual qualities of architectural space. Most concepts were easily understandable, besides of *specular reflection* and *modelling*. To improve the method the scale for *modelling* could be changed to e.g. *planar – three-dimensional* instead of *diffuse – clear*. The skin colour was evaluated as most natural, the textures as most clear and it was easiest to read in rooms with daylight predominance. The clearest correlation in this survey was found between illuminance values measured in a room, the score at the *Light level* differential, fig. 5, and the linguistic description of the room: openness/spaciousness versus darkness/gloominess.

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Interaction between colour and light
… and different spaces
… and materials
… and sound/composition/music

Gisela MEYER-HAHN
atelier farbton

Abstract

Colour-Sound-Concerts are the artistic expression of my work with perception and effect of colour and light in connection with sound and space. Our senses react with approximately 165 single perceptions to all approaching influences. It is impossible to elude them. Simultaneously our brain assimilates these influences. It is informed by experience and cultural influences, connecting them intricately. Building on understanding these relationships I develop the compositions for the concerts, in which light and colour constitute an individual instrument within the full score. The artistic expression is modified according to place, instruments/voices, interacting with the light. The themes of the compositions refer to different sources - of nature, composers or quite abstractly. The perception of the audience is focused on the space constantly changing through light and sound. Always searching regularity in this complex-space-composition between light, colour, tone, space and their effect on the human senses insights have condensed, concerning some of these parameters; irrespective of cultural background, previous knowledge, time, instrument or location. They are not concluded yet. They open new pathways I walk analytically, experimentally. Illumination has by now metamorphosed into self- illumination – a new material development. This path I explore with my manifold projects made of light and colour.

1. Idea, source and content of colour-light-concerts

The light concerts appeal to our individual perception. In the present, NOW. They evolved from the idea to find out whether audible single tones can be perceived with individual colours by the human senses. If so- which tones and colours? And are hearing and seeing then exchangeable? Do they activate the same connections? A great variety of research work has been done in this field so far; the results, however, have only rarely corresponded with my findings gained from practical experience. My intensive work since1990 is, to notice, where and how the colour blue in baltic area is in evidence, to notice how cultural imprint and the resulting background knowledge and patterns of thought may strongly determine opinions and manipulate individual perception. The results were quite surprising, and often of completely contrary content referring to common thinking.

My intention was,to counteract these effects and I had the chance of contributing a light-choreography to a complex piece of art with the help of a specific light-stage. With musicians and composers we developed our first light-concert on the occasion of the Lyonel-Feininger-Exhibition in the New National Gallery in Berlin. From the beginning the tone g and the colour red were very familiar to the Asian cellist, the cis in combination with turquoise to us northerners. My interest in the why and where was awakened there, the interest in the laws governing both, light and sound, irrespective of the cultural-area - the how of the concerts still evolves as a mixture of an analytical procedure to discern more by doing and checks in practice to see whether

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, the many deductions available in the literature are accepted by the audience; e.g. the transfer of tonecolours to lightcolours. Or are there specific compositions or texts which transferred to colour and light, undergo an increase or a decline in the intensity of their message? Or is it just our own composition, created for specific places, spaces, musicians, times ...unfolding their effect only in their singulary?

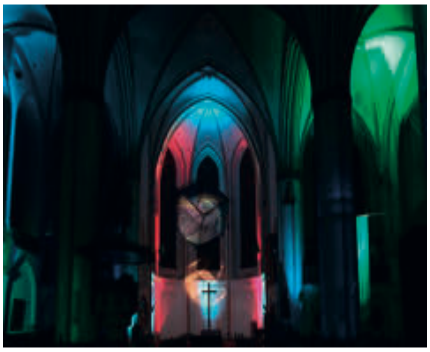
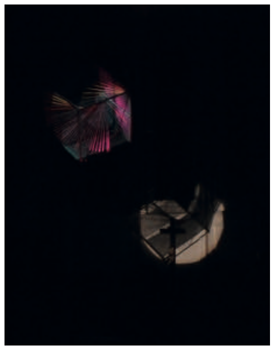
And always interesting the reactions of synaestheticians.

2. Interaction between colour and light and different spaces

A first contact with the space is an essential precondition for each performance. We have given concerts in nature, in an amphitheatre, in a huge basement garage (Biennale Lichtkunst, Frankfurt), in museums, in secular and sacred spaces, in the outer space of a facade, in a castle, a concert-barn, a planetarium... The dimension of the space, its quality, its architecture, its characteristics, its peculiarities are important to me for the development of the choreography and the performance. This also influences the kind of the music, of the composition, of the instruments and also how the light will be installed: sound volume, colourfulness, rest and silence, movement, the choice of colours ...

The prerequisites for my choreographies lie in the intensive and permanent observation of the light in nature – also under extreme conditions. Thus I analytically grasp details like the shades of the colours, the position of the light, the acoustic influences, the movement of the wind, temperature ... and I compare light and colours each hour. The results of this process influence my artistic work. So it is only natural, that an open air colour-sound-concert, influenced by the noise of the rapids of a river (CH- Baden/ Limmat 2002) is defined by different parameters than a concert in a cathedral in winter (Kaiserdom Königslutter).

I add my fine fabrics to the specific room, and I brace them so that they produce shadows or they reflect the light. They are also a means to add a new dimension to the dimension of the room. My light-Kubus normally is an independent centre which makes it possible for people to hold their concentration so intensively that they can experience a very special and close symbiosis of light, colour, movement, sound and room-dimensions in which lines and space are familiar graphic elements.

3. Interaction between colour and light and materials

Colour and light need surfaces so that the human eye is able to perceive them. I employ light with the constant alternation of its possible intensity, so that a space can be perceived as haptic, or it can simply as a wall, or as resonance for sound. Light, broken through a prism, can dissolve the

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architecture of a room completely. When at the same time you listen to spheric sounds, your thoughts will drift away. When the music of a tango is played, shades of red might concentrate and bring you back into the present.

The material must allow the colours to come alive- the light on a brick wall must have a different quality than the light on a lime-painted wall in case you are expecting the same results. So the materials of my own studio guarantee the creation of exactly the colour effect I want.

While most colours are caused by the illumination of spaces of varied surface-qualities, I have, through developing and experimenting with new materials, succeeded in creating the effect, that textiles, which are imbedded between panes of glass, seem to shine by themselves, if the edges of the glass are illuminated. When several panes are lined up, the textile structure disappears and the eye can only see the interference lines.

Thus new phenomena appear, giving the musicians new impulses for new sound structures.

4. Interaction between colour and light and sound/composition/music

As a composition single tones, sophisticated scores for atmospheres and moods, texts and phonetics and their contents are woven into a sound and light tapestry. This is realized by the co-operation between composers and interpreters from various cultural backgrounds. (Cambodia, Estonia, Lithuania, USA, Germany …). There have been the following solo instruments so far: cello, piano, guitar, marimba, harp, violin, flute, saxophone, percussion. And choirs have contributed essential elements to the performances.

I myself compose the part for the light and space. Their colour and intensity are closely related to the key, the sound of the instrument, to the motion of light in space, and the musical expression. The basis for this work is my complex background of knowledge, my openness to sensitivity and my practical work including everything from the first conception of my projects to their realization in my work studio. On the claviature of the light-mixer I always play this interaction live. A fugue by J.S.Bach, the pentatonic compositions by Sony Thet, ‘To the Light’ as a mantra by Ugis Praulins, the ‘Ave Maria’ by Franz Biebl, ‘Light my Light’ by Vytatis Miskinis or ‘Lux Auruque’ by Eric Whitacre – each existing composition as well as any other sound development requires a very specific production with respect to the quality and quantity of light, Temporarily the light can carry on optically with the content of the music - then there is acoustic silence, but the experience of the concert is intensified by the great tension of the sense of sight.

The interpreters have an additional score: in the course of the concert they change their positions, so that for example the singers of the choir are able to move through the whole room (even through the beams of light, which might create big shadows) or, if necessary, they can even rotate on their own axes. Sound and light guide the perception of the concert-visitor through the room. Thus it can be prevented, that a sort of ‘frontal stage experience’ concentrates this perception physically.

5. Result

The live colour-light concerts have several purposes. For the public, for the artists, for the research. To develop them in their whole complexity , it needs all attention about perception and science of the appearance and workings of light and colour. One insight gained is that parameters like time, architecture, space, surface, instruments, compositions,… while working interactively with light

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and colour, have an intensive effect on human perception. If only few parameters are perceptible, like one tone, one colour, one space, one movement, one quantity of light and colour, people tend to experience identical feelings. The more parameters of the complex composition are active, the more individual sense works. The more our senses are opened to the perception of the 'stories' of light and colour, sound and space, the more we can understand the connections with the rules of the universe – and can take account about them. The 'colour-sound concerts' are my artistic contribution – in practice and in comparison with the knowledge of different fields of research - to find out more about twin phenomena of our perception, having worldwide validity.

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Development of plug-in for optimizing colours of graphic and web designs for persons with dichromatic vision deficiencies

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Abstract

The purpose of this study is development of plug-in, which simulates dichromatic forms of colour vision deficiency, in consideration with the actual viewing conditions in order to enable designers to check how their work will look to "colour-blind" people. The accuracy of plug-in algorithm is evaluated by eight registered dichromatic persons, who perceived negligibly little or no colour differences between original and simulated images. The other conclusion deducted from the experiment is that decreasing in temperature colour of illuminant leads to even more reduced colour gamut of dichromats and, thus, to enhanced number of hardly distinguishable colour combinations. The other important functionality of this developed plug-in is image processing which results in increased number of distinctive hues that people with certain type of dichromacy can perceive. The developed plug-in allows creation of user-oriented design so that information can be accurately conveyed to as many individuals as possible.

1. Introduction

The percentage of human population has some form of colour vision deficiency (CVD) is significant - approximately 8% of the male and 0.5% of the female population, so it's advisable for web and graphic designers to be aware of colour vision deficiencies' frequency and avoid excluding "colour-blind" people from their designs.

Dichromacy is a moderately severe type of colour vision deficiencies which occurs when one of the cone types is missing (the L type in the case of protanopia, the M type in deuteranopia, and the S type in tritanopia). Compared with trichromatic vision, dichromatic vision entails a loss of hue discrimination and results in a reduced colour gamut (Birch, 2001).

There are many scientific reaserches and proposed methods for transforming trichromatic into dichromatic colour gamut, but the method defined by Brettel et al. (1997, 1999) is widely accepted and used.

Despite the relevance of viewing environment in which colour sample is observed, little has been published on how it affects people with common colour vision deficiencies.

Baraas et al. (2010) tested the colour constancy of people with red-green colour deficiency and came to conclusion that protanopes and deuteranopes performed more poorly than normal trichromats in a task requiring the discrimination of illuminant changes from surface-reflectance changes.

With aim to allow prediction of accurate colour appearance under various viewing conditions, the CIECAM02 colour appearance model was developed (Fairchild, 2005).

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2. Method

2.1 Simulation and re-colouring method

The algorithm of plug-in (Figure 1) implements the transformations of the CIECAM02 colour appearance model, and Brettel et al.'s dichromacy simulation method, based on the LMS (cone response) space. Since dichromats lack one class of cones, they confuse colours that differ only in the relative excitation of the missing cone response. The value of missing cone response is calculated from two existing responses. Including the CIECAM02 transformations, the influence of viewing conditions on dichromatic gamut can be also simulated.

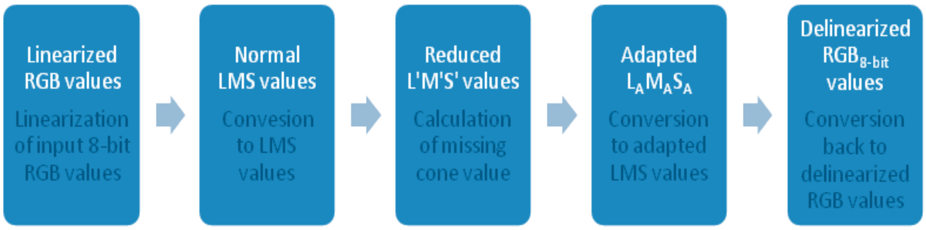

Figure 1: The algorithm of dichromacy simulation

The algorithm of image re-colouring (Figure 2) is based on mapping information from the red/green into the blue/yellow dimension, which is accomplished by changing the hue and saturation values of problematic colour combinations.

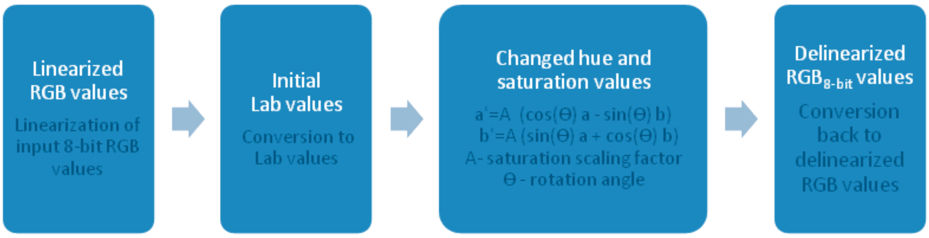

Figure 2: The algorithm of image re-colouring

2.2 The developed plug-in

Plug-in is written for Adobe Photoshop and other compatible graphic software, using the Filter Meister plug-in development environment (Figure 3). Plug-in settings are grouped in three frames:

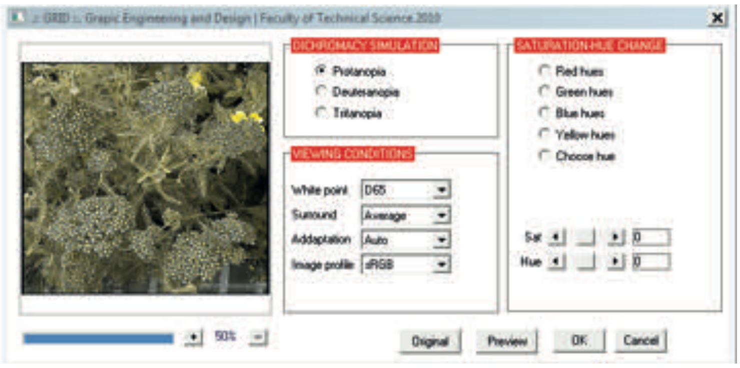

Figure 3: The interface of the developed plug-in

1) Dichromacy type
2) Viewing conditions settings
   – White point
     (opt: D65, D50, F11, A);
   – Viewing surround
     (opt: Average, Dim, Dark);
   – Degree of adaptation;
   – Image profile;
3) Hue and saturation settings.

Based on spotted problematic colour combinations, image can be processed selectively in the way that hue and saturation values can be altered separately for red, green, blue, yellow tones or any specific colour chosen using mouse cursor.

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3. Results and discussion

The accuracy of plug-in algorithm is evaluated by eight registered dichromatic persons (four deuteranops and four protanops). The observers compared and evaluated the simulation result of test chart (digital GretaMacbethSG colour checker) on monitor and the physical GretaMacbethSG colour checker viewed in light box (illuminants: D65, D50, F11 and A) in controlled conditions.[1] Table 1 summarizes the evaluation responses.

Table 1. Mean evaluation value and standard deviations between original GretaMacbethSG chart and simulated test chart (Response scale: 0- absolute colour dismatch, 10-absolute colour match)

	D65	D50	F	A
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Protanops	9.8 (0.2)	9.8(0.2)	9.4(0.2)	9.6(0.3)
Deuthernops	9.9(0.1)	9.9(0.2)	9.5(0.2)	9.6(0.2)

From Table 1 can be concluded that dichromats perceived negligibly little or no colour differences between original and simulated images, which confirms reliability of plug-in algorithm. That result presents fundament for further analysis of simulated images.

The conclusions deducted from the analysis of simulated images and also confirmed with dichromats' observations are that: a) decreasing in temperature colour of illuminant leads to even more reduced colour gamut of dichromats and, thus, to enhanced number of hardly distinguishable colour combinations; and b) changing viewing surround from average to dark leads to better image contrast, and, thus, to slightly increased initial colour gamut of dichromats. The appearance of the ECI2002 RandomLayout chart and protanopic simulations after changing illuminant, as well as corresponding colour gamut (in Lab space), are shown in Figure 4. The same results are obtained for deuteranops.

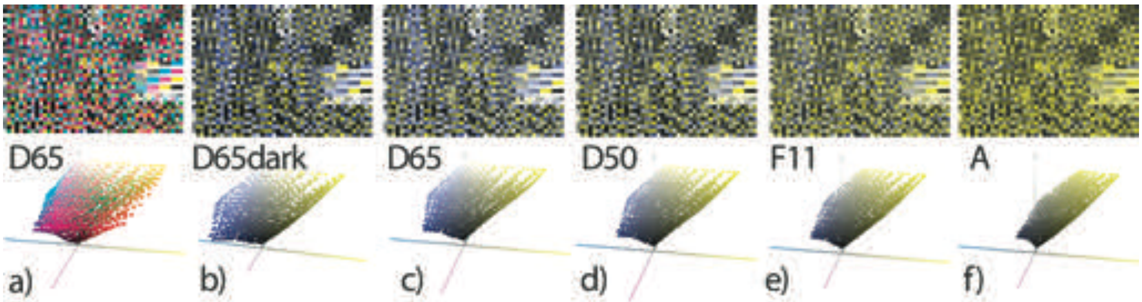

Figure 4: a) Initial image- ECI2002 Random Layout chart (white point D65) and its 3D colour gamut. Simulated protanopic version and correspondent colour gamut (gamut plane) in the case of illuminant: b) D65-6500K and dark viewing surround, c)D65-6500K, d) D50-5000K, e) F11-4000K, and f) A-2856K.

Figure 5 shows shifts in protanopic and deuteranopic colour gamut caused by illuminant and viewing surround change (test image: ECI2002 Random Layout chart).

1 Dichromats evaluated separately the first 18 patches of GretaMacbethSG colour chart, since the last 6 patches are achromatic colours. The tritanopic simulations were not taken into consideration in this work.

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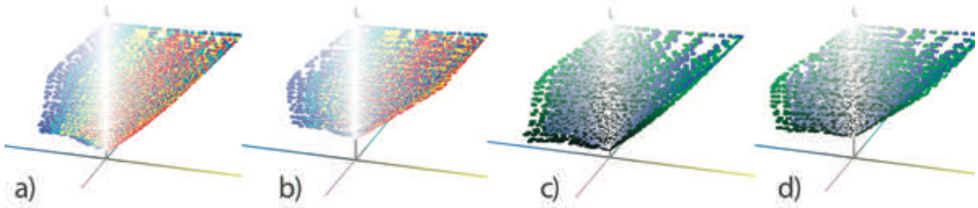

Figure 5: Change in colour gamut caused by illuminant change (red: A, yellow: F11, cyan: D50, blue: D65) for: a) Protanopia and b) Deuteranopia simulation; Change in colour gamut caused by viewing surround change (blue: D65, average; green: D65, dark) for: c) Protanopia and b) Deuteranopia simulation.

The other important aim of this developed plug-in is image processing which results in increased number of distinctive hues that people with certain type of dichromacy can perceive, without significant reducing aesthetical attractiveness and naturalness of the image for 'normal' viewers. Based on dichromats' observations, the image re-colouring gives positive results. In Figure 6 is presented example of obtaining distinguishable colour combinations for protanopes by shifting red hue values to magenta and enhancing saturation value of green tones.

Figure 6: a) Initial image, b) Protanopia simulation, c)Recoloured image, d) Simulation after re-colouring

4. Conclusion

The developed module allows designers "to view the world through their eyes" and then take advantage of such visualizations to apply colour schemes that are "safe" for anybody under all viewing conditions.

Acknowledgments

This work was supported by the Serbian Ministry of Science and Technological Development, Grant No.:35027 "The development of software model for improvement of knowledge and production in graphic arts industry".

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Sensitivity evaluation study of LED lighting colors based on natural light

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Abstract

The development of lighting source till now has been focusing on the high performance and function; however, now there is strong awareness that the lighting products should be developed from user's perspective reflecting the physiological and psychological of people. Accordingly, there is increasing number of studies on the sensitivity response of users. Since the change in lighting color results in clear psychological effect in sensitivity response, this study suggests the LED lighting colors based on the natural light. The study will evaluate the sensitivity response by analyzing and exploring the characteristics of people's sensitivity who respond to the LED lighting colors. The results suggest that there is certain range of preferred color temperature and brightness value and people's preference does not change as the natural light changes continuously. It was possible to confirm that the LED lighting colors give impact on the sensitivity response through this study.

1. Introduction

The development of lighting source till now has been focusing on the high performance and function; however, now there is strong awareness that the lighting products should be developed from user's perspective reflecting the physiological and psychological of people. [1] Accordingly, there is increasing number of studies on the sensitivity response of users. According to the sensitivity evaluation of 'Sensibility Evaluation of LED Lighting and Fluorescent Lamp based on Color Temperature', the lighting source with higher color temperature had higher activeness. On the other hand, competence was higher when the color temperature was lower.[2] Since the change in lighting color results in clear psychological effect in sensitivity response, the importance of color and lighting speed became more important in the sensitivity lighting[1] studies and development. [3]

This study suggests the LED lighting colors based on the natural light which gives absolute impact on people. The study will evaluate the sensitivity response by analyzing and exploring the characteristics of people's sensitivity who respond to the LED lighting colors. The purpose of this study is to provide with base data that will widen the understanding on user sensitivity regarding the LED lighting colors, which will be the major lighting source in the next generation.

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1 'Sensitivity lighting' is defined as a lighting method that can improve the life quality of people using the space; by changing the color of light (color, color temperature), quantity (brightness), quality (color rendering index) and lighting method while considering the psychological/physiological characteristics, culture, environment and experience of people and creating various lightings that meet the purpose of the space.[4]

2. Method

This study extracted the LED lighting colors based on natural light and used analysis method of questionnaire survey.

In order to study the LED lighting colors based on natural color, a generalization was required to sample natural color which continuously changes. Light tests were done on clear days forecasted by the Meteorological Administration for the time bands of 8 a.m., 11 a.m., 1 p.m. and 4 p.m. for five days period. Tests were done in Sinchon area of Seoul, east longitude 126° 58’ 1” and north latitude 37° 32’ 32”. LED lightings consisting of five lighting sources (Red, Green, Blue, Warm white and Cool white) were used to simulate natural light by bare-eye method and their values were extracted. Instruments such as illumination-meter and colorimeter were used to prove the similarity between natural light and LED lighting colors created by bare-eye method.

The LED lighting colors extracted from natural light were displayed on a LED Light box and the sensitivity responses were collected and analyzed by questionnaire survey. The questionnaire was evaluation of sensitivity adjectives and the evaluation of preference. Survey objects were five color specialists in 20s or 30s. They are above intermediate-technician level as indicated by Ministry of Knowledge Economy. In the sensitivity adjective evaluation, adjectives related to space were investigated and analyzed. Eight pairs of adjective vocabularies were chosen which were: “high-class - low-class“, “familiar - unfamiliar”, “calm - conspicuous”, “bright - dark”, “like - dislike”, “refined – outmoded”, “classy – cheap” and “attractive – unattractive”. Semantic Differential method (SD method) was used for the evaluation. Regarding the preference survey, subjects were asked to rank four preferred colors and the remaining four colors were regarded as not-preferred colors.

3. Results

The study results of LED lighting colors based on natural light were evaluated and analyzed in two parts; the sensitivity adjective part and the preference part.

3.1 Sensitivity adjective analysis

[Figure 1] shows the color temperature values of LED lighting colors that had been evaluated as the highest and the lowest. Five-stage SD method with eight pairs of evaluation vocabularies was used. There was relationship between color temperature and sensitivity adjectives, except in the “calm – conspicuous” pair. Most of sensitivity adjectives were evaluated high at the color temperature between 5000-5500K and evaluated low at the color temperature between 6000-6500K. In the sensitivity evaluation items, when the color temperature of LED lighting based on natural light was relatively lower, the evaluation was higher.

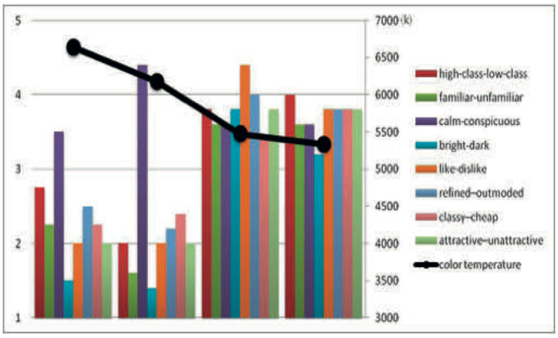

Figure 1. Graph of color temperature and evaluated sensitivity adjectives

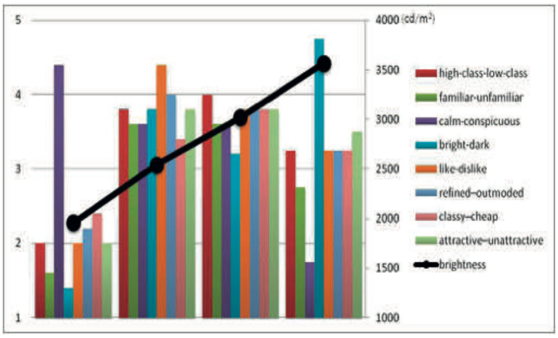

Figure 2. Graph of brightness and evaluated sensitivity adjectives

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[Figure 2] shows the brightness values of LED lighting colors that had been evaluated as the highest and the lowest. Same evaluation adjectives were used like in [Figure 1]. As seen in [Figure 2], most of sensitivity adjectives were evaluated high when the brightness value was between 2500-3500cd/m2. In the sensitivity evaluation items, when the brightness value of LED lighting based on natural light was relatively higher, the evaluation was higher.

3.2 Preference analysis

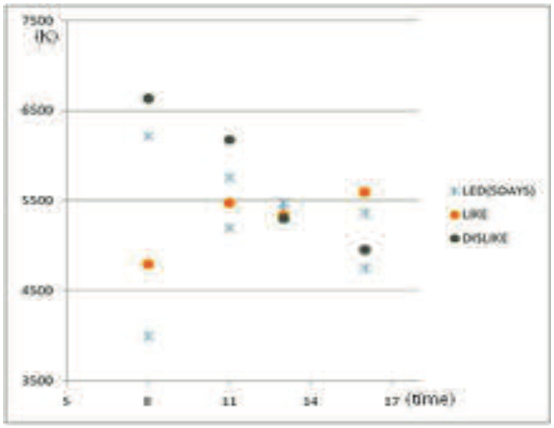

Figure 3. Graph of color temperature preference by time

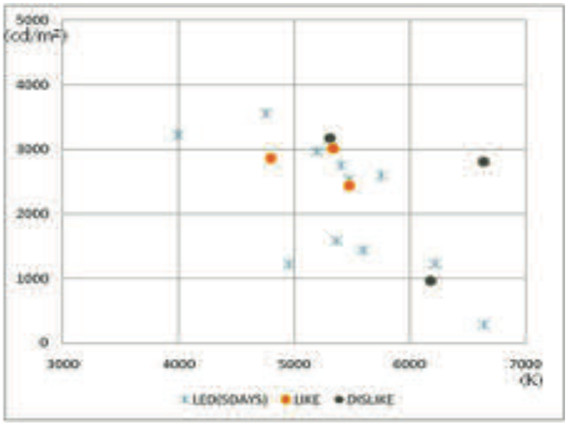

Figure 4. Graph of color temperature(x) and brightness value(y) preference

As seen in [Figure 3], at 8:00 a.m., people prefer color temperature lower than 5500K than higher. When sunset approaches, people prefer a bit higher color temperature than 5500K than lower. The results suggested that there is certain range of preferred color temperature. It is believed that people's preference does not change as the color temperature of natural light changes continuously. And, that range of preferred color temperature is located around 5500K.

The preference ranges of color temperature and brightness values are shown in [Figure 4]. It showed that the color temperature of not-preferred light is relatively higher than the color temperature of preferred light. It is believed that people relatively prefer 'yellowish' colors than 'bluish' colors. The brightness values between 2500-3000cd/m^2 seemed preferred by people; however, there was no significant difference between preferred lights and not-preferred lights by different time bands.

4. Conclusion and discussion

The results of sensitivity response of LED lighting colors based on natural light suggested that the color temperatures between 5000-5500K and the brightness values between 2500-3500cd/m^2 were evaluated high in the sensitivity adjectives analysis. In the preference analysis, the color temperatures of 5500K and the brightness values between 2500-3000cd/m^2 were highly preferred. Therefore, it is believed that there is a relationship between the sensitivity adjectives and the preference. In addition, it is believed that there is positive sensitivity response at the color temperature of 5500K and brightness value in 2500-3000cd/m^2 range. The results suggest that there is certain range of preferred color temperature and brightness value and people's preference does not change as the natural light changes continuously.

It was possible to confirm that the LED lighting colors give impact on the sensitivity

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response through this study. It is believed that continuous studies on LED lighting colors would be required so that more color characteristic analysis would widen the width of understanding on user sensitivity.

Acknowledgments

This study was done as a part of Industry Core Technology Development Project of Ministry of Knowledge Economy and Korea Evaluation Institute of Industrial Technology. [KI002180, Technology Development of Full Color Sensitivity Lighting, Control and Networking]

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Gaussian-metamer-based prediction of colour stimulus change under illuminant change

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Abstract

Predicting how the LMS cone response to light reflected from a surface changes with changing lighting conditions is a long-standing and important problem. It arises in white balancing digital imagery, and when re-rendering printed material for viewing under a second illuminant (e.g., changing from D65 to F11). Von Kries scaling is perhaps the most common approach to predicting what LMS cone response will arise under a second illuminant given the LMS under a first illuminant. We approach this prediction problem, instead, from the perspective of Logvinenko's new colour atlas, and obtain better results than with von Kries scaling.

1. Introduction

Logvinenko's new colour atlas (Logvinenko 2009) is based on idealized reflectances called rectangular metamers that are specified by 3 parameters: α (chromatic amplitude), δ (spectral bandwidth) and λ (central wavelength). The atlas has several advantages, which include illumination invariance, and a reasonable correlation of its coordinate axes with perceptual dimensions. Logvinenko's coordinates can also be used for predicting illuminant-induced colour stimulus changes, because the coordinates in the atlas specify reflectances; and, as such, they can be computationally 'relit' using the spectrum of the second illuminant in order to predict what the resulting LMS will be under it. A significant advantage of predicting the change in LMS's in this way is that it is based on relighting a member of the metamer set of the input colour stimulus; as such, the prediction will be plausible in the sense that it is based on a theoretically possible reflectance, namely, one that is metameric to the input reflectance. As Logvinenko points out, for the von Kries method, there is no such guarantee; so that, at least in principle, the von Kries error can be arbitrarily large. In practice, however, using rectangular metamers (Godau 2010) for the prediction does not always produce the best results on average, perhaps due to the sharp edges in the rectangular functions. However, Logvinenko has also proposed (Logvinenko 2010) a Gaussian parameterization of his colour atlas. Since Gaussians are smooth, we experiment with them as a vehicle for predicting the effect of illuminant change. The first step is to calculate the parameters of the Gaussian-metamer coordinates (KSM), which is analogous to computing the αδλ (also referred to as ADL) coordinates of rectangular metamers.

2. KSM metamers

Consider a three-parameter set of spectral reflectance functions $g_m(\lambda;k_m,\theta_m,\mu_m)$ and a similar three-parameter set of spectral power distribution functions $g_l(\lambda;k_l,\theta_l,\mu_l)$ both of which are Gaussian-like functions for which k, θ, and μ indicate the scaling, standard deviation and center (peak wavelength). The actual functions are not strictly Gaussians, but rather are defined on a finite wavelength interval $[\lambda_{max}, \lambda_{min}]$ and in some cases wraparound at the ends of the interval. We

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have coined the term wraparound Gaussian for spectra of this type. Following Logvinenko (Logvinenko 2010), wraparound Gaussians are defined by the following equations.

If $\mu_m \le (\lambda_{\max} + \lambda_{\min})/2$ we have two cases:

1. For $\lambda_{\min} \le \lambda \le \mu_m + \Lambda/2$:
$$g_m(\lambda;k_m,\theta_m,\mu_m) = k_m \exp[-\theta_m(\lambda - \mu_m)^2]; \quad (1)$$
2. For $\mu_m + \Lambda/2 \le \lambda \le \lambda_{\max}$:
$$g_m(\lambda;k_m,\theta_m,\mu_m) = k_m \exp[-\theta_m(\lambda - \mu_m - \Lambda)^2]; \quad (2)$$

where $\Lambda = \lambda_{\max} - \lambda_{\min}$.

On the other hand when $\mu_m \ge (\lambda_{\max} + \lambda_{\min})/2$, again we have two cases:

1. For $\lambda_{\min} \le \lambda \le \mu_m - \Lambda/2$
$$g_m(\lambda;k_m,\theta_m,\mu_m) = k_m \exp[-\theta_m(\lambda - \mu_m + \Lambda)^2]; \quad (3)$$
2. For $\mu_m - \Lambda/2 \le \lambda \le \lambda_{\max}$
$$g_m(\lambda;k_m,\theta_m,\mu_m) = k_m \exp[-\theta_m(\lambda - \mu_m)^2]; \quad (4)$$

Then, for $0 \le k_m \le 1$, $\lambda_{min} \le \mu \le \lambda_{max}$ and positive θ_m, we have a Gaussian reflectance spectrum (i.e., $0 \le g_m(\lambda) \le 1$). The Gaussians for illuminant spectral power distributions are defined similarly, except with the weaker condition ($0 \le k_l$). In this representation, μ and θ correspond in their roles to the central wavelength λ and the spectral bandwidth δ as defined in the Logvinenko's original (Logvinenko 2009) αδλ coordinate system. We will refer to the triple kθμ as the KSM coordinates. Note that Logvinenko's wraparound Gaussians are not the same as inverse Gaussians (MacLeod 2003).

Computing the Gaussian metamer parameters is analogous to computing those of rectangular metamers. We have applied the same basic interpolation approach as developed (Godau 2010) for that case. Figure 1 shows an example of a Gaussian metamer and a rectangular metamer for a sample Munsell chip illuminated by D65.

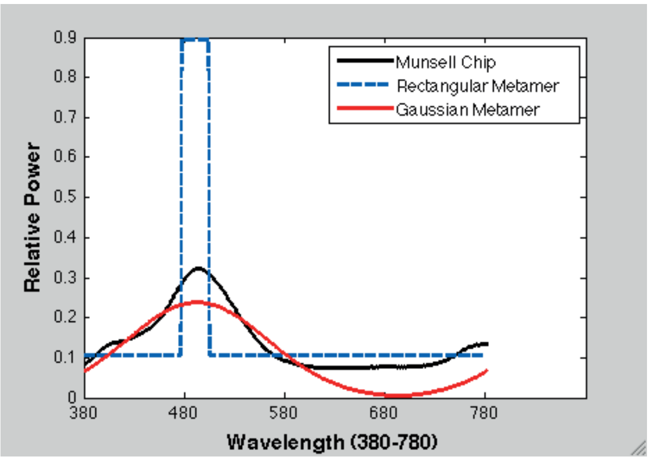

Figure 1. A sample Munsell chip's spectral reflectance illuminated by D65 and its rectangular and Gaussian metamers shown by black, blue and red respectively.

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3. Results

To compare the performance of the KSM coordinates versus the von Kries method of LMS prediction, we first synthesize the LMS tristimulus values of 1600 Munsell chips (Joensuu 2010) under one illuminant (e.g., CIE D65) using the Stockman cone fundamentals (Stockman 2000), and then predict the LMS values under the second illuminant (e.g., CIE F11) using KSM coordinates and von Kries scaling (von Kries 1970). These predictions are compared to the computed ground-truth LMS values computed for the reflectance under the second illuminant. The results for illuminants D65, A, and F11 are tabulated in Table 1, where it is clear that color prediction using KSM coordinates is significantly better in terms of the angular error measures than using von Kries scaling.

Table 1. Comparison of prediction error rates when the illuminant changes from D65 to F11 and A for the 1600 Munsells measured in terms of the angular difference in degrees between the actual and predicted LMS values.

	To	Median	Maximum	Mean
KSM	A	0.2470	2.4525	0.3698
	F11	0.3501	2.1802	0.5700
von Kries	A	0.7657	5.2859	1.0552
	F11	0.6143	6.1444	0.8786

Although the lower average prediction errors obtained via the KSM coordinates shown in Table 1 are one advantage of using them, a second important advantage is that the KSM predictions are guaranteed to be plausible in the sense that they arise from reflectances that are metameric to the input, while von Kries predictions are not. As an example of the type of large errors that can arise in the case of von Kries, consider the illuminant and reflectance spectra shown in Figure 2. Under the second illuminant the actual LMS are (5.0, 5.6, 27) while von Kries predicts (18, 18, 10) and KSM predicts (8.1, 8.0, 25). The corresponding angular errors are 53 and 8.4 degrees, respectively. Measured in terms of CIEDE2000 these errors are 58.94 and 10 .74 ΔE.

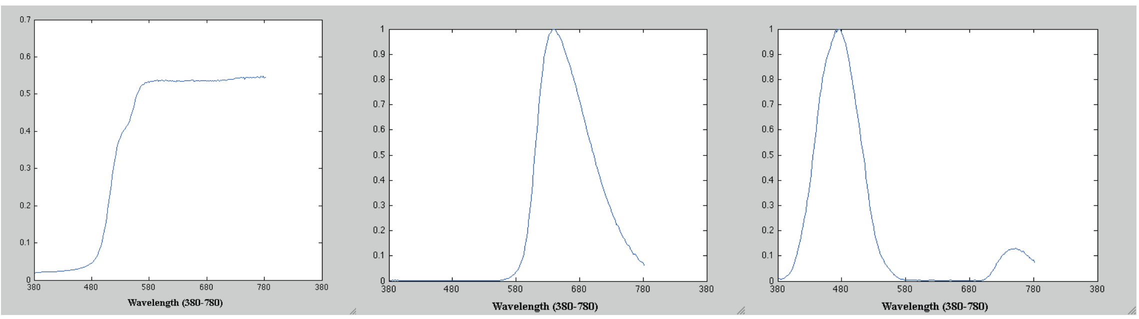

Figure 2. Reflectance and illuminant pair for which von Kries fails. Left panel, reflectance; center and right panels, illuminants.

As another test of KSM coordinates for predicting the color stimulus under a change of illuminant, we computed the KSM coordinates from the image of the Fruit scene (Joensuu 2010) under D65 (see Figure 3) and predicted what its image would be under illuminants A and F11. We have also compared the KSM with von Kries for the same prediction procedure. The corresponding results are shown in Figures 4, 5, and 6. Overall, the benefits of KSM over von Kries can be seen once again. Note that Figures 3 and 4 include conversion from LMS to sRGB for display purposes.

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Figure 3. Image of the Fruit scene from U of Joensuu spectral database (Joensuu 2010) under D65.

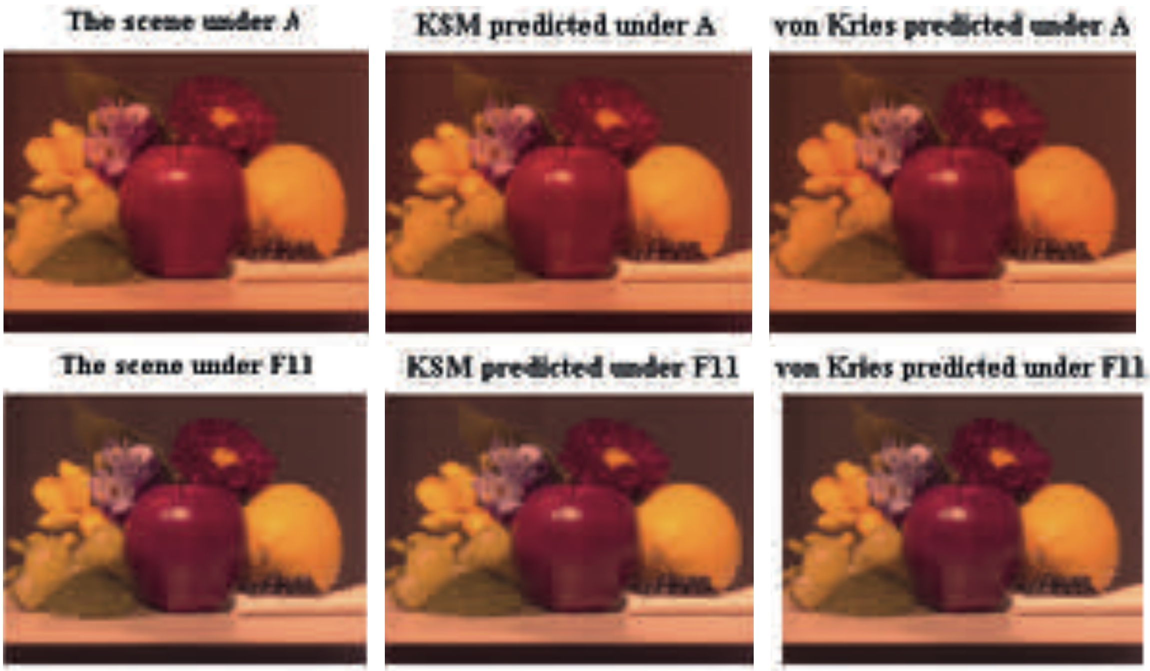

Figure 4. Given the image of the scene under D65 as input, the above images are those predicted by KSM and von Kries for the scene under illuminants A and F11. Very left column: computed ground-truth image of scene under A (top) and F11 (bottom). Middle column: images predicted by KSM for scene under A and F11. Vey right column: images predicted by von Kries for A and F11.

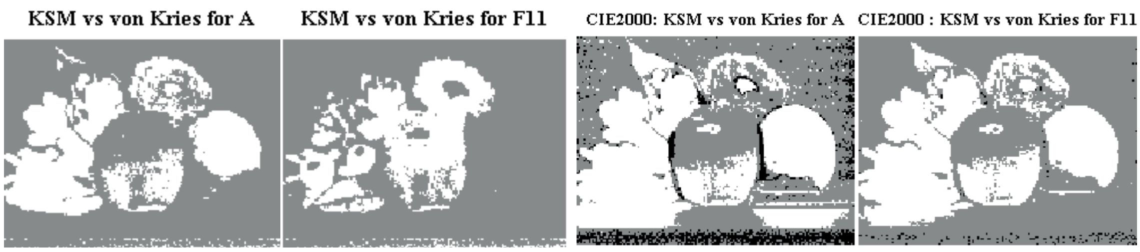

Figure 5. Comparison of KSM and von Kries using pixel-by-pixel maps of the difference angular error and also CIEDE2000 error for the predicted images from Figure 4. The two left panels illustrate a comparison of KSM and von Kries in terms of angular error. White indicates that the KSM error is at least 0.5 degrees less than von Kries; grey indicates the absolute error difference between them is less than 0.5 degrees; black indicates a von Kries error at least 0.5 degrees less than that of KSM. The two right columns depict a comparison of KSM and von Kries using maps of the difference in CIEDE2000 error for the predicted images from Figure 4. White indicates that the KSM error is at least 0.5 ΔE less than von Kries; grey indicates the absolute error difference between them is less than 0.5 ΔE; black indicates a von Kries error at least 0.5 ΔE less than that of KSM. The predominance of white areas over black ones shows that KSM generally outperforms von Kries.

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4. Conclusion

The Gaussian-metamer parameterization of Logvinenko's rectangular metamer colour atlas works well for predicting the change in LMS cone response that arises under a change of illumination. In addition to providing better predictions on average, it has the advantage over von Kries scaling that it is based on relighting a reflectance that is a metamer of the input, and as such must lead to a prediction that is constrained to be in the set of theoretically possible outcomes for the given input.

Acknowledgments

Funding was provided by the Natural Sciences and Engineering Research Council of Canada. The authors wish to thank Alexander Logvinenko for his helpful comments.

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Classification of fragrances by their similar psychological images with colors (2) - development of a law describing the harmony between fragrances and colors with special emphasis on the tones

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Abstract

The purpose of this study is to extract dimensions in impressions of fragrance and color, and to examine the relationship between their harmony with special emphasis on the tones. This study consists of three experiments. Experiment A: One hundred subjects were requested to describe the impression of eight fragrances and to select matched/mismatched colors from the color chart consisted of 18 colors. Experiment B: One hundred subjects were asked to describe the impression of 18 colors and the degree of match (4-point scale) for each of the 8 fragrances with the 18 colors. Experiment C: We used 120 fragrances and a similar experiment to experiment A was done. A total of 220 volunteers participated in the experiment. As the results, we derived the *mild* and *clear* factors for dimensions in impressions each of the fragrance, color, along with fragrance and color. We also derived the following tendency: With respect to the dimensions, the lesser the distance between fragrance and color, the greater is the rise in harmony; conversely, the greater the distance, the greater is the disharmony. In addition, tone thought to be important factor for harmony with fragrance.

1. Introduction

Colors can create many sensations, such as those of warmth and coldness, or excitation and calm. Studies of the sensations caused by colors have a long history, as well as those of the psychological and physiological effects of certain fragrances. For example, jasmine lifts the feeling of depression and lavender calms anxiety. More recently, studies on the mutual influence of fragrances and colors has been growing.

2. Background and related studies

While several different approaches to cross-sensory studies are used, such as investigations of behavior (e.g., Morrot *et al*., 2001) or brain science (Österbauer *et al*., 2005), one important approach examines cognitive aspects at the perception level. Saito *et al*. (2002), Miura & Saito (2008), and Miura *et al.*(2010) examined mutual psychological and physiological interactions in fragrance-color combinations. These studies confirmed that in harmonious pairs, the fragrance and the color synergistically enhanced each other's impressions and effects, while, in disharmonious pairs, they destabilized each other's impression. Thus, one clue to interactions between fragrances and colors is their impressions. In these background, we paid attention to the impressions of fragrances and colors to identify a law of harmony between them. Moreover, we especially emphasize on the tone of colors because the influence of the tone on color images is strong.

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3. Objectives

The purpose of this study is 1) to extract dimensions in impressions of fragrance and color, and 2) to examine harmony relationship between fragrances and colors with special emphasis on the tone. This study consists of three experiments, experiment A: Extracting impression dimensions of fragrance and examination matched/mismatched color for fragrance, experiment B: Extracting impression dimensions of color and examination the degree of harmonization with fragrance, and experiment C: Classification of fragrances by their similar impressions with the tones.

4. Method and materials

Stimuli

Color stimuli: We selected 15 chromatic colors and three achromatic colors: three tones (pale, vivid, and dark) * five hues (red [2:R], yellow [8:Y], green [12:G], blue [18:B], and purple [22:P]); white, medium gray, and black. In experiment A and C, we used a color chart consisted of 18 color chips. In experiment B, we used 18 color cards.

Fragrance stimuli: In experiment A and B, we used the following eight distinct fragrance materials: cinnamon, peppermint, vanilla, rosemary, lemon, anise, pepper, and rose. In experiment C, the fragrance was increased to 120.

Subjects

Experiment A: A total of 100 volunteers (average age, 19.4 years)
Experiment B: A total of 100 volunteers (average age, 22.3 years)
Experiment C: A total of 220 volunteers (average age, 22.9 years)

Procedures

Experiment A and C: Subjects described their impressions (SD method) for each of the fragrances and selected two sets of three colors from the color chart in terms of match or mismatch for the fragrance.

Experiment B: Subjects described their impressions (SD method) of the 18 colors and evaluated the degree of harmonization on a four-point scale of the eight fragrances with each color stimulus shown.

5. Results

5.1 Factor analysis

We conducted a factor analysis on the impressions of the fragrances (results of experiment A), colors (experiment B), and fragrances and colors (integrated results of experiment A and B; B and C). We derived *mild* factor consisted of "sweet-not sweet" and "feminine-manly", and *clear* factor consisted of "clear-muddy" and "bright-dark" for dimensions in impressions of each fragrance, color, along with fragrance and color together. For the *mild* score, vanilla, pale pink, and pale yellow had high positive scores (high *mild*), while peppermint, vivid blue, and dark blue had high negative scores (low *mild*). For the *clear*, lemon, vivid yellow, and white had high positive scores (high *clear*), while anise and dark tone colors had high negative scores (low *clear*).

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5.2 Harmony combinations of fragrance and color

We combined the results of experiment A and B to examine the harmony/disharmony relations between the eight fragrances and 18 colors. We found the following harmony combinations: vanilla-pR, pY, pG, pP, and W; lemon-pG, vY, and vG; peppermint-pG, pB, vG, vB, and W; rosemary-pG, vG, vB, and dkG; cinnamon-dkR, dkY, and dkP; anise-dkY, dkG, dkB, and dkP; pepper-dkY, dkG, and Bk; rose-vP, and dkP.

5.3 Multiple regression analysis

By the stepwise multiple regression analysis on the results of experiment A and B, for example, we derived the following formulas for pale pink and vanilla that was the harmony pair. We found that pale pink was positively correlated with the *mild* factor as matched colors. Thus, the higher the *mild* score of fragrance was, the more subjects chose pale pink as matched. On the other hand, pale pink was negatively correlated with the *mild* factor as mismatched. Therefore, the lower the *mild* score of fragrance was, the more subjects chose the color as mismatched. For vanilla, the higher a color's *mild* factor score, the higher is its degree of harmony with the fragrance.

pR as matched=.07+.11**mild* of fragrance+.01**clear* of fragrance (R^2=.97; p<.001)
pR as mismatched=.11-.08**mild* of fragrance -.09**clear* of fragrance (R^2=.95; p<.001)
vanilla=2.13+.69**mild* of color +.03**clear* of color (R^2=.77; p<.0001)

5.4 Cluster analysis and matched/mismatched color for fragrance

We conducted cluster analysis on the integrated results of experiment B and C, and considered which tone matched to each fragrance group and which do not. Figure1 shows these results. We obtained following eight groups: [*spicy; herbal*]; [*minty* & pB, vB]; [*cinnamon*]; [*flower* & vR, vY, vG]; [dkB, Gy and Bk]; [*woody* & vP, dkR, dkY, dkG, dkP]; [*citrus* & W]; [*sweet* & pR, pY, pG, pP]. In addition, For *woody*, dark tone was matched (63%), and pale tone was mismatched (48%). For *citrus* and *sweet*, pale tone was matched (49%; 51%), and dark tone was mismatched (51%; 36%).

6. Discussion and conclusions

6.1 Dimensions in impressions of fragrance and color

We obtained *mild* and *clear* factors for dimensions in impressions of fragrance and color. Reviewing the factor scores, we can note that the *mild* factor is correlated with the warmth/coldness of the hue and "sweetness" of fragrance. On the other hand, the *clear* factor correspond to the tone of color and "clarity" of fragrance.

6.2 Harmony relationship between fragrance and color

From the results of multiple regression analysis, we found that when a color and a fragrance are harmonious, they have a positive correlation with each other in one (or both) of the two dimensions. On the other hand, a color and a fragrance positively correlated with each other are disharmonious with those negatively correlated with each other. Thus, we suggested that a color and a fragrance close to each other on the impression dimensions tend to be harmonious, while those far from each other tend to be disharmonious. Moreover, the *clear* factor is an axis that determines whether a color is "pale" or "dark" and it showed the tendency that pale matched for the fragrance of the

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high score on *clear* factor, while dark matched for the fragrance of the low score on the *clear*. Therefore, tone thought to be important factor for harmony with fragrance.

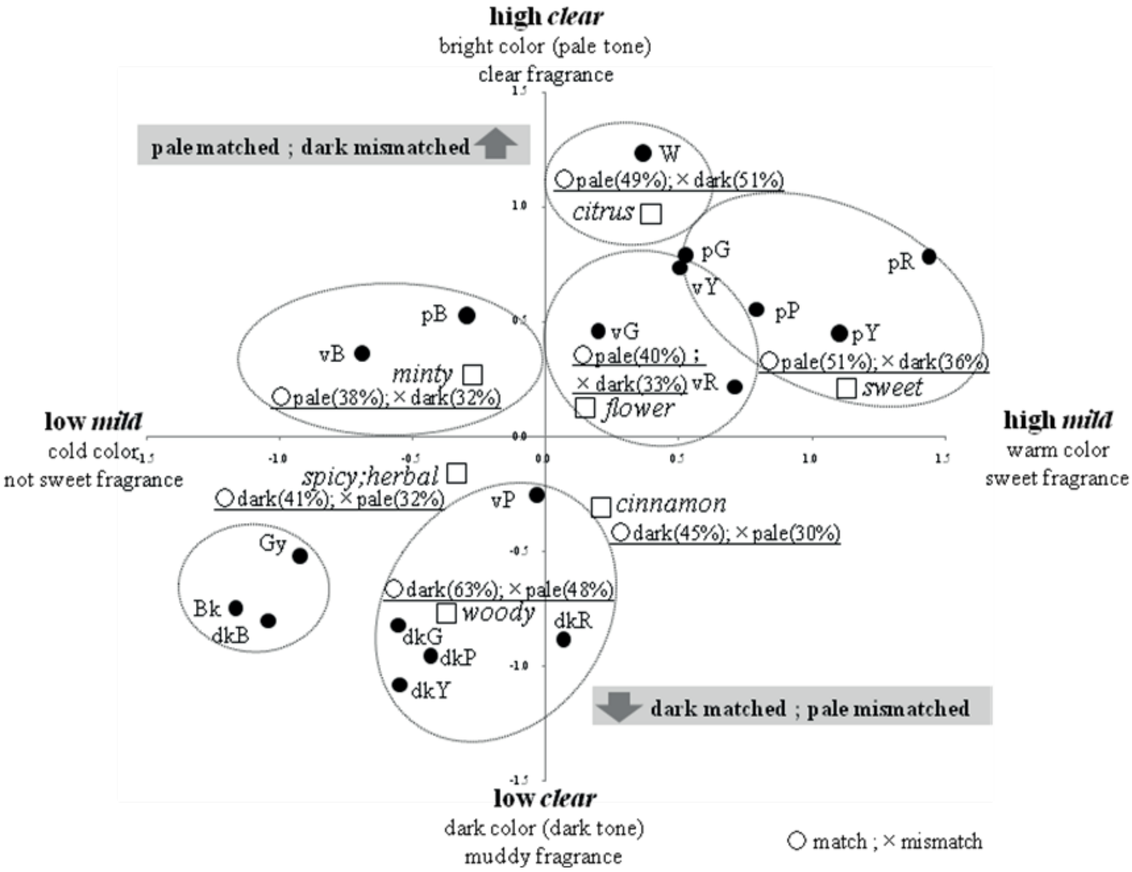

Figure 1 Classification of fragrances with colors and matched/mismatched tone for each fragrance group

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Influence of the frequency of an achromatic grating with the Bezold effect caused by a rectangular interleaved sequence inside

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Abstract

We study the relationship between the frequency of an achromatic (contrast=1) Ronchi grating (vertically or horizontally oriented) and color expansion (Bezold effect, assimilation) produced in a blue rectangular interleaved sequence within it. Also with an monochromatic Ronchi gratin (white-blue) with a gray sequence interleaved in it.

1. Introduction

In the School of Design Engineering at the Polytechnic University of Valencia have been studied for 10 years chromatic expansion (Bezold effect) produced by Ronchi gratings (achromatic and monochromatic rectangular sequence interleaved inside), presenting their results in various national and international congress, we cite as examples the last presented (Montalvá et al., 2010) at the IX National Congress of Color in Alicante 2010: "Visual perception of a rectangular sequence seen through an achromatic contrast unit grating", and the Interim Meeting of the International Color Association (Tortajada et al.), AIC 2010 in Mar del Plata (Argentina): "Effect of chromatic Assimilation (Bezold effect) in the vision of the content in a dinner plate."

We study the relationship between the frequency of an achromatic (contrast=1) Ronchi grating (vertically or horizontally oriented) and color expansion (Bezold effect) produced in a blue rectangular interleaved sequence within it (Figure 1).

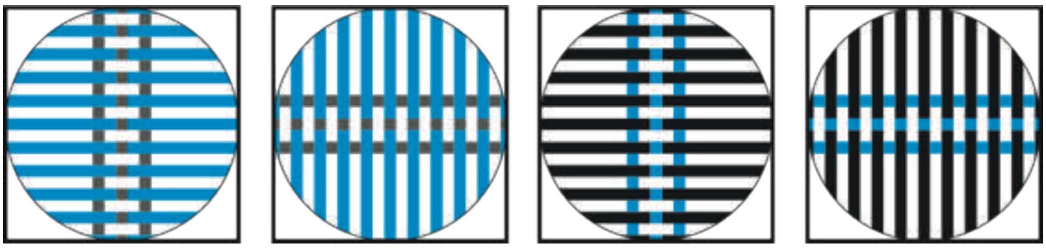

Figure 1. Picture of the 2 orientations of both gratings. From left to right: Monochromatic grating (white-blue) with gray horizontal sequences, monochromatic grating (white-blue) with gray vertical sequences, horizontal achromatic grating with blue sequences and achromatic horizontal grating with blue vertical sequences.

The explanation for the simultaneous contrast seem to be consistent in the scientific community whereas there is no such clear explanation for the assimilation or Bezold effect. Burnham experimented with drawings based on the original Bezold plates, and he realized that the Bezold effect appeared by viewing displays with a lack of sharp focus. Helson (1963) claims that assimilation occurs when there are small differences between the inducing and the test areas. On the other hand, Helson states that assimilation occurs when the inducing region is small compared to the test region.

Many authors have tried to explain the White's illusion; recently White himself (2010) gave a summary of its discovery. Howe (2005) eliminates the T-junctions in their work

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demonstrating that the effect remains justified by the Gestaltian's theory. However Salmela and Laurinen (2009) suggest that the effect is determined by the mechanisms of integration in the visual cortices.

In our laboratory we are proceeding the same way as Agostini & Galmonte (2000), Bressan (2006), White (2010), Economou et al. (1998) because we believe that the Bezold effect can not be justified only by the contrast theories. Our way of thinking follows the theory proposed by Gilchrist et al. (1999), which is based on a combination of local and global anchoring of lightness values. Bressan later delves into it.

2. Experimental technique

We followed the same experimental technique and worked with the same observers who assessed the relationship between a network monochrome (white-blue) and a gray rectangular test ($\beta = 0.5$) in the work of Alicante, what allows us to relate current results with those obtained in the work mentioned.

The experimental technique is based on the one used in the cited works. The test used is composed of three parallel straight lines (width equal to their separation, 1 cm), the background sequences that have a grating with a 2 cm period, covering a circle of 20 cm in diameter. This circle is circumscribed by a square. The grating is presented in two orientations (vertical, vertical stripes and horizontal, horizontal stripes) and color (blue), with the stripes perpendicular to the grating (Figure 1). Gratings and sequences are generated and printed by computer.

From a distance of 4 meters where is not perceived the central sequence, the observers are moving closer to the test along intermediate distances in 5, 4, 3, 2, 1 and 0.5 meters, giving the value V, which in view has the visual perception of the central sequence in a scale from 0 (there is no central sequence) to 10 (value given in all cases to the vision of the flanking sequences).

The experiments have involved 3 observers, students aged between 20 and 25.

With this value we determine the visual contrast at distances above, between the central and lateral sequences. With that contrast we quantify the Bezold effect.

$$\text{Bezold effect} = \frac{10 - V}{10}$$

In previous studies at our laboratory, we used to compare the value with a color wheel made of two discs, one red and the other one black. While spinning, there could be a change in the amount of black in the mixture according to the observer, taking as data the percentage employed (Aguilar & Urtubia, 2001). This system gave results comparable to the system used in this investigation and also in previous ones, so we have opted for this way of comparing.

It was checked that the lateral sequences with squares coinciding with the white lines experienced a color variation (darkening plus saturation) due to the expansion effect (darkening) and the direct contrast (darkening and saturation increase). It was also proved that the central sequence with squares coinciding with the black lines experienced the opposite variation (saturation decreases and luminosity increases).

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3. Discussion and results

Results and relation given in Table 1.

Table 1. Values of the Bezold effect: In the experimental technique it is showed the criteria taken to quantify the Bezold effect.

Separation Obs-test (m.)	Grating Frequency (period/ degree)	Bezold effect values					
		Grating orientation: horizontal			Grating orientation: vertical		
		Monochromatic (white-blue)	Achromatic	Δ_{M-A}	Monochromatic (white-blue)	Achromatic	Δ_{M-A}
		Sequence: Gray	Sequence: blue		Sequence: Gray	Sequence: Blue	
4	3,5	0,95	0,84	0,11	0,69	0,61	0,08
3	2,6	0,79	0,67	0,12	0,54	0,47	0,07
2	1,8	0,59	0,47	0,12	0,31	0,30	0,01
1	0,9	0,34	0,29	0,05	0,19	0,19	0,00
0,5	0,4	0,20	0,19	0,01	0,10	0,11	-0,01

The blue color chromaticity coordinates used are (x = 0.31, y = 0.41), being his Y the order of 25 cd/m^2.

From the data given in Table 1 we deduce the ratio within each grating (achromatic and monochromatic) between the frequency and the values of the Bezold effect produced in the interleaved sequence (Table 2).

The small superiority of the color expansion (Bezold effect) produced by the monochromatic grating over the achromatic grating (Table 1), is because the thresholds in the vision of the hue are smaller than the clarities (variations obtained with achromatic gratings). Changes in perceptual vision of the sequence (Bezold effect) is less than the latest gratings mentioned, which is to say that the Bezold effect is smaller.

Table 2. Equations of the lines.

Equations of the lines		
Horizontal grating		
Monochromatic: white-blue	Achromatic: gray sequence	Δ_{M-A}
y = 0,21x + 0,10	y = 0,25x + 0,12	-0,04
Vertical grating		
y = 0,16x + 0,04	y = 0,20x + 0,06	-0,04

Table 1 tells us that the Bezold effect produced is much higher in the horizontal orientation of the grating in both networks: achromatic and monochromatic.

The lines of Table 2 tell us clearly the proportionality between the frequency of the grating and the Bezold effect produced in the interleaved sequence.

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Ontological approach to a structure of color emotion: Descriptions of relationships among rating scales

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Abstract

From a viewpoint of knowledge engineering, it is an important task to clarify concepts of color emotions. One typical method in clarification of such concepts is to construct an ontology. For the aspect of applications of color research, the ontological descriptions will promote implementation of knowledge on color emotion in computer-based systems. In this paper, we ontologically specified basic concepts relating to rating scales adopted in measurement of emotional reactions to color stimuli. We then verified them according to empirical data.

1. Introduction

The color research has much interest in exploring an emotional response to a color stimulus, which is referred to as color emotion. From a viewpoint of knowledge engineering, it is an important task to clarify concepts relating to color emotion and systematically describe them, because such descriptions can serve as a basis for computer-based systems to provide knowledge about human color emotion. For example, clear distinctions among the concepts are useful for a system in suggesting color combinations a user requests by specifying a color emotion. To provide the basis in color emotion, it is beneficial to build an *ontology*, which is structured by knowledge descriptions understandable for both humans and computers. In the research area of artificial intelligence, an ontology is defined as an explicit specification of a conceptualization (Gruber, 1993). That is to say, a target world is conceptualized as an ontology. From a knowledge-based viewpoint, ontology is defined as a theory (system) of concepts/vocabulary used as building blocks of an information processing system (Mizoguchi et al., 1995). On a basis of the ontological description, knowledge of the target world is represented as an *instance* which indicates a knowledge description actually used in computer-based systems.

In this paper, we describe knowledge of color emotions through construction of an ontology and its instances. Knowledge of color emotion, which we describe in this paper, contains two different kinds of relationships; one indicates a relationship between a color emotion and a color attribute, and the other a relationship between color emotions. For describing such knowledge, we specify basic concepts relating to rating scales which are used to measure color emotions, and characterize the rating scales by focusing on qualities measured by the rating scales. We then verify the ontological descriptions through empirical data.

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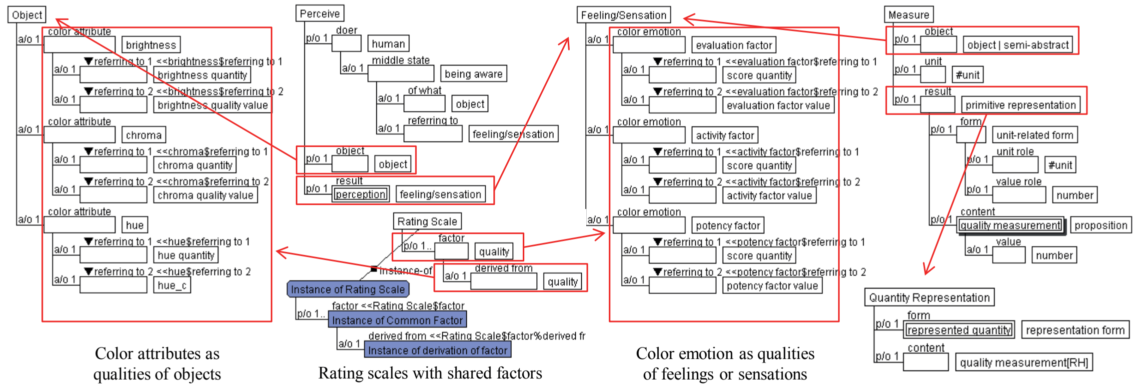

Figure 1. Basic concepts and an instance of a rating scale.

2. Basic concepts relating to rating scales

In general, the color research uses rating scales such as the Semantic Differential Scale and Visual Analog Scale to measure the emotional responses to color stimuli. The responses are expressed as numeric values on the rating scales. Thus, “a relationship between a color emotion and a color attribute” can be regarded as “a relationship between values on rating scales for the emotion and the color attribute”, and “relationships among color emotions” can be also regarded as “relationships among rating scales”. For example, in case of a factor analysis of values of rating scales, the rating scales share some common factors derive from color attributes and can be distinguished by the factor pattern. This means that each rating scales is composed of a set of some primitive concepts which play roles of the common factors in each instance on the basis of ontological descriptions.

In the current study, we specified basic concepts relating to rating scales and their instances (Figure 1) on an ontology development environment Hozo (http://www.hozo.jp/). Color attributes were specified as the qualities of an object, and color emotions are specified as the qualities of feeling and sensation. In Figure 1, the action *perceive* and *feeling/sensation* are specified in our previous study (Muramatsu et al., 2011), and the *quantity*, *quality*, *quality measurement*, and *quality representation* are originally specified in Yet Another More Advanced Top-level Ontology (http://www.ei.sanken.osaka-u.ac.jp/hozo/onto_library/upperOnto.htm). Common factors shared by rating scales were specified as *factor* slots which indicate roles played by the quality of objects, feelings, and sensations. Therefore, these concepts relating to rating scales can consistently be accepted by general ontology-based information processing systems.

3. Relationships among rating scales

Research interests in color emotion are mainly divided into two categories; one is concerned with evaluative dimensions and the other descriptive dimensions (Gao and Xin, 2006). Researchers adopt suitable rating scales belonging to either of the categories which meet with their research interests. For example, Ou and Luo (2006) used an evaluative-dimension scale, “harmonious-disharmonious” which are supposed by them to be strongly linked with “pleasantness”, and Gao et al. (2007) used twelve descriptive-dimension scales such as “light-dark”, “soft-hard”, and “warm-cool”.

We described common factors shared with these rating scales on the basis of the basic concepts we had specified. Figure 2a shows that the harmonious-disharmonious scale has the

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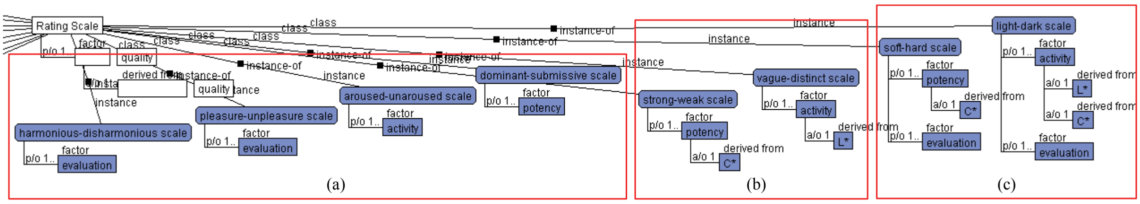

Figure 2. Instances of rating scales with common factors and their derivations.

same factor as the pleasure-unpleasure scale. Eleven of the twelve scales except a warm-cool scale have activity and potency factors which is derived from color metrics of L* and C* (Figure 2b), because Gao et al., (2007) reported that the scales marked high factor loadings of the two factors correlated with the color metrics. Evaluative-dimension scales were characterized by an evaluation factor, and descriptive-dimension scales by the activity and potency factors which derive from color metrics of L* and C*. In these relationships among the rating scales and common factors, the feeling, sensation and the color metrics can be regarded as primitive concepts. However, these rating scales are not necessarily characterized by a single primitive concept. For example, Kusumi (1988) experimentally confirmed that Japanese adjectives such as “light (or bright)” and “soft” are characterized by pleasantness. Therefore, these descriptive scales should be ontologically linked with the evaluation factor in addition to the activity and potency factors which derive from color metrics (Figure 2c).

4. Experiment

To verify the descriptions for the scales, we empirically confirmed whether or not the descriptive scales can be actually characterized by the evaluation factor of feelings. We conducted an experiment to obtain empirical data about emotional responses to color stimuli, using twelve descriptive scales (light-dark, soft-hard, warm-cool, turbid-transparent, deep-pale, vague-distinct, heavy-light, vivid-sombre, strong-weak, passive-dynamic, gaudy-plain, striking-subdued) used by Gao et al. (2007) and pleasure-unpleasure scale. In the experiment, six undergraduates were asked to assess fifteen color stimuli with the twelve seven-point descriptive scales and another twelve scales each of which was for assessment of descriptive scale with a seven-point scale of “pleasure-unpleasure”. The fifteen color stimuli were provided by combining three hues (red, green, blue) and five tones (dark, deep, vivid, brilliant, light), which are used in a study using Self-Assessment Manikin scale (Suk and Irtel, 2010). The CIELab LCh data of the color stimuli were implemented with a Java-based software (PXLab, http://irtel.uni-mannheim.de/pxlab/) and displayed on a hardware-calibrated TFT monitor (EIZO ColorEdge CG245W).

In data analysis, factor analysis (principle factor analysis, varimax rotation) was first conducted to derive factors in the descriptive scales, with the result indicating that factors and their structure were almost the same as Gao et al. (2007). Second, a correlation analysis was conducted and yielded significant results between a values of some of the descriptive scales and values of their respective “pleasure-unpleasure” scales (r = -0.60* in light-dark, r = -0.73** in soft-hard, r = -0.78*** in warm-cool, r = 0.78*** in turbid-transparent, r = 0.78*** heavy-light and r = -0.76** in vivid-sombre; * $p < .05$, ** $p < .01$, *** $p < .001$, two-tailed).

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5. Conclusion

In order to provide basic concepts in color emotions and their relationships, which are useful in clarifying color emotions themselves, the focus of the current study was on the rating scales whose values express emotional responses to color stimuli. On the basis of the concepts which we specified in our ontology, we described instances of the rating scales representing evaluative and descriptive dimensions. Our ontological descriptions of concepts and relationships successfully demonstrated conceptual distinctions of color emotions with color metrics and a "pleasure-unpleasure" scale. Our experimental validation for the descriptions proves that both scales of evaluative and descriptive dimensions can be identified by only a small number of common primitive concepts.

For the aspect of applications of color research, the ontological descriptions proposed in our study can promote implementation of knowledge on color emotion in computer-based systems. Clarification of relationships among concepts for describing knowledge will prevent ad-hoc implementations on the system development. One of the other contributions for color research by our study is to provide a comprehensive perspective on evaluative and descriptive dimensions of color emotion. Further discussions predicated on the ontological descriptions will lead us to understanding color emotion much more precisely.

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Image based technique for colorimetric characterization of the light field emitted by LED projector with variable CCT for museum lighting

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Abstract

In this paper we present an ongoing research at Politecnico di Milano Laboratorio Luce in collaboration with a worldwide leading company in the lighting industry. The research is aimed to the design of a projector for museum lighting able to enhance the painting color perception through an accurate dynamic control of color temperature (CCT). The light sources used are LED with different color characteristics. An image based measurement technique has been used for assessing the color uniformity of the light field emitted from the projector at a typical distance of installation. The measure was repeated at different color temperatures to evaluate the arrangement of LED in the projector and fix the necessary supply current for the dynamic control of light output and color temperature.

1. Introduction

Besides the one dimensional processing of the signals acquired in the measuring process (point by point measurement method), in the last ten years a new metrological methodology called ILMD (Imaging Luminance Measurement Devices), Blattner (2003), has been developed for measurement in the lighting industry. The ILMD devices, also known as video-photometers or CCD luminance meter, have been recently introduced into the market and a new CIE committee called "TC2-59 Characterization of ILMD" has been established for their metrological performance characterization. An ILMD is able to measure the levels of luminance of a real scene by returning an image with a false-color scale or grey scale relative to the measured values. They are based on CCD (Charge-Coupled Devices) from 8 to 16 bits, similar to those used in digital cameras, where the values of irradiance measured in each cell of the CCD are converted to a digital value.

A 16-bit CCD sensor is able to acquire 65,536 different luminance levels. Other types of ILMD are equipped with 8-bit low-dynamic CCD based on an automatic mechanism that captures a sequence of images with increasing exposure interval and reassemble them into a high dynamic range image - Debevec (1997). ILMD instruments are a real innovation for the evaluation of lighting projects as they are able to offer an immediate measure of the uniformity, contrast and luminance spatial distribution. In addition, implementing a new brightness measurement parameter, you have the opportunity to properly assess, from a quantitative point of view, the real vision of the illuminated elements as a function of the perceptive adaptation typical of the human visual system. Another improvement in image-based measurement capabilities developed in recent years has been the introduction of instruments able to measure the chromaticity as well as the luminance, like the Minolta Color Analyzer CA-2000, that we used in this research project. The instrument makes use of a high resolution CCD sensor and tristimulus X, Y, Z filters to achieve a measure of colors on a 980x980 array of measurement points.

The main purpose in the museum environment, where the enhancement of perception of the exhibited works is a matter of the greatest importance, is supporting Lighting Design not only

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limited to the evaluation of illuminance and luminance, but investigating the perceptual quality in terms of contrasts, direct and indirect glare. An additional improvement in the Lighting Design could be to take into account several limitation of human visual system in the perception of light and color, Rossi (2005).

On the one hand, museum lighting have to comply with norms to avoid painting damage, CIE (2004); on the other hand users prefer a coldest color temperature (daylight 5100 K) more than 3000 K commonly used in museum lighting, as it was highlighted by Pinto (2008). Although these results need a validation, due to the close relationship between color temperature of light sources and chromatic characteristics of the exhibited works, in our opinion there are the conditions for holding useful to have a lighting projectors for museum application with the possibility to adjust the correlated color temperature.

Figure 1. The measurament set-up during the calibration phase by using a spectroradiometer Spectrascan PR701.

2. The measurement technique

Although the instrument used has been developed to measure color distribution, uniformity and luminance of backlit panels, TFT or plasma display, auto-motive components such as navigator or other control panels, we would like to use it for evaluation of the chromatic light field emitted by a LED projector for museum lighting.

The research involved the development of a prototype of a projector for museum lighting that uses LED light sources arranged in five channels: red, green, blue, warm-white and neutral-white, (R, G, B, WW, NW). Various types of TIR (Total Internal Reflection) micro optic refractive lens, with different beam angle aperture were tested on the LEDs.

The light field distribution emitted by the prototype was measured, also according to the current supplied to each individual source. Through interpolation of a lookup table containing the current intensities of LED sources considered, we tried to create a device with variable color temperature in the range between 2,700K and 10000 K and with the possible chromatic variation in CIE 1931 space referring to the Planckian locus along an isotherm that introduces the desired dominant wavelength.

The first step in the evaluation of LEDs mix was the planning of the measure set. The prototype projector was placed at a distance from the measuring screen similar to museum lighting application; the sample surface consist of a perfectly diffusing white screen treated with barium sulphate paint.

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The device was oriented so that the beam maximum intensity was perpendicular to the screen while the choice of the ILMD objective of measurement was determined by the maximum distance between the instrument and the screen itself. During the measurement, the axis of the instrument was perpendicular to the screen. Measurements were carried out under conditions of thermal equilibrium at 25° ± 1°C, after turning on the projector and the measuring instrument for at least 45'. In order to choose the mix, all the primary colors of the prototype were considered; the more or less activation is linked to the desired color temperature and to the color rendering index value requested. Current supply of each channel was adjusted using a numeric keypad and a slider control to achieve the desired configuration.

For the evaluation of measurement uncertainty of the acquired images, De Santo et al. (2000), a luminance reference Gamma Scientific RS-3 with certified spectral emission and Spectrascan PR701 spectroradiometer have been used. Using a PC and a DMX control device, LEDs current supply were adjusted, and all data to build the current lookup-table were collected.

3. Conclusions

It is important to point out that the main purpose of the research was not limited to the achievement of a white light with correlated color temperature characteristics and color rendering assigned regardless the emitted luminous flux, but also had the aim of producing a colored light with assigned chromaticity. To obtain this result we started from a mix of primary with a defined color temperature, referred to the lookup table described above, and changing the current intensity in each channel ensuring white light, but with a specific dominant wavelength moving away from the Planckian locus along the same isotherm. A series of images were acquired to verify the uniformity of the projected beam varying the color temperature by adjusting the LEDs current supply. Comparing values of correlated color temperature obtained at the current values provided with the reference values, it was possible to define the resolution with which to make the table lookups more reliable.

The system allowed us to evaluate the degree of accuracy achieved in the primary mixing making a comparison between multi-dimensional linear interpolation of the table and one-dimensional interpolation of each channel. It was also possible to accurately define the choice of secondary optics for LEDs selected to achieve the best performance in terms of color uniformity of the light beam produced by the prototype.

This research was partly funded by Italian public research project Industry 2015, which is still ongoing, and therefore the detailed characteristics of the lighting product, developed in collaboration with a company of primary importance in the lighting sector, are covered by NDA until the end of the search term.

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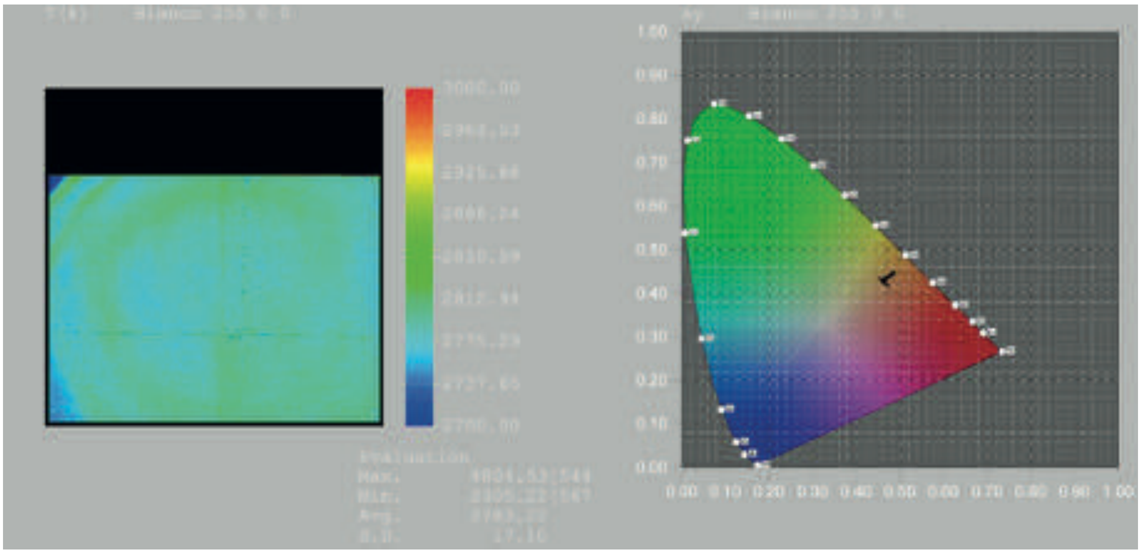

Figure 2. False colors CCT map for prototype projector under test (left side) and chromaticity coordinates of the emitted flux for a set of current values exctrated from lookup-table (right side).

Acknowledgments

Our thanks to Renato Figini and Maurizio Messa, Konica Minolta, for their kind support.

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Chromatic characterization of urban fragments: Validation of a user-oriented protocol through the study of Hors-Château street (Liège, Belgium)

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Abstract

The aim of this paper is to present a user-oriented protocol which can be used to characterize chromatic attributes of an urban fragment. A growing need for objective assessment of colour has been observed in recent years in the field of urban design. The challenge is to provide quantitative answers to these two questions: how is colour organized, how does it develop a structure in the city? The main purpose of the research is hence to investigate stable colour typologies within the city; each urban area (historic center, suburban housing district, commercial zone, etc.) being characterized by a specific colour palette. Our characterization protocol was initially tested through an application to Hors-Château street, one of the oldest roads of the city of Liège (Belgium).

1. Introduction: lack of appropriate tools for the objective assessment of colour in the field of urban design

Colour is a fundamental feature of visual stimuli that inform people about the urban context. It remains a powerful factor in the reading of shapes, due to hue contrast, and in recognition of objects. Because it plays a part in visual kinetics, colour therefore participates in space memorizing. Moreover, additionally to functional roles, colour can promote heritage values and collective identity. Besides marking our eyesight out with signals, colour makes sense in our visual environment[1].

In contrast to other building attributes like shape, size or location, which are easy to specify, urban design codes generally define expected chromatic attributes of building façades through indirect regulations considering materials. For example, the general regulations for buildings in rural sites in the Walloon region in Belgium[2], gives some instructions not well defined, when considering colours for building façades. The use of indistinct terms such as “white-tinted coating”, “light grey to medium grey masonry” or “dark-coloured local brick” is recurrent.

Some municipalities, like the city of Dinant (Belgium) or the department of l’Oise (France), propose colour charts as guidance tools for the design of urban regulations[3]. Yet those charts clearly present some disadvantages. First, the chromatic property of buildings in an urban area is summarized through the drawing up of a low number of colour samples, often visually chosen in the Munsell system. Secondly, due to the absence of quantification, it is impossible to determine the range in which colour varies. Finally, the chromatic comparison between different urban fragments is non trivial because of the visual presentation of those colour charts.

Furthermore, the measurement of material colours with a colorimeter also shows obvious difficulties, particularly in the in situ gathering of information: uneasy access to samples of the main colour (for instance, if the colour to be assessed is not located on the ground floor), limited measurement area (only a few squared centimeters) for the characterization of the main colour, etc. The price of the instrument can moreover prevent end-users to access such a technique.

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On top of these considerations, we also note that colour assessment is affected by lighting, weather and observation conditions. Indeed the same material appears differently depending on the moment of the day. The texture of the material also influences the surface appearance[4].

All these elements illustrate the challenge in chromatic characterization, which can partially explain the limited development of user-oriented tools. The obvious lack of rigorous procedures to directly address expected colour attributes in an urban area, in the purpose of characterization or regulation, was the main motivation of our research.

2. Methodology

In order to test its sensitivity to chromatic characteristics of an urban fragment, our characterization protocol was initially tested through an application to Hors-Château street, in the historic center of the city of Liège (Figure 1). A chromatic assessment was applied to all façades of terraced buildings, which first required analysing the façade system of our study area sample. Indeed, historic façades are typically made of different components: a background material superimposed by frames and sills of windows, façade base, outdoor carpentry and gutter. The first component, the "façade background" (Mr in Figure 2), was here considered as the most representative colour component of the whole façade. The other components belong to the ornamental system[5].

Figure 1. Hors-Château street, Liège, Belgium.

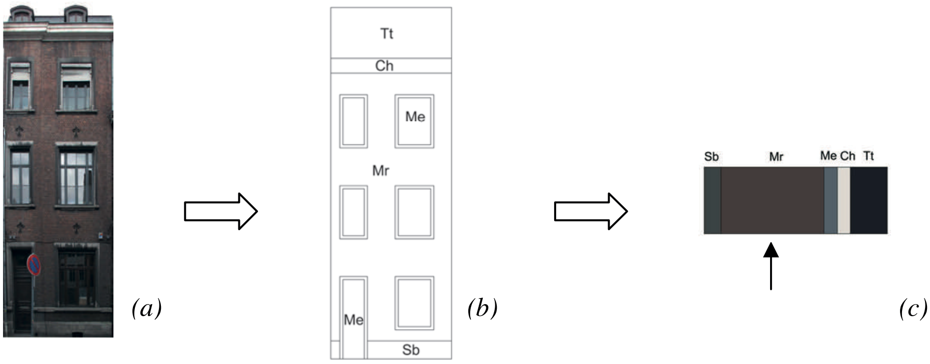

Figure 2. (a) Photograph of a façade in Hors-Château street, Liège, (b) the corresponding drawing of the façade system with the identified components, (c) chromatic chart (the arrow denotes the main component)

The method has been deliberately based on widespread use tools – digital camera and image processing software, like Gimp or Adobe Photoshop – so as to make it affordable to potential end-users like municipalities or urban planners. A rigorous measurement protocol was hence established for collecting colour samples, setting weather conditions, lighting and photo shooting. In order to maintain consistency in the comparison between different urban fragments, it is necessary to define stable outdoor lighting conditions: as explained in the introduction, solar geometry and weather conditions could indeed disturb the spectral distribution and intensity of

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illumination, which would cause variations in the colour rendering of materials (Figure 3). For these reasons, façades are photographed between 12 pm and 2 pm, beneath a covered sky in order to obtain a uniform light without shadow and to set common lighting conditions across the samples. The same white balance is applied to all samples in post-processing to achieve more uniform lighting conditions. After isolating, on each picture, a uniform area of "façade background", the average colour is removed and placed in a colour vignette that visually abstract the urban fragment (Figure 4).

Figure 3. Effect of sunlighting condition: the "façade background" presents heterogeneous values.

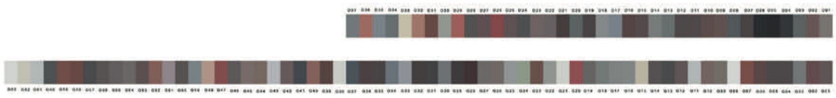

Figure 4. Chromatic values of the "façade background" components for both sides of the street.

Moreover, choosing an appropriate colour space for the method and the type of data representation is critical to a user-oriented interpretation of chromatic distributions. The (H,S,L) colour space has been adopted as its relevance from the point of view of perception is higher than that of the cartesian representation of the (R,G,B) colour space (Figure 5).

Figure 5. (H,S,L) colour space. Values are perceptually more relevant than in (R,G,B).

3. Results

The proposed protocol has been first applied to Hors-Château street in Liège (Figure 6). It adequately reveals quite a large distribution along the [355°-10°] directions in the (H,S) circle, due to the use of red clay bricks in this street. Secondly, a peak of saturation appears in the red area, which can be explained by the use of scarlet red coating, a colour very often used in Liège for the renovation of listed buildings. Finally, some values appear in the blue area, due to the use of blue stone for some buildings.

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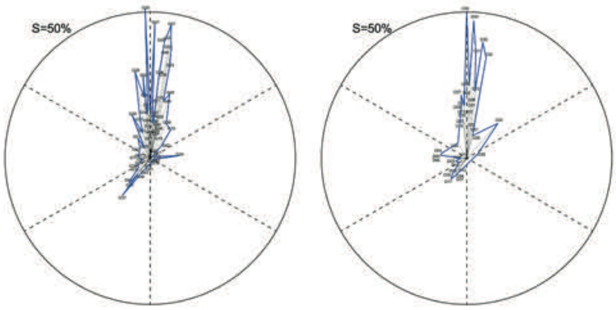

Figure 6. (H,S) circles. Results for Hors-Château street (left and right sides of the street).

4. Conclusions

The proposed protocol provides a synthetic visualization of colour distribution in urban environment. It reveals a specific contour in the (H,S) circle for Hors-Château street. The forthcoming works will show whether such a distribution appear again for another historic zone, in order to detect any possible stable colour typology. Furthermore, we will investigate other urban areas (19^{th} century housing district, commercial zone, etc.). A complementary validation of our protocol will be conducted by comparing the results obtained through our user-oriented approach with those measured with a colorimeter, in the perspective of a refinement of the results.

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Influence of color scales and subjective color impressions in the development of architectural projects

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Abstract

We have developed a psychophysical experiment for testing the influence of color in the development of architectural projects. The main building properties analyzed were the length, the size and the depth cues. A real architectural project was used as a standard reference to design a psychophysical experiment with naïve and non-naïve. Results show that the most relevant cue was the height and not the weight as expected.

1. Introduction

The evaluation of color differences and tolerances is an important issue in industry and arts. In addition the colour has a significant impact on the overall perception of an urban environment because any object introduced into the environment becomes a visual target in relation to its context. Thus, it is necessary to considerer the factors determining that relationship. Natural materials, like nature itself, tend to be richly textured and subtly coloured. Widely use of industrial products is leading to a chromatic impoverishment on the urbanscape (Marina and Morón, 2006). Although there are a huge amount of work about perceptual colorimetric systems (e.g. CIELab, NCS atlas, Munsell color system, etc.), color differences and tolerances, little is known on how color perception affects the overall impression of architectural projects. Even color emotion should be considered directly applicable in such situations. As for the specific field of architecture, we need of colour knowledge and of colour appearance and colour emotion, with and without explicit connection to architecture (Monroe, 1925; Anter, 2010).

2. Methods

We have developed a psychophysical experiment for testing the influence of color in architectural projects like the one shown in Figure 1. The building is a front view of the new University of Seville's library (located at Seville, Spain). Based on the main details of this building, the length, size and depth cues were selected as the most appropriate properties to analyze (Monroe, 1925; Gundlach, 1931; Tinker, 1938; Peters, 1943; Bevan, 1953). The real architectural project was used as a standard reference to design a psychophysical experiment with 19 naïve and non-naïve observers. A discriminative task was used to evaluate the differences between two successive stimuli viewed by the observers.

We are assessing the influence of color on the perception of a frontal view of the facade of a building. All our observers must have normal color vision, so we have used the Ishihara test, a collection of pseudo-isochromatic plates which is quite proficient in screening of the most

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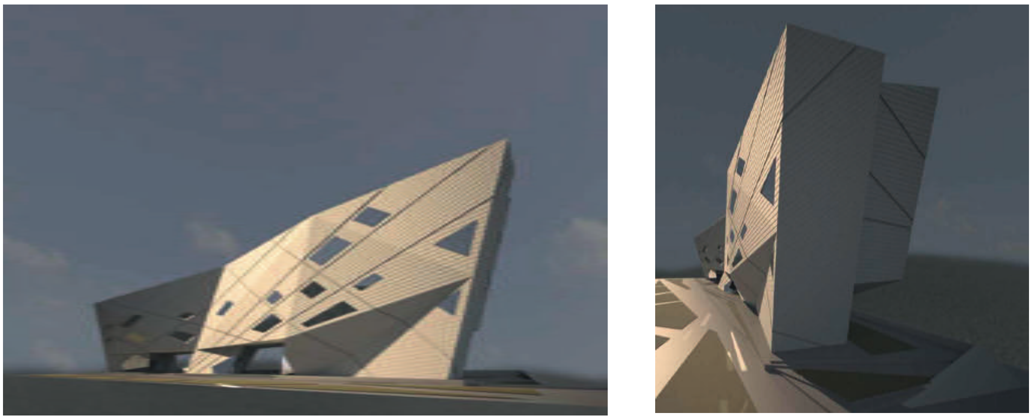

Figure 1: General views of the new University of Seville's library project (by ZAHA HADID ARCHITECTS). The left figure was the selected view to use in the experiment.

prevalent (red-green) color vision anomalies. Once the subject is cleared by the Ishihara test, he or she must perform three different experiments, which we have named as SIZE, WEIGHT and DISTANCE.

The three experiments have a similar time course: first, the subject adapts to an uniform grey field for 30 s; then, the stimulus presentations begin, each composed of two successive 1 s viewing of a façade. One of the two stimulus is colored, and the other is a neutral grey darker than the adapting field and the surround. We use different sizes of the facades along the experiment, but for each presentation, both successive stimuli have the same size. The colors used are white, black, red, blue, yellow and green, corresponding to the maximum R, G and B values of the display (most saturated colors than the display can produce).

The task of the observer is to discriminate between the two successive stimuli, indicating which of the two is perceived as bigger (in the SIZE experiment), heavier (in the WEIGHT experiment) and more distant (in the DISTANCE experiment). Figure 2 shows some example of representative stimuli for each of the three experiments. The WEIGHT experiment was performed adding some vertical support to the façade, and the DISTANCE experiment by adding a road and a human figure, to render the task easier to the subject.

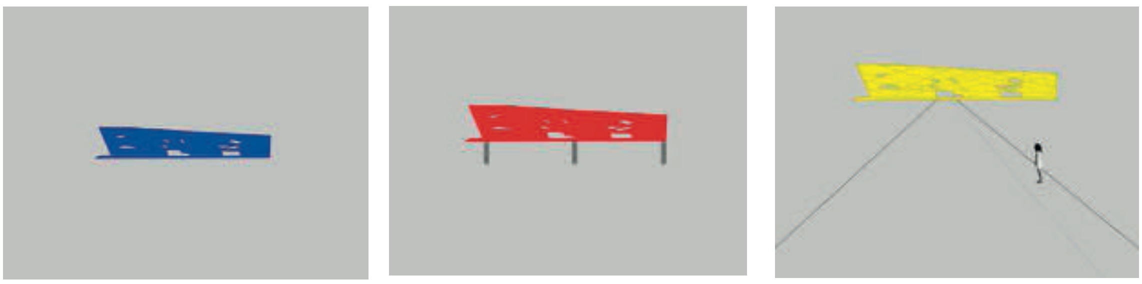

Figure 2: Examples of the size, weight and distance cues, respectively, tested in the experiment. The tests were designed based on the primal sketch of the University of Seville's new library project.

3. Results and discussion

In figure 3 we show the average number of responses given by the observers for a particular task. The bars labelled "color<grey" indicate a lesser degree of the property assessed by the experiment (size, weight or distance). For the DISTANCE experiment, "color<grey" indicates the averaged

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number of times the observers judged that the colored facade was closer than the grey facade. In the WEIGHT experiment, “color<grey” bars indicate the average number of times the observers perceived the colored facade as lighter than the achromatic one, and in the SIZE experiment the averaged number of times the observers perceived the colored facade as smaller than the grey one. The bars labelled “color>grey” indicate the opposite way of perceiving the assessed property, and the bars labelled “color=grey” indicate the invalid answers given by the observers because the response time was too long. This happened only in a reduced number of cases as shown in figure 3.

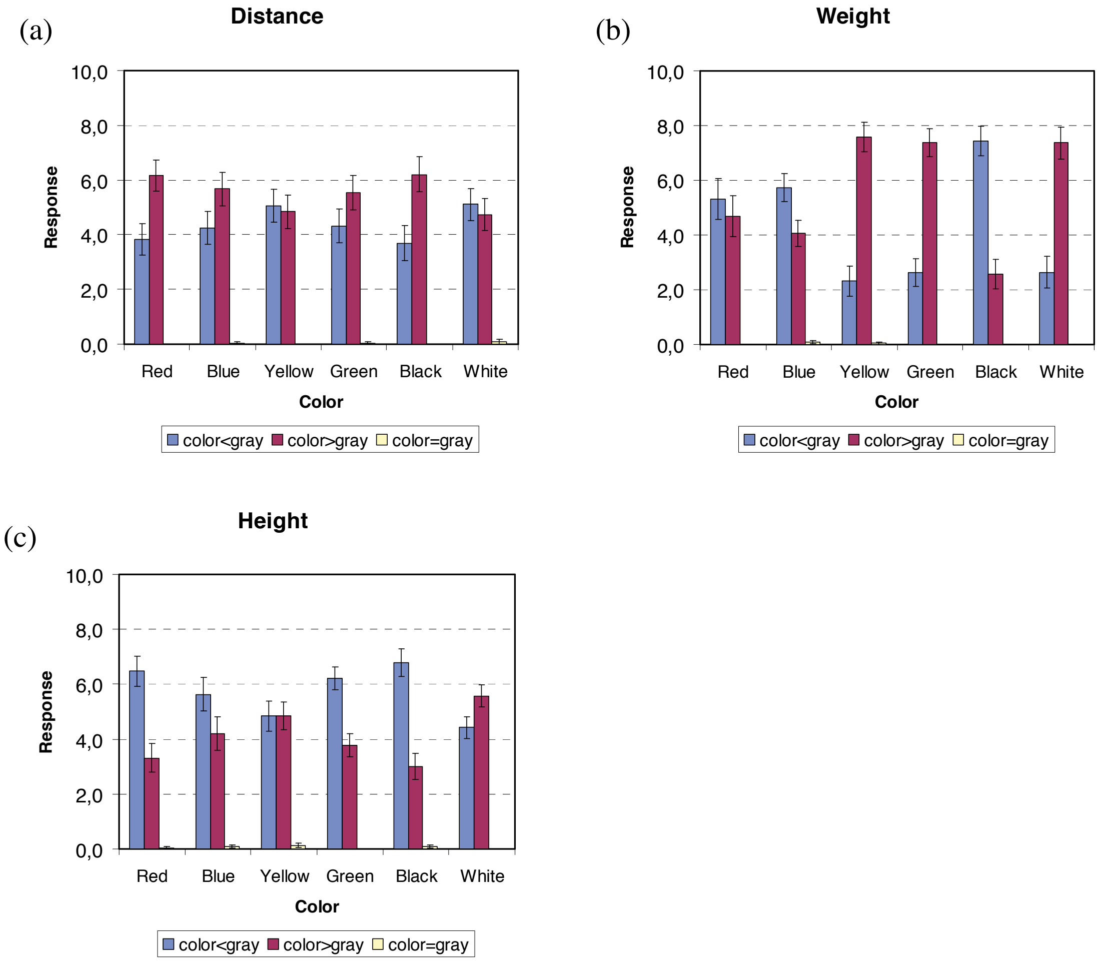

Figure 3: Results for the three perceptual cues tested in the experiement: (a) distance, (b) weight, and (c) height cues.

Summarizing the most relevant results, we can say that for the DISTANCE experiment, the building seems to be more distant when the facade is in color (the answers “color>grey” are more common) when the façade is red, blue, green or black, while there seems to be no effect of color in the perception of distance for the yellow and white facades.

For the WEIGHT experiment, the building seems to appear lighter when the color is red, blue or black, while it tends to appear heavier when the color is green, yellow or white. Finally, the SIZE experiment results indicate that the facade is perceived as smaller when the color is red, blue, green or black, and there is no effect or the trend is opposite for yellow and white colors. We see clearly how the effect of color on the perception of the building is dependent on the color used.

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In general, lighter colors produce different effects than darker colors (or colors that appear visually as darker than yellow or white).

To confirm this hypothesis, we have used a color appearance model, the CIECAM 02, to the six colors used in our experiments. The CIECAM 02 model results confirm that the colors which would be perceived as lighter are white, yellow and green. If we look at the saturation instead, the most vivid colors would be red and blue, followed by green. Thus we find that there is clearly a correlation between the results obtained in the experiments and our perceptions of the colors; in addition the critical color attributes appear to be lightness and saturation and these cues are what influence our perception of the building façade in a different way. We have analyzed the results obtained by a MANOVA statistical test with three factors, and also to Student's t tests for mean comparisons, which validate the main conclusions described above and shown in figure 3.

Acknowledgments

Supported by the regional government of the Junta de Andalucia (Spain) through grant number P07-TIC-02642.

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Construction of simulation for Kansei evaluation of colors by using linked multiple neural networks

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Abstract

This paper presents an approach to determining the best color combination of products appropriate to each individual human kansei by computer. The kansei evaluation on the computer is conducted by neural networks which are modelled on human brain functions. And then, the neural network is separated into two hierarchies based on human kansei processing. That is to say, they have an input-output of 'sensation' and 'perception', and an input-output of 'perception' and 'cognition', respectively. After neural networks learn kansei evaluation data obtained from subjects, the convergence property of learning is evaluated. As a consequence, from the mean square error and combination loads after leaning, the convergence property shows that hierarchized neural network models based on human kansei processing are superior to a single hierarchical neural network model. Therefore, the determination of the best color combination on the computer is expected to get closer to human kansei processing by linking these hierarchized neural network models.

1. Introduction

In today's rich material society, Nagata and Mitsuzuka (2007) have mentioned that the commodity value for customers has been changing function-oriented products to kansei-oriented products. In this situation, it is important to choose designs appropriate to customer's kansei, but people who evaluate a great deal of candidates are forced to put a heavy burden on their time and effort. Therefore, it is preferable that computers can extract designs appropriate to kansei of individuals. In this study, the intended design element shall be "color" that Nagamachi (1989) has mentioned that the contribution of "color" has been very large for the image of "kansei". Moreover, on the basis of facts that kansei is one of human brain functions, kansei shall be evaluated by using the neural network that Hagiwara (1994) has mentioned that the concept has been to imitate human brain function.

2. Kansei evaluating experiment

To determine the color combination based on human kansei processing by using neural networks, it is necessary to obtain appropriate data from kansei processes of real subjects and after analyzing features, the way to give them to the neural networks is determined.

2.1 Experimental samples and subjective evaluation items

In this experiment, the image of multicolor combination arranged in 4x4 squares is used. Each square is 140 pixels per side. Moreover, as shown in Table 1, kansei words evaluated for 30 different images by subjects are chosen based on the kansei process that Matsumoto and Ozawa (2003) have classified into six hierarchies between perception and cognition. All subjects evaluate

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these kansei words by using five-level SD (Semantic Differential) method, and then the eye motion is also measured by using an eye mark recorder (EMR) as one of physiological features.

Table 1. Kansei words for perception and cognition processes.

	Kansei words					
Perception process	(1) Heavy – Light		(2) Bright – Dark		(3) Warm – Cool	
	(4) Soft – Hard		(5) Loud – Quiet		(6) Strong – Weak	
Cognition process	(1) Favorite – Unfavorite		(2) Fancy – Unfancy		(3) Comfortable - Uncomfortable	
	(4) Beautiful – Dirty		(5) Harmonious – Disharmonious			

2.2 Experimental subjects and procedures

This experiment was conducted for five young college students (male: 3, female: 2). And the experimental procedure is summarized by the following five steps:

Step 1: Set up the EMR and start the measurement of the eye motion.
Step 2: Present an image of sixteen-color combination.
Step 3: Evaluate kansei words in Table 1 for the presented image.
Step 4: If the number of presented images is less than 30, return to Step 2. If the number of presented images is equal to 30, go on to Step 5.
Step 5: End the measurement of the eye motion.

2.3 Consequence analysis

In addition to hue, lightness and saturation as numerical features of physical stimulus, the gaze duration for each color in the eye motion is analyzed as features from sense organs of subjects. As a result, the gaze position shows a similar trend per subjects regardless of the difference in color combination.

Moreover, three common factors are obtained as shown in Table 2, after factor analysis is applied for eleven observed variables in order to see latent variables for kansei evaluation obtained by SD method. These factors are named "Evaluation", "Activity" and "Potency", respectively, because they are the same as factors shown in the study of the color harmony. According to Table 2, the perception and cognition processes are related to the potency and the evaluation, respectively, but the activity holds a neutral position between them. In this study, neural networks shall try to learn kansei evaluation data based on the hierarchy of the kansei process described by Matsumoto and Ozawa (2003).

3. Learning accuracy using two neural network models

In this section, two neural network models corresponding to two kansei processes from sensation to perception and from perception to cognition try to learn kansei evaluation obtained from subjects. For each model, the adequacy of the learning accuracy is evaluated by the convergence of mean square error and the bias of combination loads.

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Table 2. Results of factor analysis.

Kansei words	(Cognition) Evaluation	Activity	(Perception) Potency
Heavy – Light	0.241	0.045	-0.795
Bright – Dark	-0.177	-0.464	0.637
Warm – Cool	0.032	-0.530	0.155
Soft – Hard	-0.157	-0.201	0.554
Loud – Quiet	0.120	-0.924	0.165
Strong – Weak	0.140	-0.572	-0.040
Favorite – Unfavorite	-0.879	0.022	0.201
Fancy – Unfancy	0.012	-0.770	0.308
Comfortable - Uncomfortable	-0.896	0.072	0.204
Beautiful – Dirty	-0.675	-0.018	0.384
Harmonious – Disharmonious	-0.783	0.270	0.015

3.1 Neural network structures and input-output data

Two neural network models used for the learning of kansei are shown in Figure 1. The neural network from sensation to perception applies hue, lightness, saturation, and the gaze duration for each color received by sense organs to input data and the response of subjects obtained by kansei evaluation of perception to output data. Moreover, the neural network from perception to cognition applies output data described above to input data and the response of subjects obtained by kansei evaluation of cognition to output data.

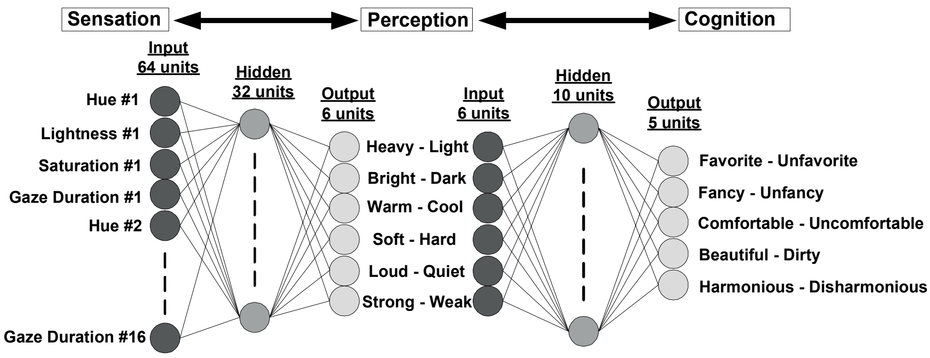

Figure 1. Neural network structures .

3.2 Leaning accuracy by using neural network model from sensation to perception

The neural network corresponding to human kansei process from sensation to perception learns kansei evaluation data obtained from subjects. It consists of 64 input units, 32 hidden units, and 6 output units, and then the learning rate, inertia coefficient, and the number of training sweeps are heuristically set to 0.2, 0.75, and 50000, respectively.

As a result, the mean square error was about 0.04%. This is dramatically improved compared with the result that Ogawa et al. (2010) has described that the error was 5% by using a single hierarchical neural network. Moreover, combination loads ranged from 0.665 to 3.773 and the standard deviation was 0.606. This is also improved. Therefore, it is expected that this model gets closer to human kansei evaluation.

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3.3 Leaning accuracy by using neural network model from perception to cognition

The neural network corresponding to human kansei process from perception to cognition learns kansei evaluation data obtained from subjects. It consists of 6 input units, 10 hidden units, and 5 output units, and then the learning rate, inertia coefficient and number of training sweeps are heuristically set to 0.2, 0.5, and 50000, respectively.

As a result, the mean square error was about 4.5%. This is slightly improved compared with the result of the previous study described above, but it remains insufficient convergence of the error. Moreover, combination loads ranged from 5.823 to 17.868 and the standard deviation was 3.644. This is also improved but the variation is greater than the model from sensation to perception. Therefore, it is necessary to investigate the way to make the mean square error and combination loads small.

4. Discussion

It was found that the learning accuracy of the neural network from sensation to perception was greatly improved by using hierarchized neural networks. It would appear that the gaze position affected the learning accuracy. Meanwhile, the learning accuracy of the neural network from perception to cognition remained low. Reasons include the existence of the activity that factor analysis showed the neutral position between perception and cognition, and the lack of effective features.

5. Conclusion

In this study, we devised neural network models divided into two hierarchies and evaluated the learning accuracy for each model. As a result, the leaning accuracy of the neural network from sensation to perception was high, but the one from perception to cognition was low. The results suggest that it is necessary to consider the activity showed by the factor analysis as a new hierarchy and newly review more effective features.

Acknowledgments

I am very grateful to students at Waseda University for their valuable cooperation in my experiments.

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The evaluation of dichromatic simulation by a visual search task

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Abstract

Dichromatic simulations (Brettel et al. 1997) are used widely in social and educational environments. We evaluated the validity of dichromatic simulation by using a visual search task. The stimulus images consisted of 13 coloured disks (one target and 12 distractors). Two colours were assigned to 6 disks as distractor, respectively. Six trichromats and three strongly anomalous trichromats participated in this experiment. The observer's task was to detect the target colour which was different from other disks as soon as possible. The reaction times (RTs) of the dichromatic simulated colour stimulus for the trichromats were qualitatively similar to those of the original colour stimulus for the anomalous trichromats. However, the RTs of the anomalous trichromats tended to be longer than those of normal trichromats in some particular colour combinations. Thus there is a possibility that the simulation overestimates the dichromats' colour detection. We can conclude that the simulation of the dichromats does not always agree with the real dichromatic people's colour perception.

1. Introduction

Human trichromacy originates in the three types of cone photoreceptors, each with different spectral sensitivity. However, there are some people who do not have one of them. They are called dichromats.

For understanding the colour appearance of the dichromats and realizing the colour universal design, dichromatic simulations have been very available. Especially, the dichromatic simulation proposed by Brettel et al. (1997) is used widely in social and educational environments. Although their dichromatic simulation is based on the behavioural data of unilateral dichromats (Graham and Hsia 1958, Alpern et al. 1983), whether the simulation really demonstrates the colour vision of dichromats has not been examined sufficiently yet.

Thus we evaluated the validity of dichromatic simulation by using a visual search task. We presented the simulated colour stimulus and the unsimulated colour stimulus for trichromatic observers and colour-deficient observers, respectively. The reaction times (RTs) to find a target colour were measured. If there is no difference between the RTs for the trichromatic observers and those for the colour-deficienct observers, the dichromatic simulation is adequate to demonstrate the colour appearance of dichromats. Contrary, if there is a significant difference between them, it would be necessary to modify the simulation.

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2. Method

2.1 Apparatus and stimulus

We used a 19 inch colour monitor (Sony Trinitron Multiscan CPD-G420) controlled by a computer (Dell Vostro 200). The monitor was set with a refresh rate of 75 Hz and a resolution of 1280 x 960 pixels. The gamma characteristics of the monitor were corrected to be linear after measurement by a spectral radiometer (Konica Minolta CS-2000). The monitor was placed in a dark room.

The stimulus images were composed of 13 coloured disks (one target and 12 distractors) whose diameters were 1 degree and these disks were arranged in a circle (see Figure 1(a)). These disks were presented on the peripheral visual field with an eccentricity of 5 degrees.

The colours of the disks were chosen from the 24 colours defined on the CIE1976u'v'UCS diagram (see Figure 1(b)). Those colours were in a constant distance of 0.06 from the D65 chromaticity. Thus they were equal in saturation and luminance but differed in hue. The target colour was one of them. Two colours, which were ±45 degrees in the hue angle relative to the target colour, were used as distractor colours. Each colour was assigned to six distractors. The background was uniformly with the D65 chromaticity grey. The luminances of the disks and the background were 8.0 and 4.0 cd/m², respectively. We called this type of stimuli the 'original stimulus'. There were four types of stimuli: one was the original, the other three types were simulated stimuli. These simulated stimuli were made according to the dichromats' colour appearance model by Brettel et al. (1997). The colours in the original stimulus shift to colours whose dominant wavelength of 475 nm or 575 nm in the protanope and the deuteranope simulations, and of 485 nm or 660 nm in the tritanope simulation. These simulated stimuli were called the 'protanopic stumulus', the 'deuteranopic stimulus', and the 'tritanopic stimulus', respectively.

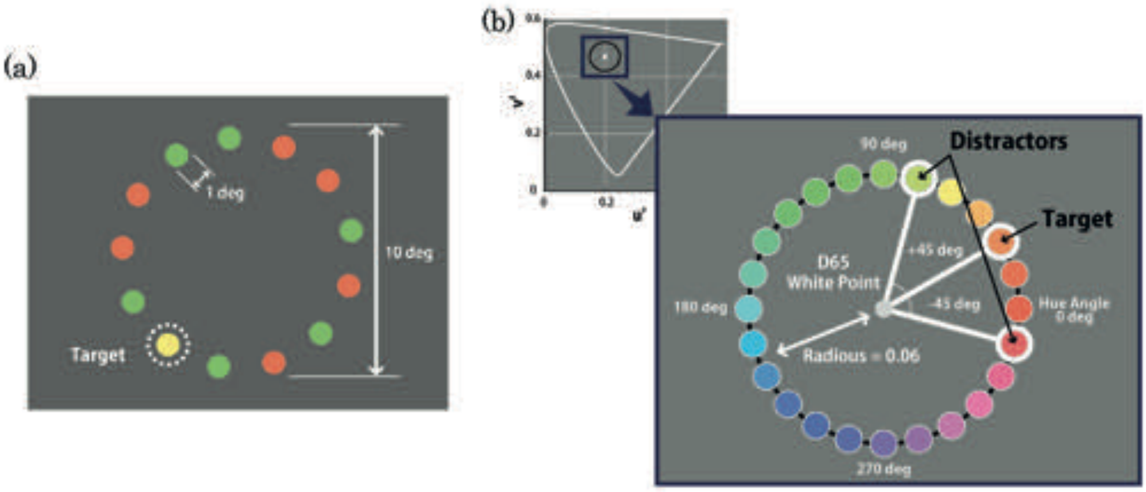

Figure 1. (a) The stimulus image. (b) The colours on the CIE1976 u'v'chromaticity diagram used in the experiment. For example, when the hue angle of target was 30 degree, one of distractors was coloured by the hue angle of 75 degrees (45 degrees relative to the target), the other was by that of 345 degrees(-45 degrees relative to the target).

2.2 Observers

Six normal trichromats and three severely or moderately anomalous trichromats (one protanomalous and two deuteranomalous) participated in this experiment. Colour deficiencies of the anomalous trichromats were assessed by the Farnsworth-Munsell 100-hue test and a colour discrimination experiment. The original stimulus and the three types of simulated stimuli were

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presented to the normal observers. For three anomalous trichromats, we presented only the original stimulus.

2.3 Procedure

Following 2 minutes of dark adaptation and 1 minutes of background adaptation, the stimuli were presented in a random order. The observer's task was to detect the target colour assigned to only one disk as soon as possible. In addition, the observer was also instructed to respond the position of the target. Ten RTs were measured for each target colour. We calculated average RTs for each target colour from the RTs when the response of the target position was correct, and compared the RTs in the original and the three simulated stimuli for the trichromatic observers with those for the anomalous trichromatic observers.

3. Results and discussion

Figure 2 shows the results of both the protan and deutan conditions. We examined two comparisons; one was the comparison between the original stimuli for both the trichromats and the anomalous trichromats, the other was that between the simulation conditions for the trichromatic observers and the original for the anomalous trichromatic observers.

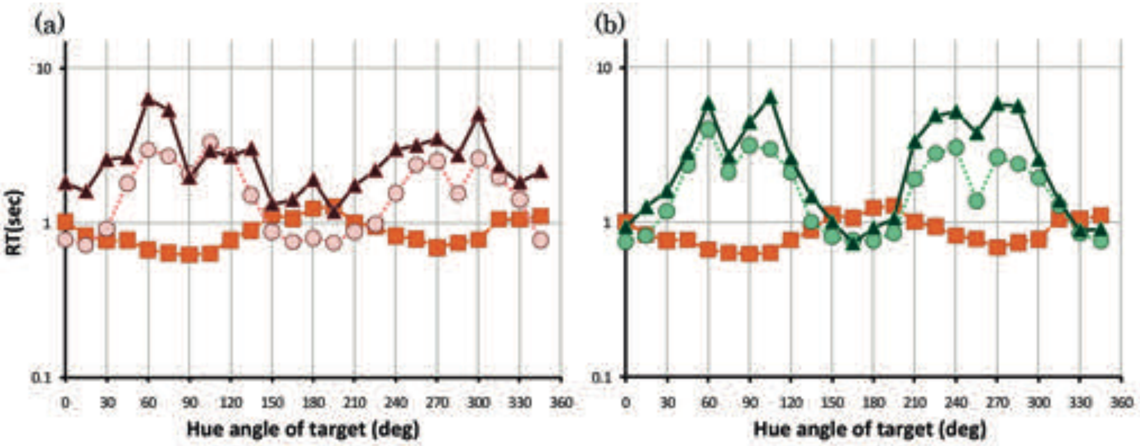

Figure 2. Reaction times as a function of the hue angle of target for the (a) protan and (b) deutan conditions. Squares(■) donaete the RTs of the original stimulus. Circles (●) donate the RTs of the protanopic or the deuteranopic stiumulus for the trichromats. Triangles (▲) donate the RTs fot the real anomalous trichromats.

3.1 Original stimulus for trichromats vs. these for anomalous trichomats

Comparing the RTs in the original condition for the trichromatic observers with those for the anomalous observers, although the RTs for the trichromatic observers were nearly constant of 1 sec, those for the anomalous observers depended on the hue angle of target. Especially, the longer RTs were obtained in the target hue angles of 30° to 120° and 210° to 300° for the anomalous observers. On the other hand, there were some particular colour combinations in which the anomalous observers could find more efficiently a target colour than trichromatic observers (Sunaga and Yamashita 2007). For example, in the task finding the blue-green target from the blue and green distractors, the RT for the deuteranomalous trichromats was faster than that of the normal trichromats. This strongly indicates that the dichromatic colour vision is not always inferior to trichromatic colour vision.

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3.2 Simulated stimulus for trichromats vs. original stimulus for real anomalous trichomats

The dependency of the RTs on the hue angle of target in the simulated stimulus for the trichromatic observers was qualitatively similar to that of the original stimulus for the anomalous trichromatic observers. However, the RTs of the anomalous trichromats tended to be longer than those of the normal trichromats in the colour combinations in which the relatively long time was needed in order to find out the target. This tendency was remarkable in the comparison of the deuteranopic stimulus for the trichromatic observers and the original stimulus for the deuteranomalous observers when the target colour was between the greenish blue (210°) and the bluish purple (300°). Thus there is a possibility that trichromats overestimate the dichromats' colour detection. We can conclude that the simulation of dichromats does not always agree with real dichromatic people's colour perception.

4. Conclusion

We evaluated the dichromatic simulation (Brettel et al. 1997) by a visual search task. Their dichromatic simulation could not demonstrate the quantitative performance in which dichromats find some particular colour in a multicoloured environment. Therefore, we conclude that it is necessary to modify the dichromatic simulation, e.g. to reduce the chromatic contrast in order to increase the difficulty of colour detection in the simulation.

Acknowledgments

We thank the participants of the experiment. We also greatly thank Dr. Hiroyuki Ito, Naoki Tameda, Go Matsumoto, and Shotaro Mitani for their useful comments.

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Survey of the exterior colors of the academic buildings – in the center of Kansai

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Abstract

Nowadays, with the aim of creating aesthetically pleasing communities, local administrations in attractive areas tend to promote attractive area planning, in accordance with the area's natural environment and its history.

In color planning, it is important to consider how colors will be perceived by the public and how they affect people physiologically and psychologically.

Here we report the results of a survey concerning the exterior colors and materials used on each of the universities. This result obtained from this survey, concludes that the colors of certain buildings are not always suitable to our current living environments, but through these surveys, the colours of new buildings could be predicted and changed accordingly. In addition, it would be meaningful to consider the colours of academic buildings which are considerably influential to other public buildings.

1. Introduction

Nowadays, with the aim of creating aesthetically pleasing communities, local administrations in attractive areas want to promote attractive area planning, in accordance with the area's natural environment and its history[1)].

Recently, there have been many cases where the exterior colors of newly constructed buildings are unsuitable and considered to be an eye sore. These buildings are problematic in terms of harmonizing with the surroundings and maintaining satisfying landscapes. However, it is very difficult to predict the reaction and visual perception of colors used for new buildings.

In color planning, it is important to consider how colors will be perceived and how they affect people physiologically and psychologically.

Before the World War II the colors of Japanese buildings were almost all achromatic colors. However, in the post war era, color planning began to grow in importance and buildings began to use bolder colors. By looking at universities and other academic buildings, we can see how the color trends have changed. Since universities are important public buildings, we have decided to focus on studying the color trends of university buildings in Japan[2)].

2. Summary of the survey

There are 105 universities in Kyoto, Osaka, and Hyogo in Japan. This research's sample consists of 38 universities, which are similar in terms of environment and numbers of students. There are 20 new universities chosen from universties established in the recent period of 1988 to 2006 and 18 old universities, established between 1872 and 1928.

Data was gathered on the exterior colors and materials used on each of the universities' buildings. The data for the each of the universities consists of the main entrance elevation, the roofs and the main gate. The temperature and time were more or less constant during the survey.

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The JPMA(Japan Paint Manufactures Association) Standard Paint Colors(2005-D: Pocket type) consisting of 608 color chips was used to evaluate the colors of each target. The research duration was from July to Oct. 2006.The authors confirmed the walls of the target buildings were not illuminated by direct sunlight during the surveys. Materials were classified by the type of architectural materials. Table 1 shows university data chosen for the researches.

Table 1 University data chosen for the research.

More than 80 years ago		**Recently established**	
name of the university	*year founded*	*name of the university*	*year founded*
Hanazono Univ.	1872, Kyoto	Univ. of Marketing and Distribution Sciences	1988,Hyogo
Kyoto Prefectural Univ. of Medicine	1872, Kyoto	Kobe Design Univ.	1990,Hyogo
Kobe Collge	1875,Hyogo	College of Nursing	1995,Hyogo
Doshisya Univ.	1875, Kyoto	Poole Gakuin Univ.	1996,Osaka
Kyoto Univ. of Education	1876, Kyoto	Kyoto Bunkyo Univ.	1996, Kyoto
Doshisha Women’s College of Liberal Arts	1876, Kyoto	Kansai Univ. of Social Welfare	1997,Osaka
Kyoto City Univ. of Arts	1880, Kyoto	Tokiwakai Gakuen Univ.	1999,Osaka
Kansai Univ.	1886,Osaka	Kobe Yamate Univ.	1999,Hyogo
Kwansei GakuinUniv.	1889,Hyogo	Osaka Univ. of Tourism	2000 ,Osaka
Kyoto Prefectural Univ.	1895, Kyoto	Osaka Univ. of Human Science	2001,Osaka
Kyoto Unv.	1897, Kyoto	Kyoto Saga Univ. of Arts	2001, Kyoto
Kyoto Institute of Technology	1902, Kyoto	Hagoromo Univ.of International studies	2002,Osaka
Kobe Univ.	1902,Hyogo	Osaka Seikei Univ.	2003,Osaka
Ritsumeikan Univ.	1913, Kyoto	Kansai Univ. of Health Sciences	2003,Osaka
Osaka Shoin Women’s Univ.	1917,Osaka	Senri Kinran Univ.	2003,Osaka
Otani Univ.	1920, Kyoto	Higashiosaka College	2003,Osaka
Ryukoku Univ.	1920, Kyoto	Osaka Jyogakuinn College	2004,Osaka
Osaka Univ. of commerce	1920,Osaka	Osaka Aoyama Univ.	2005,Osaka
		Shijyounawate Gakuen Univ.	2005,Osaka
		Osaka Univ. of Comprehensive Children Education	2006,Osaka

3. Results and discussion

1) Materials

Entrance Gate: 100% of gates of the old universities can close , however 80% of new ones can close . Figure 1 shows that overall, 45% of the universities‘ gates were made of iron , 32% of stone and 14% of tile finishing. The gates of the old universities were made 43% from iron and 40% from stone. The gates of the new universities were made 47% from iron , 25% from tile finishing and 22% from stone.

Roof: Roofs were classified into two styles, from flat (71%) and other□24% from Japanese slate and the remainder from cement slate□.

Exterior wall: Regarding the finish on the universities shown in figure 3, (exterior walls) 41% was tile, 22% was plaster and 19% was concrete finish. 15% of the finish on the old universities exterior wall was plaster, 30% was tile finish, 19% was concrete, 18% brick and 15% stone. In comparison, over 50% of the finish on new universities exterior walls was tile, 30% plaster and 19% concrete.

Exterior wall (Universities of Coeducation and/or women) : Figure 5 shows the finish of the outside of the universities of coeducation and women. There are 18 women-only universities, 3(16%) are ‘old‘and 15(75%) are ‘new‘. In the last ten years, 13 changed to coeducation and two

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remained women-only. The finish of the women-only universities was 51% plaster and 26 % tile. These buildings do not suit their surroundings according to the people questioned in the survey.

2) Colors

Entrance gate: Figure 2 shows the colors used on the entrance gates to the ‘old‘ universities and the ‘new‘ universities. 25% of the gates surveyed were R series colors, 30% were YR series colors and 13% were Y series colors. In terms of ‘old‘ universities, 15% were R series colors, 20% were YR and 23% were Y, PB series colors and silver accounted for 5% each. Regarding ‘new‘ universities, 15% were R series colors, 26% were YR series colors, 9% were Y series colors, 5% were BG series colors and 11% were PB series colors. Achromatic colors accounted for 28% of the gates‘ colors at both the ‘old‘ and the ‘new‘ universities.

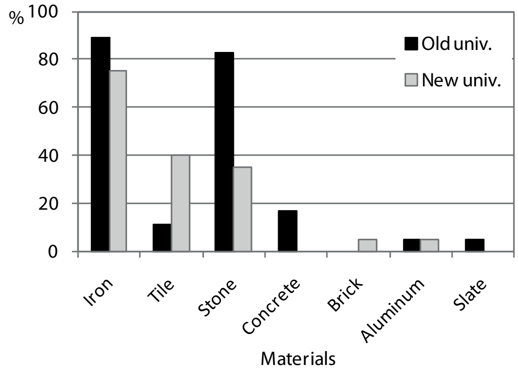

Fig.1 Materials of gates on old and new univ.

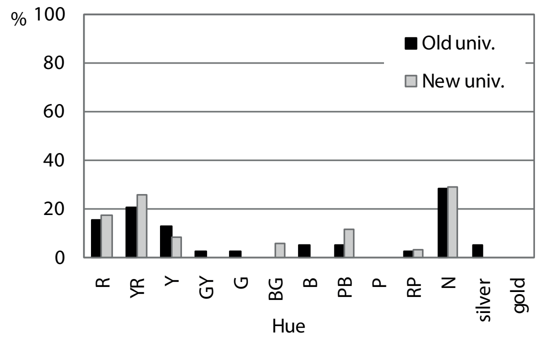

Fig.2 Hue of gates on old and new univ.

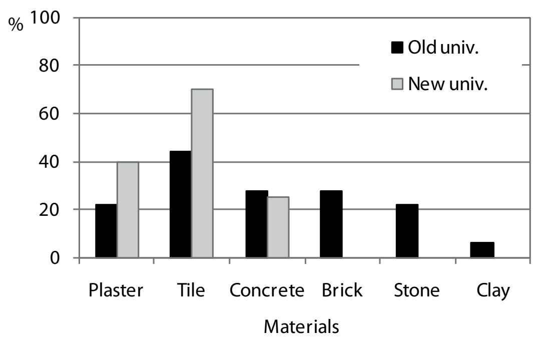

Fig.3 Materials of exterior wall on old and new univ.

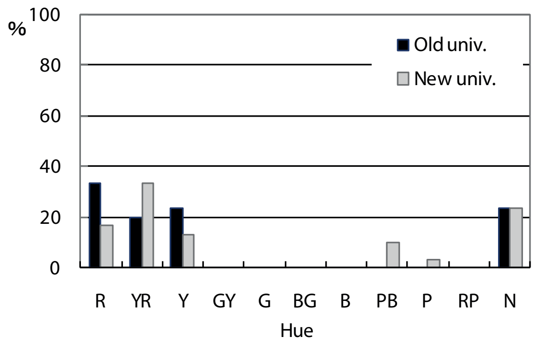

Fig.4 Hue of exterior wall on old and new univ.

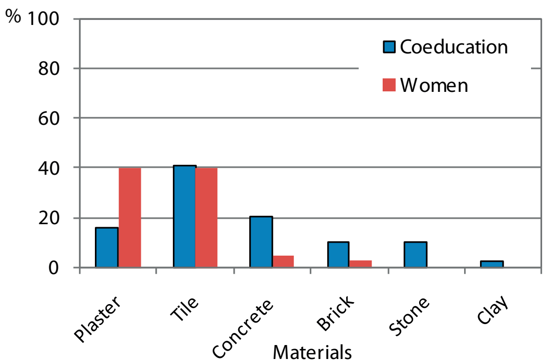

Fig.5 Materials of exterior wall on coeducation and women univ.

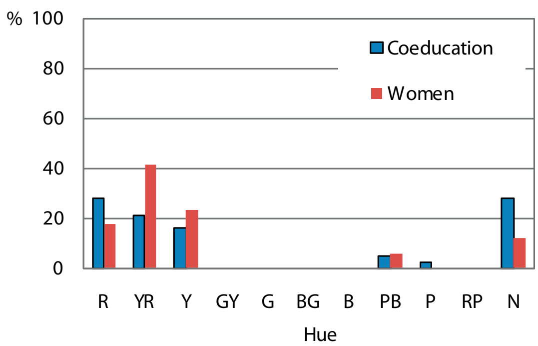

Fig.6 Hue of exterior wall on coeducation and women univ.

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Roof: PB series colors and achromatic colors each accounted for 10% of roof colors. A further 6% of roofs were R series colors and the remainder could not be seen because they have flat roofs.

Exterior wall: Regarding the exterior walls shown in figure 4, 16% were R series colors, 27% were YR series colors, 23% were Y series colors. In terms of 'old' universities, 33% were R series colors, 20% were YR series colors and 23% were Y series colors. 80% were warm series colors. Regarding 'new' universities, 16% were R series colors, 34% were YR series colors, 13% were Y series colors, 70% were warm series colors. Achromatic colors accounted for 23% of the exterior wall colors at both the 'old' and the 'new' universities.

Exterior wall (Universities of Coeducation and/or women) : Figure 6 shows the colors used on the exterior wall at the 'coeducation' universities and the 'women' universities. In the case of 'coeducation ' universities, 28% were R series colors, 22% were YR series colors, 18% were Y series colors, 5% were PB series colors, 28% were achromatic colors. Regarding 'women' universities, 15% were R series colors, 41% were YR series colors, 25% were Y series colors, 5% were PB series colors and 10% were achromatic colors. 70% of exterior walls were warm series colors.

4. Conclusions

The survey showed that the exterior walls of old buildings had been finished with brick, stone and other high quality and expensive materials. New buildings (in both Old and New Universities) had been finished with reinforced concrete, tiles, brick foundations, spray and other cheap and poor quality materials. There is a small difference in color and material used between the old buildings and the new buildings. The walls of recent buildings were painted with warm colors, whereas old buildings were finished with achromatic colors on stone.

1. Exterior walls of almost all the old universities were built with brick and stone.
2. The new universities were built with reinforced concrete, tile, brick and so on.
3. Women-only universities were finished with plaster and painted with warm colors.
4. Coeducational universities establised recently were painted with warm colors.

Some buildings were painted with RB series colors. Those colors were not used before 1988 / the time / period of new universities. This result obtained from this survey, concludes that the colors of certain buildings are not always suitable to our living environments, but we can predict the colors of new buildings and change them accordingly. In addition, it would be meaningful to consider the colors of academic buildings as considerably influential to other buildings in public.

Acknowledgment

The authors express their gratitude to Miss Aimi Yamamoto, then the student of Otemae university.

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Estimation of color concentrations for human skin color reproduction

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Abstract

This paper describes a new method for estimating the concentrations of color substances in human skin using surface-spectral reflectance. We define a model equation to represent surface-spectral reflectance of human skin using the concentrations of those substances. First, we assume an optical human skin model with a new feature considered to the stratum corneum (SC). Then, by applying the Kubelka-Munk theory (Kubelka 1948, 1954, K-M) to our optical human skin model, we define a model equation. Finally, we examine the validity of the proposed method experimentally by evaluating estimated concentrations of oxygenated hemoglobin and melanin.

1. Introduction

In order to determine optimal illumination/lighting conditions in studios, photo scenes, or dance halls, it is important to consider the color reproduction of human skin. An understanding of true human skin color is important to determine optimal illumination conditions to produce an accurate color reproduction. Human skin is multilayered and inhomogeneous, while its color depends on the concentration of color substances contained within, such as hemoglobin, carotene, and melanin. Therefore, analysis and evaluation of human skin color can be performed by estimating the concentration of color substances in skin. Herein, we describe a method for estimating the concentration of color substances in skin using surface spectral reflectance.

In the field of computer-enhanced visualization, a number of algorithms for analyzing human skin using image and surface spectral reflectance have been proposed. However, most algorithms disregard the stratum corneum, the outermost layer of human skin, which functions to maintain moisture and forms the surface texture. Thus, it is necessary to consider the transmittance of the stratum corneum in multiple reflection models in order to perform color analysis of human skin. In addition, accurate values for color substances in skin have not been provided by previous analyzes, because many of the algorithms employed used index values for human skin color substances.

This paper describes a new method for estimating the accurate concentration of color substance in the skin using the surface spectral reflectance. In order to analyze multiple reflections from human skin, we defined a model equation to represent the surface spectral reflectance. The validity of the proposed method is examined experimentally by evaluating estimated concentrations of oxy-Hb and melanin. We estimate oxygenated hemoglobin (oxy-Hb) concentrations in cheeks of Japanese female subjects and compared the results with direct measurements.

2. Estimation method

To define a model equation to represent surface-spectral reflectance of skin, we assumed an optical human skin model, as shown in Figure 1, which was defined as follows. Human skin consists of 4 layers; the SC, epidermis, dermis, and subcutaneous tissue (ST). Noteworthy features of this

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model are reflectance k_1 and transmittance T_{SC} of the SC. Incident light at the interface between air and skin is reflected by the surface structure of the SC (reflectance k_1), while light passing through the SC is decreased by the moisture condition of the SC (transmittance T_{SC}). The epidermis and dermis possess color substances. Light passing through the epidermis is scattered and absorbed by melanin, while that passing through the dermis is scattered and absorbed by 4 color substances in blood; oxy-Hb, deoxygenated hemoglobin (deoxy-Hb), carotene, and bilirubin. The optical influence of the color substances in ST is assumed to be negligibly small. To define an equation that represents the above multiple reflections, we use K-M functions. Numerical equations of the absorption coefficients are defined based on the Lambert-Beer (L-B) law and our definition. The L-B law enables calculation of absorption coefficients as a product of mol concentration w (mol/l) and molar absorption coefficients $\varepsilon(\lambda)$ (cm-1). The absorption coefficients of epidermis $K_e(\lambda)$ and dermis $K_d(\lambda)$ are defined as follows:

$$K_e(\lambda) = \varepsilon_{melanin}(\lambda) w_{melanin} \tag{1}$$

$$K_d(\lambda) = (\varepsilon_{oxy-Hb}(\lambda) w_{oxy-Hb} + \varepsilon_{deoxy-Hb}(\lambda) w_{deoxy-Hb} + \varepsilon_{bilirubin}(\lambda) w_{bilirubin} + \varepsilon_{carotene}(\lambda) w_{carotene}) \tag{2}$$

where each index indicates the color substance. Figure 2 shows the molar absorption coefficients of 5 color substances. In addition, we use Anderson's data (Anderson 1981) for scattering coefficients of the epidermis $S_e(\lambda)$ and dermis $S_d(\lambda)$, as shown Figure 3.

Next, we define equations for reflectance and transmittance of the epidermis and dermis. Note that K-M functions are dependent on the optical property. Since the scattering coefficient of dermis is higher than the epidermis coefficient, we select a K-M function for the strong scattering material. Using the thickness D_e of epidermis and optical coefficients, reflectance $R_e(\lambda)$ and transmittance $T_e(\lambda)$ of the epidermis were defined as follows.

$$R_e(\lambda) = \frac{1}{a_e(\lambda) + b_e(\lambda)\coth b_e(\lambda) S_e(\lambda) D_e} \tag{3}$$

$$T_e(\lambda) = \frac{1}{a_e(\lambda)\sinh b_e(\lambda) S_e(\lambda) D_e + b_e(\lambda)\cosh b_e(\lambda) S_e(\lambda) D_e} \tag{4}$$

$$a_e(\lambda) = (S_e(\lambda) + K_e(\lambda)) / S_e(\lambda) \quad , \quad b_e(\lambda) = \sqrt{(a_e(\lambda)^2 - 1.0)}$$

Similarly, reflectance $R_d(\lambda)$ and transmittance $T_d(\lambda)$ of the dermis were defined as.

$$R_d(\lambda) = \frac{S_d(\lambda) D_d}{a_d(\lambda) S_d(\lambda) D_d + 1.0} \tag{5}$$

$$T_d(\lambda) = \frac{1}{1 + a_d(\lambda) S_d(\lambda) D_d + \frac{1}{2} b_d(\lambda)^2 S_d(\lambda)^2 D_d^2} \tag{6}$$

$$a_d(\lambda) = (S_d(\lambda) + K_d(\lambda)) / S_d(\lambda) \quad , \quad b_d(\lambda) = \sqrt{(a_d(\lambda)^2 - 1.0)}$$

Then, we define a model equation for surface-spectral reflectance for a total 4 skin layers by integrating the reflectance of each layer. Since color substances have little influence on light in ST, reflectance of ST $R_h(\lambda)$ is defined as 1.0 at a visible wavelength. The total reflectance $R_{est}(\lambda)$ of the 4 skin layers is defined as follows:

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$$R_{est}(\lambda) = k_1 + (1 - k_1) T_{SC} R'(\lambda) \qquad (7)$$

$$R'(\lambda) = R_e(\lambda) + \frac{T_e(\lambda)^2 R_{dh}(\lambda)}{1.0 - R_e(\lambda) R_{dh}(\lambda)} \quad , \quad R_{dh}(\lambda) = R_d(\lambda) + \frac{T_d(\lambda)^2 R_h(\lambda)}{1.0 - R_d(\lambda) R_h(\lambda)}$$

where $R_{dh}(\lambda)$ is the integrated reflectance of the dermis and ST, and $R'(\lambda)$ the total reflectance of 3 skin layers, without the SC.

Using these, we estimate the unknown parameters using the following steps. The unknown parameters are considered to be 5 concentrations of color substances w, reflectance k_1 and transmittance T_{SC} of the SC, and thickness of the epidermis D_e and dermis D_d. Surface-spectral reflectance is estimate by determining these parameters, so that estimated reflectance is fitted to the measured reflectance of human skin, using the least squared method. For the fitting computation, reflectance and transmittance of the dermis are calculated by adjusting the 4 concentrations of color substances (oxy-Hb, deoxy-Hb, carotene, and bilirubin) and thickness of the dermis. Then, reflectance and transmittance of the epidermis are calculated by adjusting melanin concentration and thickness of the epidermis. Finally, each reflectance of the 4 layers is integrated. We then determine the optimal parameters to minimize fitting errors.

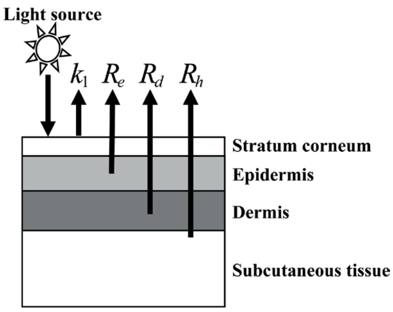

Figure 1. Human skin model.

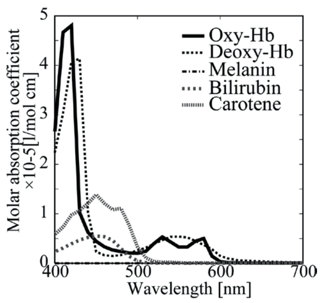

Figure 2. Molar absorption coefficients of color substances.

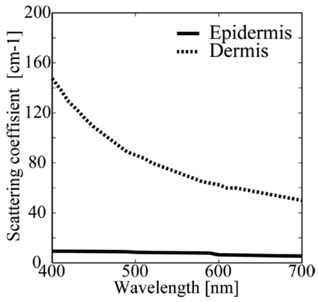

Figure 3. Scattering coefficients of epidermis and dermis.

3. Experimental results to validate our method

In order to confirm the validity of our method, we evaluated the concentrations of oxy-Hb and melanin in subject samples. In this experiment, we measured surface-spectral reflectance within the visible wavelength range [400-700nm] using a spectrophotometer (CM2600-d, KONICA MINOLTA). The measurement/illumination area was 8/11 mm in diameter. For evaluating oxy-Hb concentration, we used surface-spectral reflectance obtained from 70 Japanese female subjects and compared the estimated concentrations with direct measurement values. oxy-Hb mass concentration can be obtained using a blood test and is used for medical evaluation purposes. We used oxy-Hb mass concentrations obtained in blood tests of the same subjects as the direct measurement values. In addition, we transformed the estimated mol concentration into mass concentration (g/dl) using molecular weight. Figure 4 shows a scatter diagram plotting direct measurements and estimated oxy-Hb concentrations by our method. The strong correlation (R=0.81) indicates that our method is useful for accurate determination of oxy-Hb concentration.

In addition to estimated melanin concentration, we used surface-spectral reflectance for 30

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pigment and non-pigment areas in the same subjects. In general, the melanin concentration in a pigment area is higher than that in non-pigment areas, because of increased melanin production. Figure 5 shows a comparison of average melanin concentrations in pigment and non-pigment areas, which were significantly different, as shown by a t-test ($p<0.01$). This result indicates that our method for estimating melanin concentration is effective.

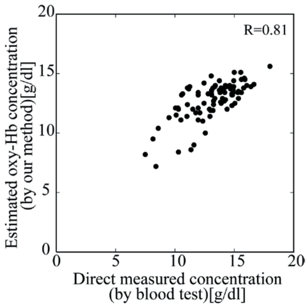

Figure 4. Experimental results of oxy-Hb.

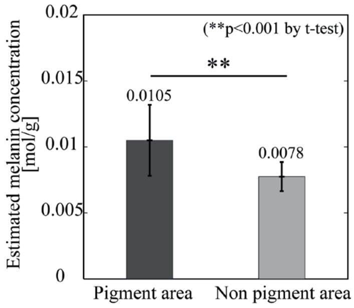

Figure 5. Experimental results of melanin.

4. Conclusion

We have developed a method for estimating the concentrations of color substances in human skin using surface-spectral reflectance. For this method, we (1) assumed a new optical human skin model that includes the SC, (2) defined equations for absorption coefficients, (3) and deternined a model equation to represent surface-spectral reflectance of human skin based on the K-M theory. In a validation experiment, oxy-Hb concentrations estimated by our method were strongly correlated with direct measurement values obtained in blood tests. Moreover, we confirmed a significant difference between pigment and non-pigment areas. Our results show that this novel method can be used to accurately estimate the concentrations of color substances in human skin. Merits include accurate reproduction of the color appearance of human skin based on the concentration of a specific color substance and a non-invasive approach.

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Effects of light on food appearance in color, glossiness, and visual texture

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Abstract

This study aims to determine the effect of light on the food appearance concerning its color, glossiness, and visual texture. We conducted a sensory experiment on food appearance of dishes under different light sources. We used the digital images of the 12 kinds of food dishes to give the subject the same visual stimuli and no olfactory cues. As a result, there were strong correlations between "visual taste" and "color appearance" in all foods. "Glossiness" could be contributing factor to "visual taste" in some foods, whereas "visual texture" was little affected by the light sources.

1. Introduction

The food appearance in a food dish influences its visual taste. However, visual taste is determined by not only the properties of the surface of the food but also by the lighting condition on the table. Recently, new light sources, such as LED lamps, are increasingly being installed in restaurants and houses, because their usage can reduce energy consumption and produce various light color environments. Therefore, it is important to address the question of how lightning conditions influences visual taste.

The subjective experiment on "freshness", "appeal", "natural appearance" and "reliability" of some kinds of food didn't show any remarkable difference between the conventional light source (incandescent lamp or fluorescent lamp) and the LED lamp (Ixtaina, et al. 2010). On the other hand, another study reported that the color rendering evaluations in LED lighting was lower than in incandescent light, and "fresh" and "bright" evaluation were higher with high color temperature LED light (Lee, et al. 2010). In addition, the results of a sensory evaluation of food appearance of a real product were in accordance with the results when using its photograph, in "overall color" or "color of the border", but there was disagreement in "the oily appearance" (Ferraris, et al. 2010).

This study aims to determine the effect of light on the food appearance concerning its color, glossiness, and visual texture. In this study, we conducted a sensory experiment on food appearance of dishes under different light sources. We used the digital images of the dishes to give the subject the same visual stimuli and no olfactory cues.

2. Methods

We prepared 12 kinds of food dishes (as shown in Figure 1), Sashimi (raw fish), Tempura (Japanese fritter), Teriyaki fish, Japanese omelet, Hamburger steak, Beef steak, Green pepper steak, Shrimp in chili sauce, Salad, Roll bread, Fried rice, and Mont-Blanc cake. These were chosen among those frequently served in Japanese restaurants and households and having in consideration of their characteristics in colors, glossiness, and visual texture.

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First, we measured the chromaticity values of the 12 dishes using a 2D Color Analyzer (KONICA MINOLTA / CA-2000) under 6 kinds of light sources, 5000K and 3000K fluorescent lamp, 5000K and 3000K LED lamp, halogen lamp, and D_{65} lamp. Each light source was set 40 cm perpendicularly above the dish, and the illuminance on the dish was 200 lx. Next, we transformed the measured data into their respective RGB values using calibration data of a display (EIZO / CG245W). This color management process ensures that the digital images are displayed with the same chromaticity values as the real object. Twenty subjects observed each image of the dishes presented on the monitor, and evaluated the "visual taste", and answered subjectively 3 items: "color appearance", "glossiness" and "visual texture" according to a 6 steps categorical scale. They were female university students, in their twenties.

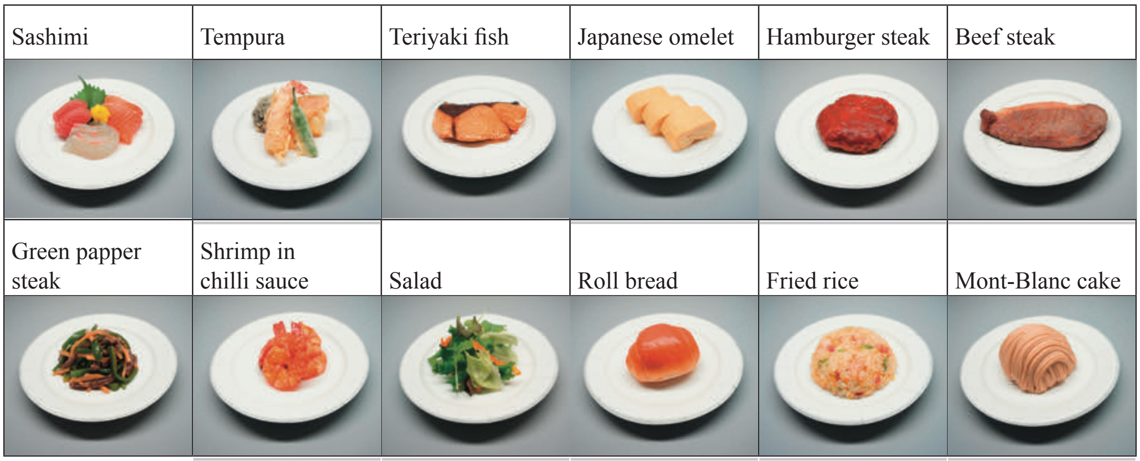

Fig. 1 Food dishes used as visual stimuli in this experiment

3. Results and discussion

3.1 Evaluation results

Figure 2 illustrates the evaluation results of Sashimi, Tempura, Japanese omelet, Beef steak, Salad and Fried Rice under each light source. "Visual taste" and "color appearance" of Sashimi, Tempura, and Japanese omelet were good in 5000K fluorescent lamp, D_{65}, and 5000K LED; "glossiness" of Sashimi was better in LED light conditions, but that of Tempura was not so good in all light conditions. "Glossiness" of Japanese Omelet was better in halogen lamp and LED lamp. The results of Beef steak showed that "visual taste" was not good in 3000K fluorescent lamp and that "color appearance" was good in D_{65}. Also, "glossiness" was better under the conditions of halogen lamp and LED, but "visual texture" was not different among lighting conditions. "Visual taste" of Salad was bad in halogen lamp and 3000K LED, and it was much correlated to "color appearance". The results of Fried Rice showed that "visual taste" was not good in halogen lamp and that "color appearance" was good in D_{65} light. Also, "glossiness" was better under the conditions of halogen lamp and LED; "visual texture" was better in 5000K LED, but not better in 3000K fluorescent lamp.

It is comprehensively concluded that D_{65}, 5000K fluorescent lamp and 5000K LED were better suited for lighting of foods and LED tended to enhance "glossiness" of foods.

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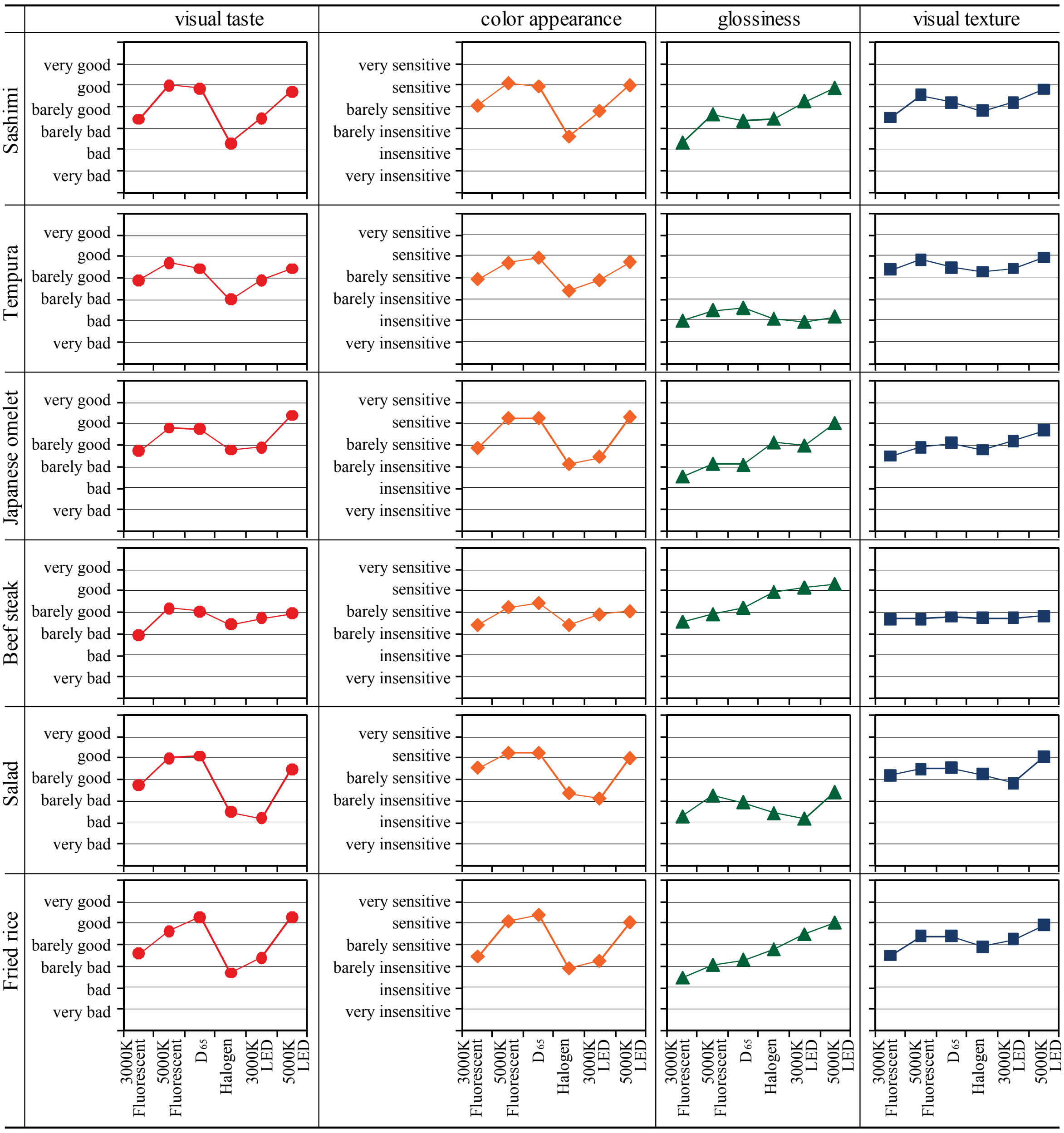

Fig. 2 Evaluation results of Sashimi, Tempura, Japanese omelet, Beef steak, Salad, and Fried rice

3.2 Statistic analysis

We analysed these evaluation results with Pearson's correlation coefficient and standardized multiple regression coefficient; we used "visual taste" as response variable, and "color appearance", "glossiness" and "visual texture" as explanatory variable. Table 1 shows the statistic results of Pearson's correlation coefficient and standardized multiple regression coefficient.

There were strong correlations between "visual taste" and "color appearance" in all foods. A statistically significant ($P<0.001$) strong positive correlation was observed between "visual taste and "color appearance" in Sashimi, Japanese omelet, Salad, Fried rice and Mont-Blanc cake. "Visual taste" of Sashimi and Salad, raw food, were statistically predicted by "color appearance" and "glossiness". Also in Green pepper steak and Shrimp in chilli sauce, Chinese dishes with sauce, "visual taste" was explained by "color appearance" and "glossiness" ($P<0.01$).

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Table 1. Statistic results of Pearson's relation coefficient and Standardized Partial regression coefficient.

Statistic method	Pearson's correlation coefficient			Standardized Partial regression coefficient		
Food dishes	color appearance	glossiness	visual texture	color appearance	glossiness	visual texture
Sashimi	.756***	.379***	.350***	.728***	.219**	-.075
Tempura	.695***	.231*	.434***	.639***	-.026	.134
Teriyaki fish	.595***	.342***	.307**	.519***	.143	.081
Japanese omelet	.755***	.350***	.352***	.708***	.228***	.078
Hamburger steak	.594***	.417***	.290**	.505***	.212*	.014
Beef steak	.510***	.252**	.148	.474***	.134	.015
Green pepper steak	.593***	.352***	.069	.573***	.299***	-.118
Shrimp in chilli sauce	.679***	.454***	.347***	.588***	.238**	.113
Salad	.763***	.526***	.405***	.706***	.326***	-.126
Roll bread	.672***	.305**	.291**	.628***	.181*	.040
Fried rice	.815***	.252**	.456***	.762***	.084	.093
Mont-Blanc cake	.741***	.294**	.376***	.687***	.056	.100

*p<0.05, **p<0.01, ***p<0.001

4. Conclusion

In visual evaluation of foods, "color appearance" is the most important factor in the estimation of "visual taste". "Glossiness" could be contributing factor to "visual taste" in some foods, whereas "visual texture" is little affected by the light sources.

Acknowledgments

This study was supported by a grant from Asahi Breweries Foundation, 2010-2011.

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Computer color matching system for metallic and pearlescent color applied gonio-photometric spectral imaging

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Abstract

In this study, a gonio-photometric spectral imaging system was developed to apply CCM for effect coatings. It was composed of 2 directed white LED illuminates, a liquid crystalline tuneable filter (LCTF), and CCD imaging device with pertier cooling unit. This spectral imaging system can get high accurate gonio-photometric colour values. Illuminates are 20°, 45° from normal direction of sample and the CCD device captures the images via the LCTF. Each image captured in a spectral manner was divided into 8 parts accounting for slight differences in illumination. Inside these parts of the images the CIELAB colour coordinates and the spectral radiance factors are calculated and clustered.

To check the accuracy of this CCM, four kinds of materials, that is absorption pigment, metal flake, interference mica and a flop control agent were used to create test panels with coatings on a white and a black substrate by spray application. These panels were applied for calibrating the CCM. Further 8 target panels composed of 4 to 5 materials with a well-defined formulation were prepared in the same way coating. Developed CCM Software has two functions, one is components material identification, the other one is formulation calculation, and checked both functions accuracy.

Regarding components identification, 7 in 8 targets were selected same materials of target panel. And formulation accuracy ware checked colour difference value of CIELAB and DIN6175-2 between right and calculated formulation by CCM. In the case of 7 targets which selected right components, both colour difference values were smaller than 5.39 at 20° illuminate, and smaller than 4.53 at 45° illuminate. By applying the CCM and checking the accuracy of the calculated data in comparison with the known components and formulation, the benefit of multispectral gonio-imaging and calculating method were shown in this study. Gonio-photometric spectral imaging technology was quite useful for metallic and pearlescent CCM.

1. Introduction

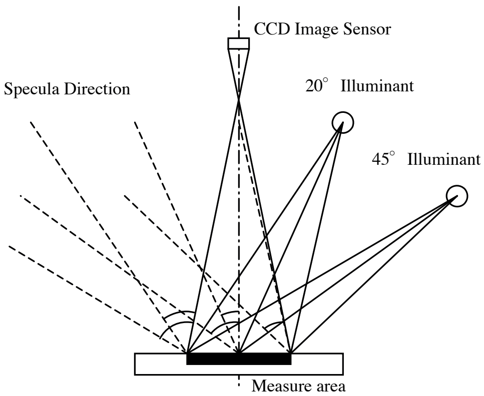

Figure 1. Optical geometry of spectral imaging system

Metallic and pearlescent colours such as recent automotive exterior coatings are included many types of effect pigments, for example, aluminium and pearlescent pigment. Effect coatings show colour, sparkle, and graininess and related visual perceptions changing with illumination and observation angle. On the other hand, the manual colour matching work is very difficult and requires high human skill. Also computer colour matching systems (CCM) for effect coating require complex calculation. The main idea to reach colour and texture match by CCM is the use of combined spectral and imaging information.

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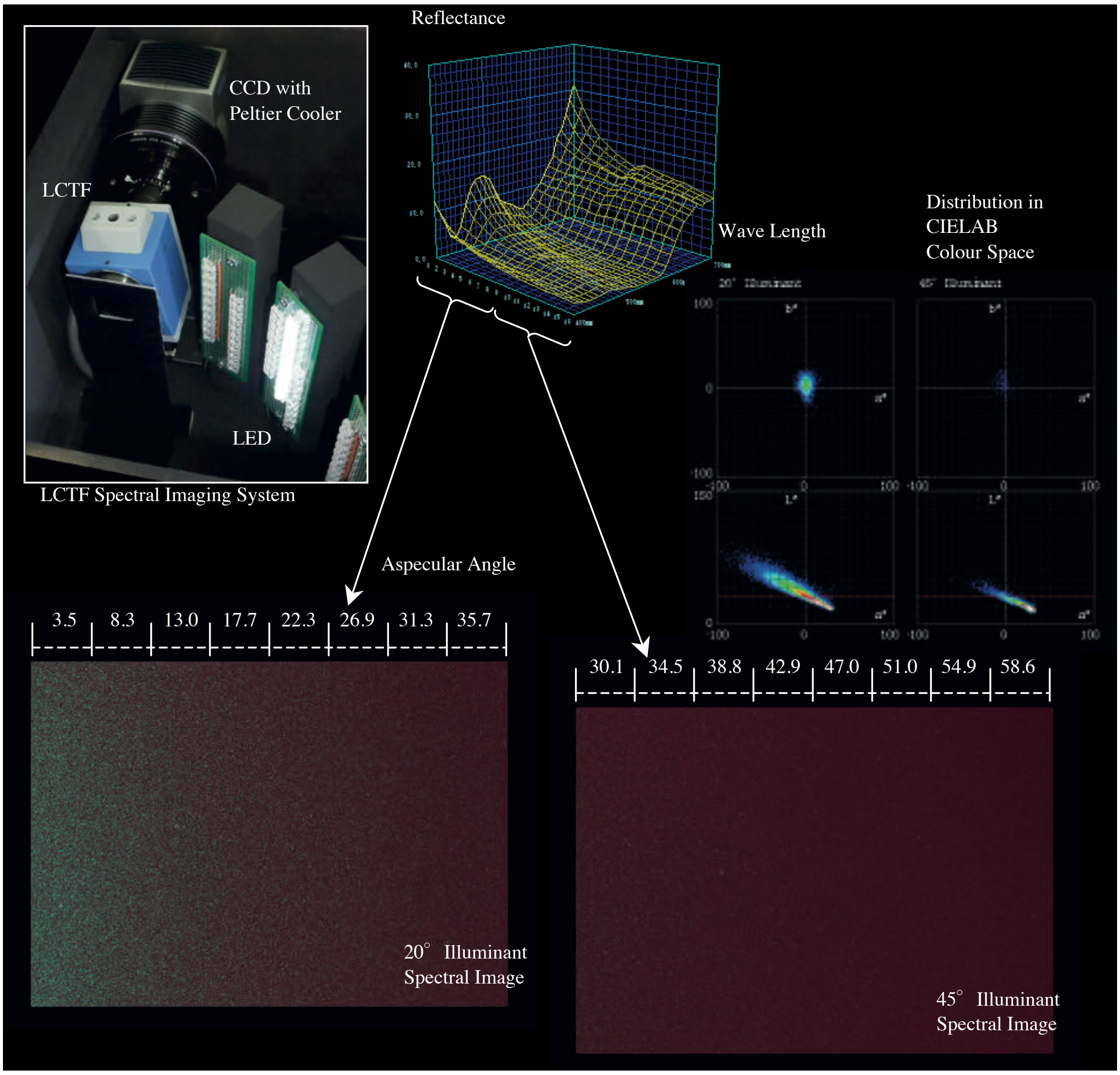
2. Experiment

2.1 Gonio-photometric spectral imaging system

In this study, a gonio-photometric spectral imaging system was developed to apply CCM for effect coatings. It was composed of 2 directed white LED illuminates, a liquid crystalline tuneable filter (LCTF), and CCD imaging device with pertier cooling unit. This spectral imaging system can get high accurate gonio-photometric colour values. Illuminates are 20° and 45° from normal direction of sample and the CCD device captures the images via the LCTF. Each image captured in a spectral manner was divided into 8 parts accounting for slight differences in illumination (see Figure 1, 2). Detect a-specula angles are from 3.5° to 35.7° at 20° illuminate, and 30.1 to 58.6° at 45° illuminate.



Calibration was used diffuse surface white plaque, and got well dynamic range by optimization of exposure time during calibration for each wavelength automatically. Spectral imaging measure range was from 420nm to 700nm each 10nm.

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2.2 Color matching calculation

To check the accuracy of this CCM, four kinds of materials, that is absorption pigment, aluminium flake, interference mica and a flop control agent were used to create test panels with coatings on a white and a black substrate by spray application. These panels were applied for calibrating the CCM (see Table 1, 2).

Table 1. Category and Component

Category	Component
Absorption pigment	Balck FW200, Cappoxyt Yellow, Palomer Blue, Hostaparm Red, Monastral Green
Metal flake	Alpate NS7670NS
Interference mica	Futura Green, Turquoise, Lilac, Blue, Violet, Indigo, Xirallic Crystal Silver, Color Stream Arc. Fire
Flop control agent	TiO_2

Table 2. Formulation of calibration panel (A: Absorption pigment, B: Black pigment M: Metal flake I: Interference mica, F: Flop control agent, C: Clear paint)

	Absorption pigment	Metal flake	Interference mica	Flop control agent
1	A/C = 0.5/99.5	M/C = 1.0/90.0	I/C = 1.0/90.0	F/M/C =0.5/0.0/99.5
2	A/C = 2.0/98.0	M/C = 1.5/98.5	I/C = 1.5/98.5	F/M/C =2.0/0.0/98.0
3	-	M/C = 2.5/97.5	I/C = 2.5/97.5	F/M/C =0.5/1.0/98.5
4	-	M/B/C = 1.0/0.3/98.7	I/B/C = 1.0/0.3/98.7	F/M/C =1.0/1.0/98.0
5	-	M/B/C = 2.5/0.3/97.2	I/B/C = 2.5/0.3/97.2	F/M/C =2.0/1.0/97.0

Inside 8 parts of the images the CIELAB colour coordinates and the spectral radiance factors were calculated and clustered. Scattering and absorbance coefficient were calculated from two different concentration panel coated on white and black substrate applied Kubelca-Munk theory and Saunderson correction way. Regarding metal flake and interference mica, reflectance, hiding and transparent coefficient were calculated from three difference concentration panel, and light path length were calculated from two difference concentration with black absorption pigment. Flop control agent scattering and absorbance coefficient were calculated same way of absorption pigment, and orientation coefficient were calculated from three different concentration with aluminium flake panel.

On the other hand, spatial distribution in CIELAB colour space, Fractal dimension and Laplacian filter value were calculated from each panel spectral imaging, and applied to CCM calculation.

2.3 Test samples

Further 8 target panels composed of 4 to 5 materials with a well-defined formulation were prepared in the same way coating (see Table 3).

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Table 3. Target panel aomponent

	Absorption pigment	Metal flake	Interference mica	Flop control agent	Total
1	Black, Yellow, Red		F. Turquoise		4
2	Black, Yellow, Red		F. Green, Turquoise		5
3	Blue, Green	Alpate 7670NS	X. C. Silver		4
4	Yellow, Blue, Red, Green		Cs. Arc. Fire		5
5	Black, Blue, Red		F. Indigo, Lilac		5
6	Blue, Green	Alpate 7670NS	X. C. Silver, F. Green		4
7	Black, Blue, Green		X. C. Silver, F. Indigo		5
8	Red, Green		Cs. Arc. Fire	TiO2	4

3. Result

Developed CCM Software has two functions, one is components material identification, the other one is formulation calculation, and checked both functions accuracy. Regarding components identification, 7 in 8 targets were selected same materials of target panel. And formulation accuracy ware checked colour difference value of CIELAB and DIN6175-2 between right and calculated formulation by CCM. (see Table 4).

Table 4. Test result

Components identification (Percentage of correct ansewers)	97%	
Formulation error rate	41%	
Color difference value (CIELAB Delta E^*_{ab} mean value)	20° illuminate: 5.39	45° illuminate: 4.54

4. Conclusion

By applying the CCM and checking the accuracy of the calculated data in comparison with the known components and formulation, the benefit of multispectral gonio-imaging and calculating method were shown in this study. Gonio-photometric spectral imaging technology was quite useful for metallic and pearlescent CCM.

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Age effect on colour emotion: An examination by looking into individual responses

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Abstract

A psychophysical experiment was carried out to investigate whether or not colour emotion responses will change with the advance of the viewer's age. Four word pairs, warm/cool, heavy/light, active/passive and like/dislike, were used to assess colour emotion and preference of 30 colour patches presented using a calibrated cathode ray tube display. Forty Taiwanese observers participated, including 20 young (aged between 20 and 30 years) and 20 older (over 60 years). The experimental results show that older observers tended to have stronger reactions to active or heavy colours than by young observers. Older observers were more likely than young observers to regard active colours as "heavy", and to regard heavy colours as "active". In addition, heavy or active colours were liked more by older than by young observers.

1. Introduction

With rapid growth of older population in the society, there is an increasing demand for consideration of the impact of age-related changes in the visual system (Sagawa and Takahashi 2001; Werner 1996) on older people's accessibility and social requirements. For colour designers, the perhaps more important question is whether such an age effect also influences the emotional reactions to colour, or the so-called "colour emotion" (Sato et al. 2000; Ou et al. 2004). Empirical studies in this area (Dorcus 1926; Child et al. 1968) have typically focused on comparisons between mean responses of each age group. However there is a concern as to whether it is justified to do such direct comparisons without any inspection of responses given by individual observers. Note that colour emotion can be influenced by many other factors such as gender, cultural background, educational training or personality. Without information of individual responses, it is hard to know whether any difference shown in the mean responses is in fact attributed to the age effect only, or to any other factor.

To address the issue, the present research used the experimental settings similar to a previous colour emotion study (Ou et al. 2005) and looked into responses given by individual observers rather than comparing mean values of each age group, in an attempt to establish whether or not age has a strong impact on colour emotion.

2. Methods

A psychophysical experiment of colour emotion was carried out using 30 colour patches as the stimuli. Each colour patch was 7cm by 7cm in size, presented individually in random order on a 20-inch calibrated cathode ray tube (CRT) display, with a viewing distance of 50cm from the

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observer, situated in a darkened room. Each colour was presented twice to ensure good data repeatability. The luminance of the display peak white was 70 cd/m^2, with the chromaticity coordinates (0.315, 0.340), which was close to D65 (0.313, 0.329).

A total of 40 Taiwanese observers, including 20 young and 20 older adults, participated in the study. The young observers were aged between 20 and 30 years; the older observers were aged over 60 years. Each observer's colour vision was checked using Farnsworth-Munsell 100 hue test. Spectacles were allowed to wear during the experiment to correct some observers' visual acuity. Each observer was asked to spend three minutes adapting themselves to the viewing conditions prior to the experiment. The task for the observer in the experiment was to describe each colour sample in terms of active/passive, warm/cool, heavy/light and like/dislike, the four primary scales of colour emotion (Sato et al. 2000; Ou et al. 2004). The ratings were based on a ten-step force-choice scale.

The following shows three approaches of data analysis performed after the experiment. Factor analysis, a widely adopted ordination technique for visualisation of data in a multi-dimensional space, was used as the main method in this work.

2.1 Approach 1: Conventional mean value method

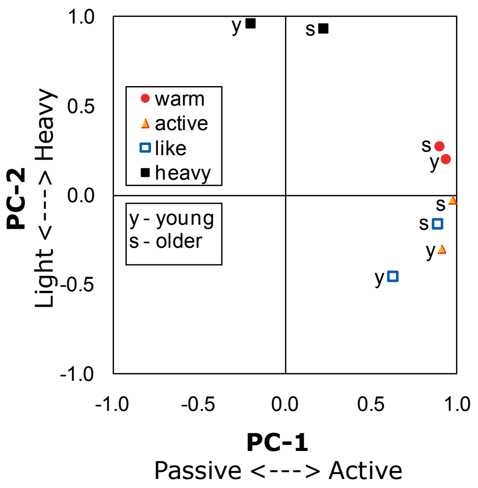

Figure 1. Factor plot based on mean responses

First, a conventional approach was conducted by dividing the observers into two age groups, young and older, and then comparing the mean responses between the two groups in terms of correlation. As a result, high correlation was found between the mean responses of the two age groups, with a correlation coefficient of 0.87 for active/passive, 0.93 for warm/cool, 0.86 for heavy/light and 0.62 for like/dislike.

Factor analysis was performed using the SPSS computer software, based on the mean observer responses, in an attempt to reveal the interrelationship between the four colour emotion responses given by the two age groups. Figure 1 shows the factor plot based on two extracted factors PC-1 and PC-2, representing "activity" and "heaviness" respectively, standing for 89.4% of the total variance (57.1% for PC-1 and 32.3% for PC-2). In the graph, the four responses were represented by different marker types: circle for "warm", triangle for "active", no-fill square for "like" and filled square for "heavy". Next to each marker is either a letter of "y" or "s", representing young or older observers, respectively.

Figure 1 shows differences in the mean responses between the two observer groups. For heavy/light, older observers seemed to be more likely than young observers to regard active colours as "heavy". For active/passive, older observers were more likely than young observers to see heavy colours as "active". For like/dislike, older observers tended to like active or heavy colours more than young observers did.

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2.2 Approach 2: Looking into individual responses for the 4 scales

Note that Figure 1 is based on mean responses of each age group. To see whether the original responses given by individual observers also reflect the findings, factor analysis was conducted again, using the observer raw data instead of the mean values.

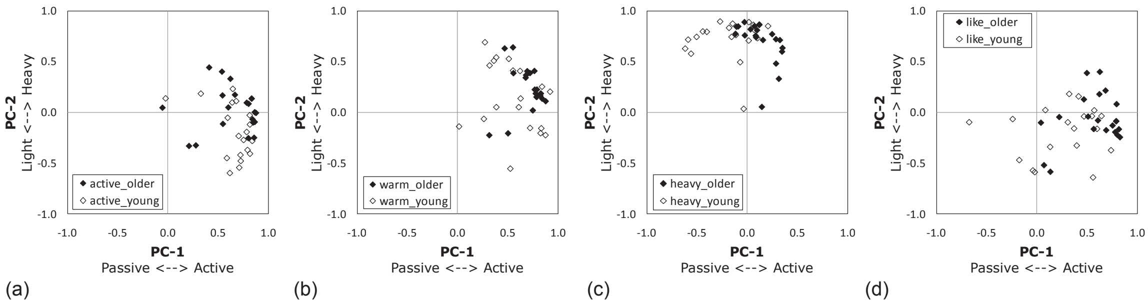

Figure 2. Sub-graphs of factor analysis based on the individual responses, with only one scale shown in each sub-graph: (a) active/passive, (b) warm/cool, (c) heavy/light and (d) like/dislike

Two factors were extracted, also labelled "activity" and "heaviness", similar to those shown in Figure 1. Figures 2 (a) to (d) demonstrate the sub-graphs of the factor plot, showing results of one colour emotion scale at a time. The four sub-graphs were made due to the large number of data points shown in the original full version of factor plot (containing 40 observers x 4 colour emotion scales). Each sub-graph illustrates the interrelationship between the 40 observers (i.e. each point represents an observer) in terms of colour emotion responses for the four scales. The filled points represent older observers, and the no-fill points represent young observers. The graphs show different tendencies in the responses by young and older observers. For instance, in Figure 2 (c), the filled points tend to be located to the right side of the no-fill points, suggesting that older observers were more likely than young observers to regard active colours as "heavy", a finding in close agreement with that demonstrated in Figure 1. Despite such different tendencies, however, there are a wide spread of points that overlap each group.

2.3 Approach 3: Focusing on individual responses only

The overlap of data points shown in Figure 2 seems to suggest poor differentiation of the colour emotion responses by age. It should be noted, however, that the factor analysis shown in Figure 2 reveal not only the interrelationship between each observer, but also the relationship between the four colour emotion scales. To focus solely on the relationship between individual observers, factor analysis was conducted for the third time, using the following settings. For each observer, one single variable was used as input (each variable containing 120 responses = 30 colours x 4 scales), instead of four variables for each observer as shown in Figure 2 (where each variable contains 30 responses). Figure 3 shows the resulting factor plot, demonstrating a clearer differentiation of the two observer groups in terms of colour emotion responses.

To interpret the meanings of PC-(a) and PC-(b), not only Figure 3 but findings shown in Figures 1 and 2 also need to be considered. According to Figures 1 and 2, older observers tended to regard active colours as "heavy", and to regard heavy colours as "active". In addition, older observers tended to like active or heavy colours more than young observers did. These findings seem to suggest stronger responses to active or heavy colours by older than by young observers. Thus, the two dimensions PC-(a) and PC-(b) in Figure 3 were labelled "activity" and "heaviness" respectively.

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3. Conclusion

The experimental results demonstrate clear differences between young and older observers in colour emotion responses, despite high correlation coefficients based on the mean responses of the two observer groups (r = 0.87 for active/passive, 0.93 for warm/cool, 0.86 for heavy/light and 0.62 for like/dislike). The results show that older observers tended to have stronger reactions to active or heavy colours than by young observers. Older observers were more likely than young observers to regard active colours as "heavy", and to regard heavy colours as "active". Heavy or active colours were liked more by older than by young observers. These findings were visualised by factor plots using the three approaches mentioned previously, as demonstrated by Figures 1 to 3. To fully understand why there were such differences between young and older observers will require both quantitative and qualitative studies in related areas.

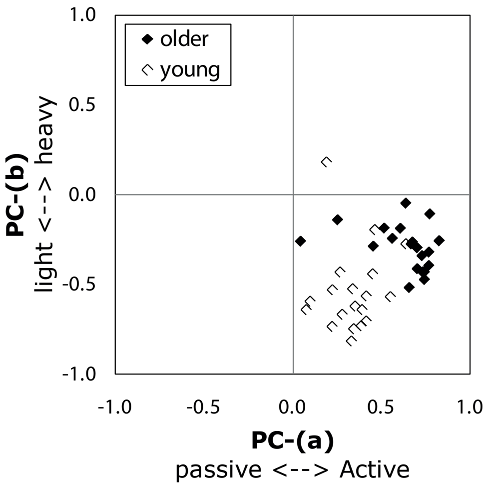

Figure 3. Factor plot based on individual responses in which the four scales were combined into one single variable for each observer (represented by each "point" in the graph)

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The effect of coloured LED lighting in the emotional and cognitive responses to affective picture stimuli

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Abstract
Two experiments were carried out to confirm how the colours of LED lighting influence on human emotion and cognition by presenting various IAPS (international affective picture system) photos containing affective content as the experimental stimuli under several coloured LED lighting conditions and by using affective rating and recognition memory tasks. In Experiment 1, red, green, blue, and white coloured LED lightings were used and participants rated them on valence and arousal dimensions in the first task and then recognized them as soon as possible in the second task. The results showed that green and white coloured LED lightings elicited a significantly higher response of pleasantness compared to red and blue ones in the valence dimension and red coloured LED lighting evoked higher excitement response compared to other colours in the arousal dimension. In Experiment 2, secondary colours, cyan, magenta, yellow, and white, were used as the experimental lighting colours and the results showed a similar pattern of responses to that of Experiment 1. The results of this study confirmed the effects of the coloured LED lightings on emotional and cognitive responses, and will provide an empirical basis for the development of LED affective lighting system.

1. Introduction
Recently, LED lighting is in the spotlight as an affective lighting because it can easily implement a variety of color characteristics which is one of the most important elements affecting human emotion and cognition. In fact, color affects every aspect of our lives every day (Fehrman & Fehrman, 2004). Therefore, it is required to understand the influence of the color properties of LED lighting to human emotion and cognition before utilizing the LED affective lighting in diverse areas. Nevertheless, empirical research on LED lighting has not been enough so far. In this study, we tried to find out the affective characteristics of coloured LED lighting to human emotion and cognition using twenty five IAPS photos, two experimental tasks, i.e. an affective rating and a recognition memory task, and two colour categories of lighting, i.e. the primary and the secondary colours.

2. Experiment 1: RGBW LED Lighting Colours

2.1 Method
Participants: Thirty one students of Yeungnam University took part in the experiment (Male: 18, Female: 13, 23.3 years old in average). They have normal eye sight (naked or corrected) and color perception. They participated voluntarily and were paid with some amount of money for the participation.

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Stimulus and apparatus: Twenty five affective photos were selected from IAPS (international affective picture system, 2008) and used as the experimental stimuli. They are assigned to 4 coloured LED lighting conditions: red, green, blue, and white, in the same number. The average values of photos on valence and arousal dimensions included to each condition were almost equal and counterbalanced. The illumination and colour coordinates of the experimental lighting conditions were measured using Konica-Minolta CL-200 chromameter and the lighting system was controlled by DMX 512 protocol. For the experiment a LED lighting ceiling system, E-prime 2.0 experiment software, and 2 personal computers were used.

Table 1. Specification of lighting condition in Experiment 1

Lighting Colors	Lux	X	y
Red	107.50	0.687	0.304
Green	114.56	0.188	0.739
Blue	108.60	0.141	0.029
White	112.36	0.257	0.197

Procedure: In the affective rating task, individual participant observed each affective picture presented on the LCD screen for 3 seconds and rated it using 7 points scale on the valence dimension (pleasant-unpleasant) and arousal dimension (exited-relaxed) sequentially. The numbers were written on the buttons of center line of computer keyboard. There was no time limit to press the buttons for the rating. When the first task was finished, participants had 5 minutes break time and continued to the recognition memory task. In the task, they had to press a specified button when they thought the stimulus on the screen was the photo presented in the previous task (go/no-go task). It took about 40 minutes to complete the whole experiment.

2.2 Result

According to the repeated measures ANOVA on the affective rating data using SPSS, although there was no significant difference among LED lighting colours in the affective rating of valence dimension [$F(1,30)=2.074$, p=n.s.], significant differences were found between red and green [$t(30)=-2.590$, $p<.015$] and red and white [$t(30)=-2.153$, $p<.039$]. The rating values in the arousal dimension showed a significant difference [$F(1,30)=12.389$, $p<.001$] among the colours, and again paired comparisons revealed significant differences between red and green[$t(30)=2.364$, $p<.025$], red and blue[$t(30)=2.250$, $p<.048$], and red and white[$t(30)=3.780$, $p<.001$].

On the other hand, the result of repeated measures ANOVA on the recognition memory data did not show any significant difference in the response time(RT) according to the LED lighting colours under which the affective photos were presented[$F(1,30)=0.021$, p=n.s.]. Similarly, there was no significant difference in the paired comparisons. However, the RTs to the photos presented under the green coloured LED lighting tended to be faster compared to other conditions, although there was no significant difference statistically.

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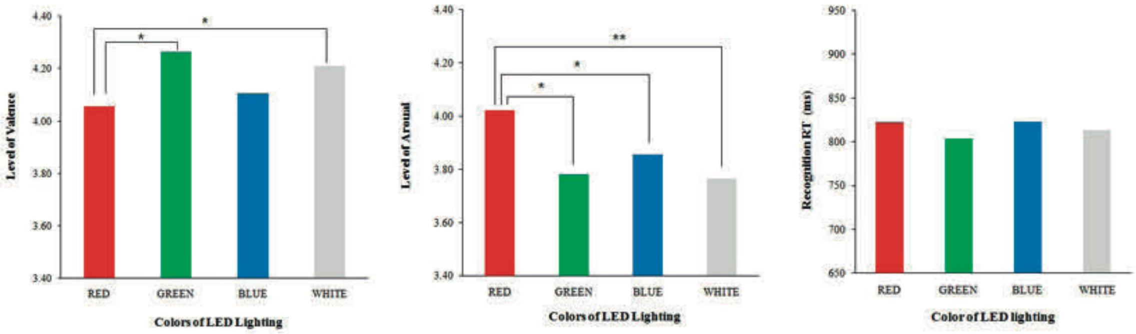

Figure 1. Results of affective rating and recognition memory tasks in Experiment 1

3. Experiment 2: CMYW LED lighting colours

3.1 Method

Participants: Thirty one students of Yeungnam University from a new recruitment took part in the experiment (Male: 17, Female: 14, 23.6 years old in average). They have normal eye sight and color vision. They were paid for the participation.

Stimulus and apparatus: The same photos were used as the experimental stimuli. They are assigned to 4 coloured LED lighting conditions, cyan, magenta, yellow, and white, in the same number. The illumination and colour coordinates of the experimental lighting conditions were shown at Table 2. The same apparatuses as Experiment 1 were used.

Table 2. Specification of lighting condition in Experiment 2

Lighting Colors	Lux	x	y
Cyan	228.48	0.150	0.168
Magenta	220.20	0.271	0.094
Yellow	227.50	0.466	0.504
White	222.83	0.259	0.197

.

Procedure Experimental procedure was the same as in Experiment 1.

3.2 Result

A repeated measures ANOVA did not show any significant difference among the lighting colours in the affective rating of valence dimension [$F(1,30)=.071$, p=n.s.] and in the paired comparisons. Similarly, there was no significant difference among the rating values in the arousal dimension [$F(1,30)=.013$, p=n.s.], but a significant difference was found between magenta and cyan [$t(30)=-2.401$, $p<.023$] and magenta showed higher values when compared to yellow and white although they were no statistical significance.

The result of repeated measures ANOVA on the recognition memory data did not show any significant difference [$F(1,30)=1.254$, p=n.s.]. Again, there was no significant difference in the paired comparisons, but the RTs to the photos presented under the cyan coloured LED lighting have a tendency to be faster compared to other conditions, although the differences were not statistically significant.

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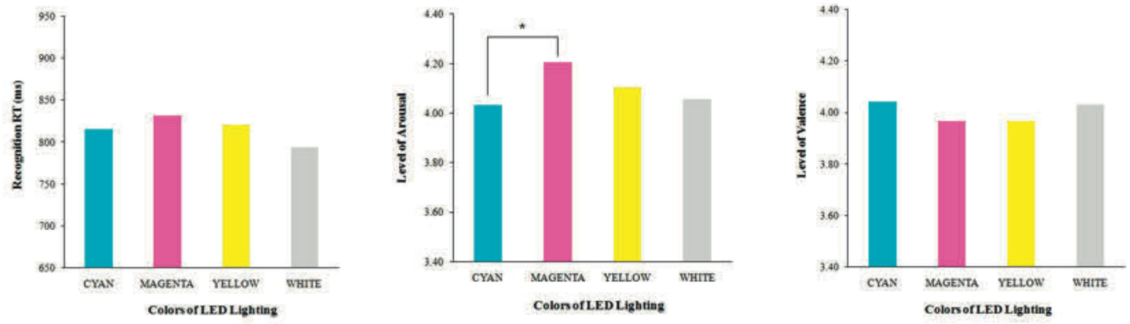

Figure 2. Result of affective rating and recognition memory tasks in Experiment 2

4. General discussion

According to the results of this study, green and white LED lightings seemed to elicit a pleasant emotion but red one induced an unpleasant one in the valence dimension. Likewise, green and white LED lightings are likely to evoke a relaxing response but red one stimulating one. The result of recognition memory task did not show any significant difference among the RTs of each condition, but the responses to the photos presented under green LED lighting tended to be faster than responses under other lighting colours. The insignificant differences in the recognition memory task might be caused by the short break time and the saliency of the affective photos, and a resulting ceiling effect. When secondary colours were applied to the LED lightings, the patterns of emotional and cognitive responses were a bit weakened but similar to those of Experiment 1.

These results suggest that coloured LED lighting influence on human emotion and cognition and they could be used as the affective lighting for specific purposes. For the development and application of LED affective lighting system, more studies are required to identify the effect of colored LED lighting by using diverse tasks and conditions.

Acknowledgments

This work was supported by the Technology Innovation Program (Industrial Strategic Technology Development Program, 10033630) funded by the Ministry of Knowledge Economy (MKE, Korea).

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Bon appetit! The best versus worst light color for dining

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Abstract

In this study, the impact that certain colors of light pose on one's appetite is explored with an endeavour to facilitate broader use of LED lighting. Thus, to investigate the ideal match between the color of light and that of food, the empirical study was conducted. The subjects were provided with dishes consisting of seven colored Processed Food and natural colored food. They were asked to pick the best and the worst light color for each dish by using the LED lamp. Once the best color was selected, the Chromaticity (x, y) and illumination (lx) values were measured. Based on the data, the selected colors were sorted into groups by referring to the CIE chromaticity diagram. The best and worst combinations were identified. Despite slight differences between people, it was found that light can have an impact on appetite. Orange followed by yellow was the most appealing light colors. On the other hand, red followed by daylight may reduce one's appetite, especially when the food is green or blue.

1. Introduction

Not merely making things visible, light is now applied to make things appear attractive. Since LED lighting with higher reproduction rate than previous CCFL(Cold Cathode Fluorescent Lamp) has come into wider use, LED lamp with various colors can be easily seen in our daily life. However, compared to technical development of lamp using LED, the study of emotional effect according to lighting contents is not properly made out. Especially in case of gustatory experience whose emotional reaction differs according to colors, the study of light color is very important to be examined.

2. Purpose

This is the research to investigate whether the light color has an effect on one's appetite. In order to find out the relationship between food color and light color, an empirical study was conducted and the result was analysed scientifically.

3. Research scheme

3.1 Developing emotional criteria for appetite

Appetite is the result of numerous nerves' interactions. However, there is the difficulty of measuring brainwave or an amount of neurotransmitter being emitted. Since study of blood sugar level doesn't provide any significant difference, this research has focused on psychological reactions rather than biological one like Hong et al. (2010). Subjects were asked to choose the most and the worst light for appetite. The impact of light on appetite was determined by emotional evaluation.

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3.2 Experiment environment

In order to set up the default light condition which is most similar to natural light, the multi light viewing booth from Botek was used. Philips' mini living colors was used as an input LED light. The lighting tool was fixed by stanchion so that participants could easily adjust colors. Foods were laid under the input light. Every light condition was regulated from 300 to 600lx , suitable for restaurant and dining table condition according to KS A 3011.

Figure 1. The setting of the empirical study: As the color varied, the illumination was varied between 300 and 600lx, a range acceptable for a dining table according to the KS A 3011 specifications.

Figure 2. Mini Living Colors has a wheel for a color selection.

3.3 Stimuli composition

Subjects were provided with 11 sets of foods. The first 7 Processed Food sets were monochrome combination of snack and drink (colors- red, yellow, green, blue, purple, white, black)(snack-candy, jelly, drink with food coloring). Another 3 sets were natural food dish such as green salad, purple blueberry cake and polychromatic Kim-Bab. The other set was a combination of snacks of whole 7 colors.

Figure 3. The seven dishes of Processed Food

Figure 4. The four dishes of natural food and various color food

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4. Experiment research

4.1 Experiment outline

In this research, subjects were asked to choose light that increases or decreases their appetite. Thirty participants were composed of sixteen women and fourteen men.(average 23.3 years old, standard deviation being 3.05 years old).

4.2 Experiment result

Regardless of the food color, the average illumination level of making food appear delicious(891.576Lx) was higher than those of making food seem less tasty (613.02Lx). Colors of selected light were measured with an illuminometer. Data were classified into 7 colors according to Goldstein (2007). When analyzing the selected colors for improving participants' appetite, orange was thought to be the best for one's appetite in both foods and dish sets followed by yellow. (Orange- 34.3% in processed food, 45.8% in natural food)(Yellow- 26.7% in processed food, 38.3% in natural food) Red light was chosen as the most influential for decreasing one's appetite. Natural light without any color input was ranked the second. (Red- 33.3% in processed food, 33.3% in natural food)(Natural light- 28.1% in processed food, 25.8% in natural food)

Table 1. The selected light color that increases appetite, Processed Food

The best light color	Food color, Processed Food							Total
	Red	Yellow	Green	Blue	Violet	Black	White	
Daylight	10.0%	20.0%	16.7%	30.0%	20.0%	20.0%	20.0%	19.5%
Red	6.7%	0.0%	0.0%	3.3%	16.7%	3.3%	0.0%	4.3%
Orange	**70.0%**	36.7%	26.7%	13.3%	26.7%	43.3%	23.3%	34.3%
Yellow	6.7%	40.0%	33.3%	20.0%	23.3%	20.0%	43.3%	26.7%
Green	3.3%	3.3%	23.3%	13.3%	3.3%	10.0%	6.7%	9.0%
Blue	0.0%	0.0%	0.0%	10.0%	3.3%	0.0%	6.7%	2.9%
Purple	3.3%	0.0%	0.0%	10.0%	6.7%	3.3%	0.0%	3.3%

Table 2. The selected light color that decreases appetite, Processed Food

The worst light color	Food color, Processed Food							Total
	Red	Yellow	Green	Blue	Violet	Black	White	
Daylight	23.3%	16.7%	30.0%	33.3%	36.7%	36.7%	20.0%	28.1%
Red	10.0%	46.7%	**50.0%**	**50.0%**	13.3%	26.7%	36.7%	33.3%
Orange	0.0%	10.0%	3.3%	3.3%	3.3%	0.0%	3.3%	3.3%
Yellow	0.0%	0.0%	0.0%	0.0%	3.3%	0.0%	0.0%	0.5%
Green	**50.0%**	23.3%	3.3%	6.7%	36.7%	20.0%	33.3%	24.8%
Blue	16.7%	3.3%	10.0%	6.7%	6.7%	16.7 %	0.0%	8.6%
Purple	0.0%	0.0%	3.3%	0.0%	0.0%	0.0%	6.7%	1.4%

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Table 3. The selected light color that increases appetite, Natural Food

The best light color	Natural Food				Total
	Cake	Roll	Salad	Sweets	
Daylight	0.0%	6.7%	0.0%	6.7%	3.3%
Red	3.3%	0.0%	0.0%	0.0%	0.8%
Orange	53.3%	53.3%	33.3%	43.3%	45.8%
Yellow	40.0%	33.3%	36.7%	43.3%	38.3%
Green	0.0%	6.7%	30.0%	6.7%	10.8%
Blue	0.0%	0.0%	0.0%	0.0%	0.0%
Purple	3.3%	0.0%	0.0%	0.0%	0.8%

Table 4. The selected light color that increases appetite, Natural Food

The best light color	Natural Food				Total
	Cake	Roll	Salad	Sweets	
Daylight	26.7%	16.7%	30.0%	30.0%	25.8%
Red	6.7%	56.7%	33.3%	36.7%	33.3%
Orange	0.0%	0.0%	3.3%	3.3%	1.7%
Yellow	0.0%	0.0%	0.0%	0.0%	0.0%
Green	53.3%	13.3%	0.0%	6.7%	18.3%
Blue	13.3%	6.7%	26.7%	20.0%	16.7%
Purple	0.0%	6.7%	6.7%	3.3%	4.2%

5. Light color and appetite relationship

It has been turned out that light poses an impact on people's appetite. On average, foods seem to be more delicious under high illumination level. Additional experiment such as fixing chromaticity with changing illumination level will be help to gather meaningful results. Orange and yellow lights are considered appropriate but red and green are inappropriate when setting the lights over foods.

Acknowledgments

This research was supported by following programs: 1) BK21 Program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology, 2) Foundation Research Program through the Korean Food Research Institute funded by Ministry of Knowledge Economy.

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Research on the elderly people's color distinction scope subsequent to color

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Abstract

This research is going to suggest the basic data for color arrangement taking safety into account in time of color planning within the same colors by analyzing the color distinction scope quantitatively subsequent to value and chroma by individual color from a viewpoint of the elderly people. This research conducted a survey on the color discrimination scope consequent upon the value and chroma by individual colors by suggesting 5 colors including 5R,5Y,5G,5B,5P targeting the elderly in their 60s to 80s. Then the experimental results were extracted through frequency analysis in the scope of common distinction.

1. Introduction

Aging of population is emerging due to the extension of an average lifespan along with the development of health and medical technology and with the rising interest in health. With the increase in age, the function of a sensory organ is aging. Among the changes in vision which takes up more than 80% of information acquisition, the yellowed eye sight phenomenon is the main reason for the decline in color-perceptive ability and changeable color distinction ability according to colors.

Due to the visual characteristic subsequent to aging, the elderly might suffer discomfort because environmental colors they see in daily living are diversely changed or might suffer discomfort because important information is not perceived. Moreover, they are in a degraded state physically, there might happen a hazard to safety in a moment. From this point of view, in time of planning color environment, a substantial consideration about visual characteristics of the elderly people should be applied.

In the preceding research works related to the elderly people's color perception, they examine the change characteristic of color perception and suggest the confusing section of several colors and tones, but there still remains to be desired in dealing with concrete distinction scope subsequent to the value and chroma in the same colors. Thus, this research is going to suggest the basic data for color arrangement taking safety into account in time of color planning within the same colors by analyzing the color distinction scope quantitatively subsequent to value and chroma by individual color from a viewpoint of the elderly people.

2. Experimental method

This research targeted 30 physically healthy elderly in their sixties to eighties as its subjects and suggested the detailed contents about these subjects in the following table 1. For this experiment, this research conducted a direct survey in the form of this researcher's writing the results in experiment papers after having individual elderly point at the colors which looked the same with each other, and similar to their eyes by suggesting Mate Collection Munsell Chart-included major

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5 colors(5R, 5Y, 5G, 5B, 5P). This research conducted the direct survey from Feb. 24 until March 1, 2011, and used only the north side daylight from 10 in the morning until 3 in the afternoon at the same place within J senior center. In time of the direct survey, the illuminance of the experimental side was 1000-2000 lx[averaging 1542.62lx] and color temperature was 6760K on an average.

Table 1. The construction of subjects

Gender	Female : 13 Male : 17
Ages	From 61 to 89 (Average 76)
Total	30

3. Results and analysis

The experimental results were extracted through frequency analysis in the scope of common distinction. First, looking at the common part in 5 colors, in case of value 4, on the whole it was possible for them to discern the colors consequent upon the difference in value while in case of value less than 3/chroma less than 2[value less than 3 in case of 5P], they were found to perceive the colors as the same or similar and black at the same time. In addition, their color discernment consequent upon chroma difference was found to be difficult, and in the part of mid-high chroma[especially in the part of high chroma] it was found that they perceived the colors as the same or similar in spite of the fact that the chroma difference was more than 2. Additionally, at the same value stage, the low chroma colors with chroma less than 2 were found to be perceived as very similar to each other.

It was found that 5R was the easiest for them to discern between colors in comparison with other colors among the 5 colors while it was the most difficult for them to tell 5Y from 5P, and subsequently the scope of perceiving these two colors as the same or similar was found to be wide. To take a close look at the results by color, In case of 5R, it was found that they felt it difficult to discern between colors in the part of high chroma & low value.

In case of 5Y, though showing a big difference with chroma difference more than 4 in the part of high chroma, they were found to perceive it as the same. In addition, in the part of high value with value more than 7, they perceived the colors with chroma more than 6 as very similar, especially the high chroma colors with chroma more than 8 and less than 12. Further, it was found that at stage 6 of value, they perceived the colors with chroma more than 6 and less than 8 as the same; at stage 5 of value, they perceived the colors with chroma more than 4 and less than 6 as similar, and at stage 4 of value, they perceived the colors with chroma less than 4 as the same. In addition to this, it was found that they perceived the low chroma colors with chroma less than 2 as the same at the same value stage- roughly, they perceived the colors with value less than 3, value more than 4 and less than 5, value more than 6 and less than 7, and value more than 8 and less than 9 as similar respectively.

In case of 5G, it was found that they felt it difficult to discern the colors in the high value part of value more than 7, in the low value/low chroma part of value less than 3/chroma less than 2, and in the high chroma part.

In case of 5B, it was found that they perceived the colors as the same in the low value part of value less than 3, and in the mid-high chroma part of chroma more than 6 and less than 8.

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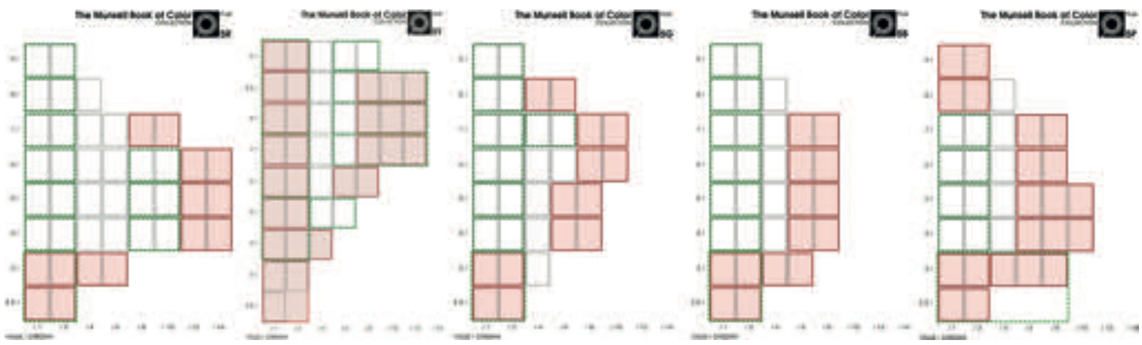
Lastly, in case of 5P, it was found that they perceived the colors the same in the low value part with value less than 3, in the high value part with value more than 8, and in the mid-high chroma part with chroma more than 6 in the middle value with value more than 4 and less than 7. Especially at stage 4 and 5 of value, it was found that they perceived the colors the same in spite of a big difference in chroma amounting to more than 4. In addition, they were found to perceive all the colors with value less than 3 as similar.



[legend] same similar

Figure 1.The scope of common distinction

Based on such results, it's necessary to make the difference in value into 1 at least in all colors in time of color arrangement in consideration of the safety of the senior citizens. In addition, in case colors are arranged by adjoining more than two colors at the stage of the same value, it's necessary to arrange colors in consideration of the discrimination power consequent upon the scope of value and chroma as specified in table 2.

4. Conclusion

This research conducted a survey on the color discrimination scope consequent upon the value and chroma by individual colors by suggesting 5 colors including 5R,5Y,5G,5B,5P targeting the elderly in their sixties to eighties.

As a result, it was found that color discernment consequent on the difference in value was commonly easy for them, but they felt it difficult to discern the colors consequent upon the difference in chroma. Especially in the part of low value, low chroma and high chroma, they were found to feel it difficult to discern the colors. In addition, in the part of mid-high chroma, there came out the color discrimination scope consequent on chroma by color differently from each other. As the result of the above research, it's considered that there needs to be a color arrangement in serious consideration of the color discrimination scope consequent upon the value and chroma of colors used in time of the color arrangement within the same color.

In addition, there needs to be a more detailed research on YR and Y series which are much used as dominant and assort colors for the interior and exterior of architectural space, and the discrimination scope of high value and low chroma.

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Table 2. The plan of color scheme at the stage of the same value

Color	Value	Chroma	The plan of color scheme
5R	more than 4	less than 8	• Make the chroma difference into more than 2
		more than 8	• Make the chroma difference into more than 4
	less than 3	less than 2	• Sublate the color arrangement between colors within this scope
		more than 4	• Sublate the color arrangement between colors within this scope • It's necessary to arrange the colors in the part of low chroma with chroma less than 2
5Y	more than 6	less than 6	• Make the chroma difference into more than 2
		more than 6	• Sublate the color arrangement between colors within this scope • It's necessary to arrange colors with low-mid chroma [chroma less than 4]part.
	all scopes	less than 2	• Make the chroma difference into more than 2 • Sublate the color arrangement between the colors at the same value stage.
5G	more than 7	less than 2	• Sublate the color arrangement with the colors within this scope • It's necessary to arrange the colors in the part of mid-high chroma with chroma more than 4
		more than 4	• Make the difference in chroma into more than 4
	more than 4 and less than 6	less than 6	• Make the difference in chroma into more than 2
		more than 6	• Make the difference in chroma into more than 4
	less than 3	less than 2	• Sublate the color arrangement between the colors in this scope
5B	more than 4	less than 6	• Make the difference in chroma into more than 2
		more than 6	• Sublate the color arrangement between the colors in this scope • It's necessary to arrange the colors in the low-mid chroma with chroma less than 4
	less than 3	less than 2	• Sublate the color arrangement between the colors in this scope
		more than 4	• Sublate the color arrangement between the colors in this scope • It's necessary to have a color scheme with the colors in the low chroma part with chroma less than 2
5P	more than 4	less than 6	• Make the difference in chroma into 2
		more than 6	• Sublate the color arrangement between the colors in this scope • It's necessary to arrange the colors in the low-mid chroma with chroma less than 4
	less than 3	all scopes	• Sublate the color arrangement between colors in this scope

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The relationship between the brand images of cosmetic brands and the colors applied in their merchandising spaces

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Abstract

The aim of this study is to analyze the relationship between the brand images of cosmetic brands and the colors used in their merchandising spaces. The brand images of eighteen brands and the characteristics of color usage in their merchandising spaces were first identified. Then the relationship between the brand images and the color usage was studied. First, each brand's dominant color was compared to adjectives used to describe the brand image. Second, the color strips of each brand were mapped on the Kobayashi image scale in order to visualize the relationship between the brand colors and their corresponding image areas. As a result, similar adjectives were used to describe groups of brands that share the same dominant colors, and brands with similar hues and color combinations were concentrated in same or neighbouring areas of the Kobayashi image scale. This indicates that certain colors convey particular images to people, which can be leveraged effectively in the field of marketing to create a powerful and consistent brand image.

1. Introduction

Today, many enterprises utilize powerful brand images as effective means to communicate their identities to customers. One of the most influential tools used in such process is customer experience, which imprints the brand image in customers' minds through interactive engagements. Therefore more emphasis is being placed on merchandising spaces, the very place where customer experience takes place. Merchandising space consists of different visual elements, among which color plays a central role. Color evokes specific emotions in people's minds, leaving a long lasting impact on people's minds.

2. Methods

Eighteen brands located in six department stores of three largest department store chains in Korea were selected for study, under the premise that these are the most representative cosmetic brands. Secondly, objective data of aforementioned brands were collected. These include the brand concept, advertisement, webpage, and packaging images. The brand image was defined through data analysis, and was described using three adjectives derived from the Kobayashi image scale. Then their merchandising spaces were photographed. White balance of all photographs was adjusted accordingly using Adobe Photoshop CS3 to offset the effects of halogen lighting inside department stores. Colors were then extracted and studied in order to characterize the color usage in different merchandising spaces. Finally, the colors used in each brand were analyzed. First, the relationship between the dominant colors and the brand image adjectives was defined. Second, the relationship between the brand colors and each brand's Kobayashi image areas was examined.

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3. Results

3.1 Brand image

Table 1 includes the names of eighteen cosmetic brands, adjectives used to describe these brand images, and the Kobayashi Image Area that these brands belong to.

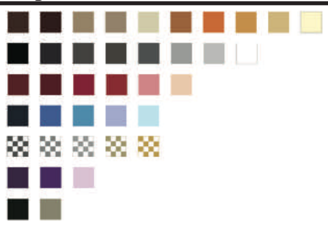
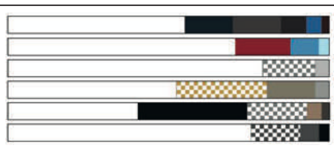
Table 1. Brand Image

	Brand Image Adjectives	Kobayashi Image Area
AMOREPACIFIC	pure & elegant, quiet & sophisticated, tranquil	ELEGANT
AVEDA	practical, simple, wholesome	DANDY
BENEFIT	merry, cheerful, cute	CASUAL
BOBBI BROWN	stylish, chic, simple	CHIC
CHANEL	elegant, graceful, refined	ELEGANT
CLARINS	refreshing, fresh & young, clear	CLEAR
CLINIQUE	clean & fresh, clear, modern	CLEAR
DIOR	brilliant, luxurious, elegant	ELEGANT
ESTEE LAUDER	rich, mature, gorgeous	GORGEOUS
GUERLAIN	alluring, polished, feminine	GORGEOUS
HERA	feminine, delicate, polished	ELEGANT
LANCOME	polished, fashionable, feminine	ELEGANT
MAC	bold, intense, dynamic	DYNAMIC
O HUI	urban, progressive, modern	MODERN
SHISEIDO	young, mysterious, modern	COOL-CASUAL
SISLEY	tranquil, pure & elegant, feminine	NATURAL
SK II	healthy, mild, natural	NATURAL
SULWHASOO	traditional, conservative, dignified	CLASSIC

3.2 Brand color

Included in Table 2 are the extracted color chips, color strips, and a description of the hues and color combinations used in the eighteen brands.

Table 2. Brand Color Analysis

	Caption	References in text
Hues	 * check pattern indicates metallic colors	1. They can be classified into achromatic, chromatic, and metallic colors. 2. Most achromatic colors are low in value. 3. Hues used for chromatic colors are brown, red, blue, purple, and green, and most colors are intermediate-high in value and high in saturation.
Color combinations		1. Every combination consists of a single dominant color and multiple supplementary colors. 2. In most cases, achromatic and chromatic colors are used together, with achromatic colors occupying a dominantly larger portion.

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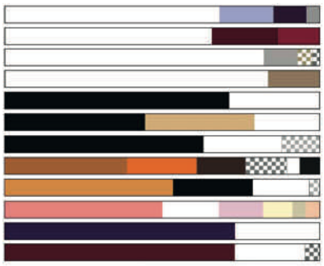
Color combinations (cont.)	 * check pattern indicates metallic colors	3. There are frequent uses of accent colors and contrast in value. 4. Gradation in value, use of adjacent colors, tone-in-tone and tone-on-tone arrangements are also found. 5. The number of colors used in most brands is less than four.

3.3 Dominant color and brand image

Dominant colors define the overall atmosphere of space. There were a total of six dominant colors; white, black, brown, pink, purple, and red. In order to analyze the relationship between the dominant colors and brand images, the brands were grouped according to their dominant colors, and all adjectives used to describe these brands were examined. As a result, same adjectives appeared repeatedly in brand groups that were categorized under the same dominant color. For white, most frequently appearing adjectives were *feminine* and *modern*, for black, it was *elegant*, and for brown, it was *simple*. Pink, purple, and red had only one brand each, so there were no overlapping adjectives. The adjectives for pink were *merry*, *cheerful*, and *cute*, for purple they were *feminine*, *delicate*, and *polished*, and for red they were *healthy*, *mild*, and *natural*.

3.4 Brand color and Kobayashi image area

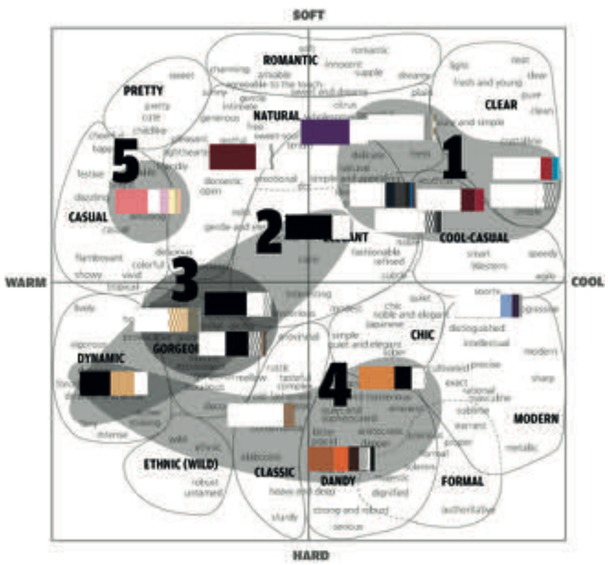


Figure 1. Brand Colors on Kobayashi Image Scale

The eighteen cosmetic brands appeared on eleven out of fifteen image areas of the Kobayashi image scale. The color strips of each brand were mapped on the image scale in Figure 1 in order to visualize the relationship between the image areas and the brand colors.

From this, five observations were made: 1) Color strips with the dominant color white were concentrated over *clear*, *natural*, *elegant*, and *cool-casual* areas. In many cases chromatic colors were used as accents. 2) Color strips with the dominant color black were concentrated over *elegant*, *gorgeous*, and *dynamic* areas. Almost all color strips consisted of achromatic colors. 3)

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Color strips with the dominant color brown were concentrated over *chic*, *dandy*, *classic*, and *dynamic* areas. 4) Color strips with substantial contribution from metallic colors were concentrated over *gorgeous* area and the left lower part of *elegant* area. 5) The only color strip with substantial contribution from pale colors was concentrated over *casual* area.

4. Conclusion and discussions

Table 3. Conclusion

	Hues	Color Combinations
Overall Use of Color	1. They can be classified into achromatic, chromatic, and metallic colors. 2. Most achromatic colors were low in value. 3. For chromatic colors, brown, red, blue, purple, and green hues were used, and most colors were intermediate to high in value and high in saturation.	1. Every combination consisted of a dominant color and multiple supplementary colors. 2. The total number of colors used in most combinations was less than four. 3. In most cases, achromatic and chromatic colors were used together. 4. There was a frequent use of accent colors and contrast in value.
	Dominant Color and Brand Image	**Brand Colors and Kobayashi Image Area**
Relationship between Brand Color and Brand Image	Brands with same dominant colors were described by overlapping adjectives. Most frequent adjectives were, for WHITE: modern and feminine, BLACK: elegant, BROWN: simple, PINK: merry, cheerful, cute, PURPLE: feminine, delicate, polished, RED: healthy, mild, natural	Brands with similar hues and color combinations were concentrated over the same or neighboring areas. This phenomenon was dominant in case of dominant colors.

As shown in Table 3, each cosmetic brand has an intentional color usage plan for their merchandising spaces in order to effectively communicate their brand identity to the customers. This can also be applied to any elements that are influential in controlling the brand image, suggesting that the brand image construction through the use of proper colors is an extremely effective and powerful method.

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A research on the development method of a practical digital color palette using natural flower images

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Abstract

This research aims to understand the characteristics of digital devices and colors and by doing so, to enhance the satisfaction of the designers work by providing them with data about the nature of the original colors. Studies show pigments that determine the color of a flower mostly are mostly located in the petals. Upon analyzing the colors using the pigments in the flower's petal, different characteristics in chromatic and lightness were noted. White flowers had high lightness and low chromatic; yellow flowers had a proportionate relationship among the two factors while orange flowers displayed similarity in lightness with diverse chromatic. Red, magenta flowers had higher chromatic than lightness and pink flowers showed lower chromatic in comparison with lightness. Violet, mauve colored flowers had a balance in chromatic and lightness and blue flowers had low chromatic and a relatively high lightness. Purple, black flowers showed low in both lightness and chromatics. On the basis of this data, an ACO file with classified flower colors was made to be utilized as a flower color swatch on Photoshop and illustration programs.

1. Introduction

Nature is the source of designing inspiration. Floral patterns and material based on flowers are mostly used in fashion, fiber, product surfaces, wallpapers and interior fabric designs. Therefore, it is essential to observe and extract the formative characteristics and analyze the obtained data. With this fact in mind, we started the research to develop a flower color image palette.

2. Direction of palette development upon theoretical review

2.1 Analyzing development methods of color palette

This research creates natural images of flowers through digital work, comprehends the characteristics of digital colors, and enables the production of a color palette by extracting the color from the flower image. The process is explained in the table below.

Table 1 : Research experiment steps

Capture Flowers Under D65 by digital camera	Macbeth Color Charts XYZ measure	Capture color charts Under D65 by digital camera	Deriving the relationship using polynomial regression methods	Clustering Flower Images	Make Color Swatch

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2.2 Factors of color palette development

2.2.1 Digital camera characterization

Digital cameras have the advantage to measure objects without directly being in contact with it. However, they rely on RGB numbers which produce different outcomes of color depending on the brand and model. Therefore, in order to reduce the difference, a characterization of digital cameras was conducted. The experiment conditions are as follows.

- Flowers: Full bloom cut flower samples were purchased in a flower wholesale market and stored in the laboratory at temperatures 24~25°C.
- Charts: The GregMacbeth chart consists of 240 colors and has a grey scale on the boundary all around. These are used to test the uniformity as well. In this experiment the 10 glossy samples that are contained within this chart were excluded.
- Light: D65
- Lux: 1385 lx (Konica Minolta CL-200)
- Digital Camera: Canon D6, Close up mode, Stabilizer on, MF, 28mm~55mm lenses

The chart's position was set to 0/45 and digital pictures were taken under D65 glare source. The Macbeth Chart and flowers were taken under the same experiment conditions. Color transformation matrix of the digital camera was obtained by using the polynomial regression. After a credibility assessment of the matrix, generalization of the number of color samples and factors influencing color changes were evaluated.

Table 2 : The graph shows the comparison between expected outcomes of L,a*,b*, and actual outcomes of L*,a*,b**

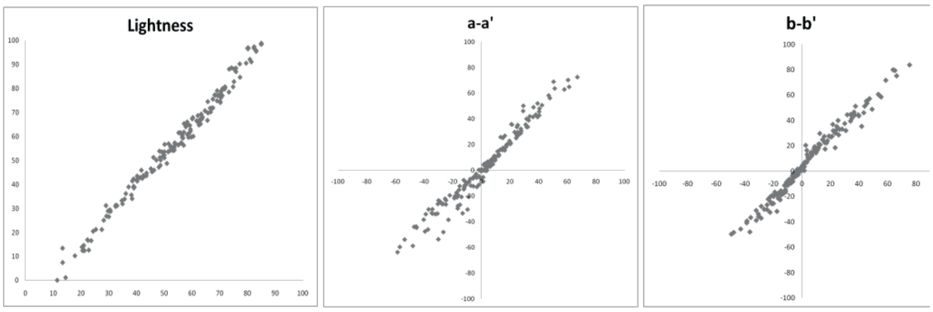

Table 3: Errors in digital camera characterization

Model	Average Error(ΔE^*_{ab})	Maximum Error(ΔE^*_{ab})
Canon D6	10.16	25.38

2.2.2 Color image cluster program

The Color Image Cluster Program calculates the RGB components in a digital color image and analyzes the percentage. The program then calculates each RGB value for every pixel and groups similar RGB values for when it is outputted on the monitor. It also produces a more elaborate and vivid outcomes than the mosaic method. The shadows in the image were turned black and removed from the clustering extraction outcomes to highlight the main colors of the flower. Following Forgy's Algorism theory, 30 colors were generated.

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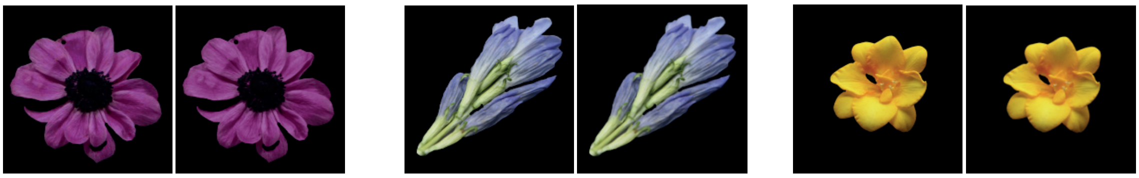

Figure 1: Original and clustered sample images of anemone, gentian, freesia

2.2.3 Analyzing flower's characteristics as a subject to digital colorimeter analyzing flower Colors

According to a documentary research on botany, there are two significant factors that determine the color of a flower. As part of a flower that determines its color is mainly the petal. below, colors were extracted, focusing on the corolla located above the dotted line.

3. Analyzing the colors of natural flower images and developing palette samples

3.1 Analyzing the colors of natural flower images

Using parts from Harborn J.B's research related to flowers and pigments, 11 flower colors were categorized. An analysis was then conducted on the characteristics of each color using the CIELAB and L*C* graph. The results were divided into three categories.

3.1.1 Chromatic of flower color

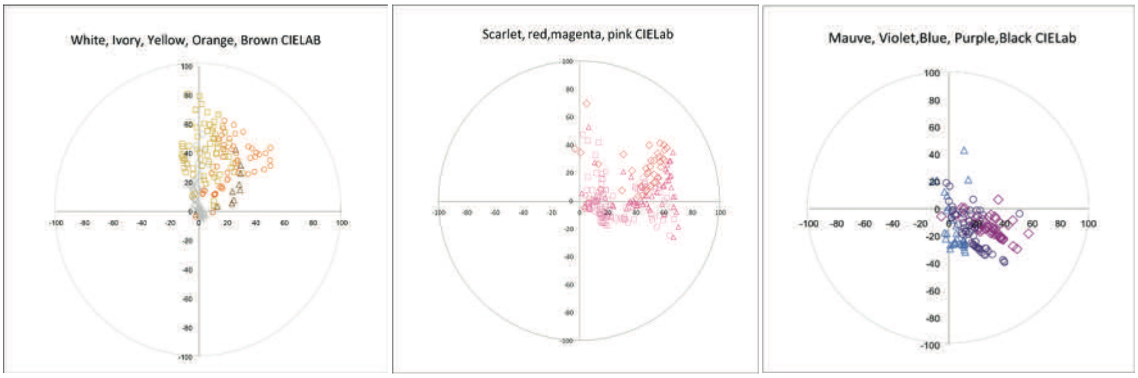

Figure 2,3,4: 2 is White, Ivory, Yellow, Orange, Brown Flower Color, 3 is Scarlet, Red, Magenta, Pink Flower Color, 4 is Mauve, Violet, Blue, Purple, Black Flower Color

3.1.2 Tone of flower color

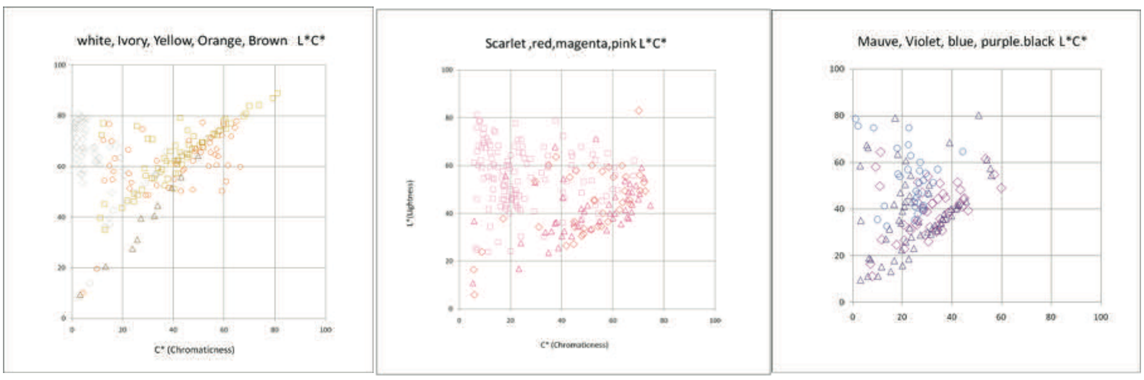

Figure 5,6,7: 5 is White, Ivory, Yellow, Orange, Brown Flower Color, 6 is Scarlet, red, magenta, pink Flower Color, 7 is Mauve, Violet, Blue, Purple, Black Flower Color

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3.1.3 Overall

According the results stated above, the characteristics of chromatic and lightness differs greatly depending on the change in the flowers' hue. Many flower petals that have hues closer to Y showed low chromatic and high lightness. Other flower petal hues that were closer to R had moderate lightness and chromatic. However, in the case of pink, the natural characteristics of the color are that it has low chromatic and moderate lightness. The flower petal colors in the third category which is seen between B and R had very low chromatic and moderate lightness.

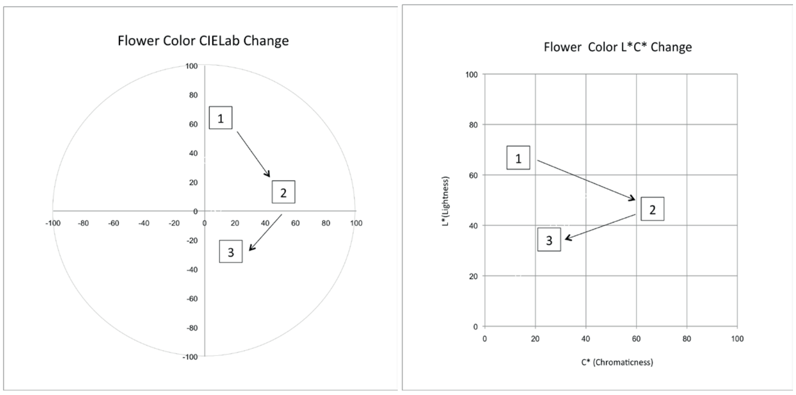

Figure 8: Flower color change cycle in hue, lightness, chromatic

3.2 Examples of the usage of the color palette of a natural flower image

The objective of this research is to study the development of a digital color palette by analyzing natural flower colors. Finally, reflecting the characteristics of digital colors and flower colors, an ACO file was made so it could be used in the color swatch window while using Photoshop or illustration programs. The following are examples of a color swatch.

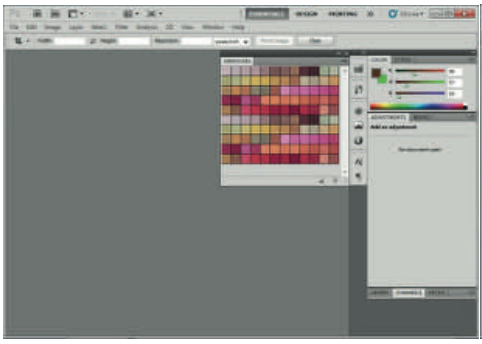

Figure 9: Color Palette of Rose Colors

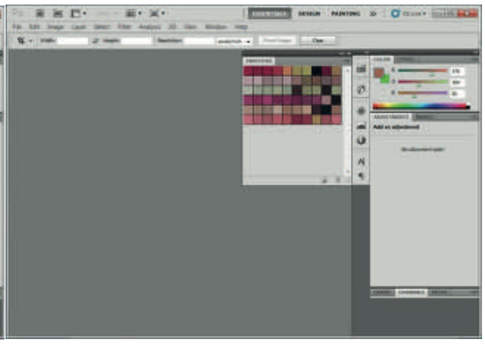

Figure 10 : Color Palette of Transvaal daisy

4. Conclusion

In this research, by studying the object's image, we developed a method to make a digital color palette that is loyal to the original colors. This research's meaning lies in the fact that we have analyzed in depth of digital colors that can be easily overlooked in the designing process or digital color analysis. The productive outcomes of this research are that to recreate colors closest to the original, the color error range was reduced by characterizing the digital camera and color value of the elaborate digital image was obtained by a cluster program instead of the mosaic method.

Colors were divided into 11 groups according to the pigment manifestations of flowers and into three categories upon analyzing the relation between chromatic and lightness. The results of this research help to find out how flower colors change in accordance to hue. Also, when designing

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floral patterns, it will help naturally express the characteristics of changing lightness and chromatic depending on the hue. Therefore, it is forecasted that it will be widely utilized in design industries such as fashion, interior and fabric design where floral patterns are often used.

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Colour filtering of lighting systems based on wLEDs to improve their colorimetric characteristics

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Abstract
New "white" lighting systems based on light emitting diodes (LEDs) have appeared in the market with many advantages over other light sources. However the wLEDs are not optimal to get an adequate visual comfort. Thus, it is necessary to improve them in order to fulfil commercial demands. For this reason, it is proposed a method for designing lighting systems based on wLEDs with an optimized colour rendering index filtering their light emission. Four coloured filters were used. We found a filter which improved the colorimetric characteristics of the wLED (colour rendering index, colour temperature and colour diversity) emulating the HP2 lamp. Therefore, it is checked that it is posible to improve the colorimetric characteristic of light sources modulating their light emission.

1. Introduction
Today, there is a great variety of lighting for both interior and exterior illumination. Their spectral power distributions (SPD) are quite different according to different light technologies (incandescent, fluorescent, discharge, etc). Therefore, these lightings have different characteristics of colour appearance and different colour rendering indexes which affect the visual perception of light environment. In particular, there are new "white" lighting systems based on light emitting diodes (LEDs). Currently, the white LEDs have many advantages over other light sources (Schubert and Kim 2007; DiLaura et al. 2011): greater energy-efficiency, environmental degradation, longer life, smaller size, greater, etc.

On the other hand, a light source has a good colorimetric quality whether it provides a wide colour gamut, has good colour discrimination between objects of similar spectral reflectance and keeps the naturalness of the scene. For many years there have been many works related to the colorimetric assessment of light sources based on the study of the colour rendering (CIE 13.3:1995; CIE 51.2:1999). In fact, the CIE adopted in 1974 an algorithm for calculating a colour rendering index (CRI) for light sources.

The white LEDs are not optimal to get an adequate visual comfort taking into account the visual and colorimetric quality metrics established by international standards (Rea and Freyssinier 2010). In fact, some visual experiments contradict some of the results obtained with the current CRI proposed by the CIE (Sándor et al. 2004; Schanda et al. 2006). Furthermore, another important aspect to consider is to know the chromatic diversity offered by the illuminant, that is, the number of colours that can be obtained using this illuminant. These two aspects provide information on the effects produced by a light source on certain scenes and it can be very useful in the design of new light sources for optimal chromatic discrimination.

In a previous work, an alternative method for colorimetric quality assessment of light sources was proposed (Martínez-Verdú et al. 2007). This is based on the estimates of the volume of the theoretical colour solid. However, there is no standard alternative for evaluating the

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colorimetric quality of light sources. Thus, it is necessary to optimize the CRI associated with lighting systems based on LEDs since they are in demand.

Our purpose is to develop new lighting systems based on wLEDs with an optimized colour rendering index filtering their light emission in order to go beyond the colorimetric and visual quality of the incandescent and luminescent light sources.

2. Methodology

Firstly, a set of coloured filters was used (in particular, 4 coloured filters). Their spectral transmittance was measured with the UV-VIS UV2-200 ATI UNICAM spectrophotometer from 400 to 800 nm in steps of 1 nm.

Secondly, the CIE CRI (R_a and R_b), the colour temperature (CCT) and the volume of the theoretical colour solid associated with the filtered LED were calculated in order to compare the new colorimetric characteristics with those of the wLEDs.

The theoretical colour solid was obtained following the method proposed by Li *et al* (Li et al. 2010). This method is simple and faster and has the advantage of keeping the characteristics of the true boundary. Therefore, this method has been used instead of the method of Martinez-Verdú (Martínez-Verdú et al. 2007) in order to reduce the calculation time. The XYZ tristimulus values were computed using the CIE 1931 colour-matching functions and were encoded them into the CIELAB colour space. The volume of the theoretical colour solid, or number of distinguishable colours, was estimated with a convex hull program due to its low computational power.

3. Results

In the Figure 1, the relative SPD of the wLED together the coloured filters is shown. We made the comparison with the HP2 lamp because this lamp is normally used in purchase and sale installations in Spain and many companies are interested in to emulate this lamp.

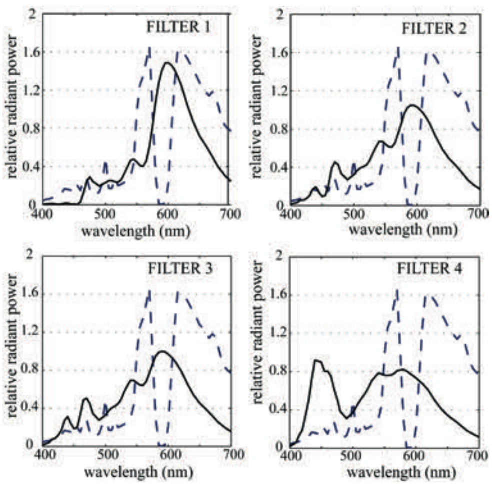

Figure 1. Relative radiant power of the lighting system based on a wLED and a coloured filter. The black solid line correspond to the new lighting system and the blue dashed line correspond to the HP2 lamp.

In the Table 1, the colorimetric characteristics ot the new lighting systems based on a wLED and coloured filters is shown. It can be observed that the lighting system with the wLED and the filter 2 is more similar to the HP2, with a colour temperature around 3000 K, with a high colour

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rendering index, and with an increase of the number of distinguishable colours regarding to the wLED light source and even the HP2 lamp.

Table 1. Colorimetric characteristics of the lighting system based on a wLED and a coloured filter.

Light source	CCT (K)	R_a	R_b	Distinguishable colours (V)
HP2 (ref.)	2510	82.58	76.58	2198200
wLED	7883	80.05	72.54	2129300
wLED + filter1	2046	70.25	65.95	1931600
wLED + filter2	**3094**	**78.79**	**72.15**	**2249100**
wLED + filter3	3373	79.14	72.19	2261100
wLED+ filter4	5358	80.29	72.89	2220800

Moreover, a more specific comparison between the HP2 lamp and the lighting system based on a the wLED and the filter 2 is done. For that, the theoretical colour limits for these light sources are plotted at some constant lightness profiles. As it can be seen, they are very similar, but for intermediate lightness value (L*=40-60), with the new lighting system (wLED + filter2) is able to distinguish more colours (blue and green colours).

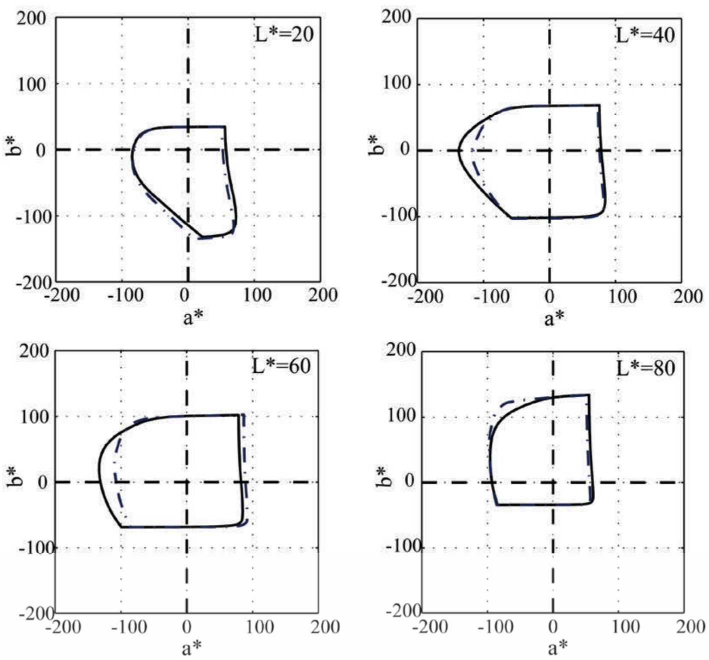

Figure 2. Theoretical colour limits for the HP2 lamp (blue dashed line) and the lighting system (wLED + filter2) (black solid line) at some constant lightness profiles

Therefore, in this preliminary study it has been checked that it is posible to improve the colorimetric characteristic (CCT, CRI, chromatic variability) of light sources based on wLEDs modulating their light emission with coloured filters. Although it is necessary a more deep study (other filters, develop of a theoretical calculation for the coloured filters…) in order to built these new light sources.

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Acknowledgments

This work was supported by the Spanish Ministry of Science and Innovation (DPI2008-06455-C02-02).

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Semantics of shape-color combinations

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Abstract

Every single colour or shape has its basic semantic meaning including its positive and negative polarity in relationship to its entire surroundings. The basic semantic meanings of colours, derived from a perception of the natural-cycle sequences, are justified in the Periodic model of colours. The informative potential and effect of colours are only obtained by combining colours within a new phenomenon, which means that the final result still depends on the relationships among constituent colours and shapes. These relationships are the quantitative presence of shapes and colours and qualitative identification of them by their typologies and tectonics. The Gestalt theory was used for colour-shape classification and evaluation. Relationships between colours and shapes are quite complex, but this presentation will be limited to only those basic classes and structures, that serve as the foundation for the grammatical system of visual communications. All other more advanced shape-colour classes are derived from these basic models.

1. Background

Basically any colour has an double (bi-semantic) meaning, being on the one hand the fundamental holder of visual information and thus shapes and texture and, on the other hand, because of its colour properties the potential for emotional expression, and information. In addition, colours have positive or negative emotional expressions. The basic semantic of colours, as derived from the perception of natural-cycle sequences, is justified in the Periodic model of colours (1, 4). Informative potential and the effect of colours are obtained only by combining colours within a new phenomenon, which means that the final result still depends on the relationships among constituent colours and shapes. These relationships are the quantitative presence of shapes and colours and the qualitative identification of them by their typology and tectonics. The Gestalt theory was used for colour-shape classification and evaluation.

2. Methods

Contrasts are complementary as every colour defines its opposite one (1, 3). Therefore, every colour should be always treated in relationship to others. Relationships among colours are quite complex. It is assumed that, at the lowest level of colour polarity (P1CP, P2CP, P2+1CP) (*Table 1),* the relationships among unique colours are relatively simple, but from the conceptual point of view very extensive, approximate and, defined broadly and symbolically. All further divisions are mainly due to conceptual symbolic definitions. Colour polarity models may be the foundation of every visual point and, at the same time, symbolic expression.

3. Results

The models of primary, secondary and tertiary colour polarities in their gradually increasing complexities are presented in *Table 1* and *Table 2*. The simpler the model, the broader range of symbolic meanings covered, and vice versa. This model has its limitations such as the ability to

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visually express, being mostly too loose or too exaggerated. However, it is always unambiguously discriminating. W-K is the first law.

Table 1. Complexity categorization of colour polarity models - from simplest to uncontrollable complexity

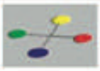
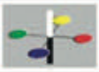
Title	Primary x-Colour Polarity - (PxCP)			Secondary x-CP - (SxCP)				Tertiary x-CP - (TxCP)	
Acronym	P1CP	P2CP	P2+1CP	S3CP	S3+1CP	S4CP	S4+1CP	T6CP	T6+1CP
Pairs of Colour Polarity	W-K	Y-B, R-G	Y-B, R-G, W-K	Y-B O-C, YG-M	Y-B, O-C, YG-M, W-K	Y-B, O-C, R-CG, M-G,	Y-B, O-C, R-CG, M-G, W-K	Y-B, OY-BC, O-C, R-CG, M-G, P-YG	Y-B, OY-BC, O-C, R-CG, M-G, P-YG, W-K
Colour Model									

Table 2. Conceptual classification of P1CP with a range of symbolic meanings (5)

	White	Black
Cyclic aspect	Day	Night
Positive aspects	light, clear, clean, apparent, understandable, inconceivable, starting point, birth, day, waking, winter, snow, coldness, frost, freshness, emptiness, peace, silence, unspecified, tenuous, willingly, openly, clean, sterile, innocent, hygiene, inexperienced, untouchable, precise, pedantically, strict, commitment, marriage, unforced, spontaneous, playful, flamboyant, young, balance, mild, delicate, gentle, graceful, tenderness, happiness, peace, freedom, sensitivity, ease, grace, salvation, angels joy…	silence, quiet, peace, serenity, sleep, dream, tranquil, overpowered, discreet charm, hidden attraction, festive, elegant, fashion, beauty lost, timeless, covert, hidden, unobtrusive striking, provocative endlessly, nonconformist, invisible, strong contrast, perfection, restrained-a sustained, special, depth…
Negative aspects	nothing, emptiness, unbalanced, anger, fear, inhibited, despair, doubt, sterile cold, alienated, vacuum, blinded, emptily, ignorance, boredom, inexperienced, undefined, colourless …	darkness, loneliness, emptiness, decay, dying, death, depression, sorrow, grief, fear, isolated, alienated, closed in self, void, delusion, evil, war, hell, dread, despair, vanity, pathetic, hidden…

Table 3 presents all four basic colours (Y-B, R-G) in two polarities – positive and negative conceptual classifications (5). This P2CP model is based on the four seasons. Next – the secondary level of Colour-Polarity models (S3CP, S4CP) represent the natural upper-limit of our ability to understand colour systems. After this level, the entire relationship becomes so complex, non-transparent, and requires a broader agreement for the further development of colour semantics!

Table 3. Conceptual classification of P2CP represents the substantial ground for all further divisions (5)

	Yellow	Blue	Red	Green
Cyclic aspect	late morning - midday, late spring - summer, light, heat…	night, winter, cold, dark…	late afternoon-evening, hot, late summer-autumn, mature, declining..	early morning, early spring, fresh, cold, immature…
Positive aspects	youth, beauty, light, radiation, glow, heat, dynamic, gentle, joy, laughter, happiness, food, life energy, warmth, glow, radiate, crying, naive, childish, vivid, vivacious, playful, cheerful, love, friendly, gentle, beautiful, lovely, optimism, pleasant, safe, striking, promising, enlightened…	water, sea, infinity, distance, freshness, coolness, cold, honestly, loyalty, friendly, love, tenderness, rest, peace, calm, sensible, softness, elegant, noble, attractive, hushed, spiritual, memories, dreams, longing, rational, thoughtful, hidden power, defiance, introverted, depth, ideally, wide, relaxation, spiritual, dreamily, deep experience...	life, happiness, joy, love, hot, steadfast, strong, steady, friendly, happy, life energy, mature love, expression, joy, temperament, happiness, cheerfulness, optimism, strong will, creativity, energy, hot-tempered, strong emotions, sexuality, passion, laughter, energy, expressive, pervasive, dominant…	unbridled growth, vigorous, easy, relaxed, relaxing, live, fresh, lively, sincere, naive, gentle, sensual, young, fertile, nutritious, grass, woods, nature, pure life energy, organic, healthy, naturally beautiful, calm, friendly, equal, neutral, quietly, kindly, emerging, alive, youthful, relaxing…
Negative aspects	naive, drugged, suspicion, blindness, anger, envy, shouting, hatred, closed, envious, intrusive, uncomfortable, hypocritical, jealous, timid, ruthless, disgust, pain, silenced, helpless, bitterness, hesitant, doubtful, violence sickly, dull, malicious, poisonous…	night, hatred, rejection, depression, defiance, dreamy, melancholy, distant, sad, sadness, alienation, mistrust, hushed, mean, passive, winter, ice, cold, dark, massive, introverted-self-sufficiency…	irritability, hot-tempered, passion, aggression, excitement, tension, agitation, restlessness, anger, hatred, brutal, blood, terror, revolution, fighting, killing, wild, fear, crying, striking, risk, intrusive, pervasive, infamous…	unfriendly, seamlessly, mimicry, roughly, toxic, cruelty, evil, fear, anxiety, estranged, envy, jealousy, unhappiness, disgust, apathy, cold, doubt, sullen, alienated, immature…

If the four-seasons concept supports the understanding of P2CP, the same principles can be applied for the annual-cycle of 12 periods. However, 12-period structure (P6CP) is already too complex and the distinction of individual tones is now unreliable. The orientation of colour within the set of 12 tones on different backgrounds has already been lost. Therefore, P4CP may be the most optimal and sensitive system, made by a doubling of the four seasons, and based on an otherwise

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natural phenomenon, but it is no longer a purely natural experience. It is a secondary replica, which has to be taught. It represents an optimal distinctive and conceptual model for colours and shapes (*Figure 1*).

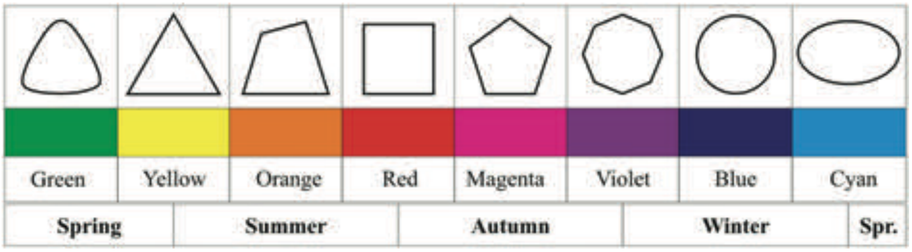

Figure 1 presents the relationship among shapes, colours and four seasonal cycles, where small differences already appear in the structure.

The properties of colours and shapes supplement each other to form an integrated system. Their collective interactions can represent a synergy that emphasizes support or counteraction. In any case, it is a question of a redundant repeating of the same meanings in different forms. For example, the sharp corners of a triangle has similar characteristics to the penetrating symbolic of edgy yellow. Within the same features of colours and shapes certain relationships are unable to achieve better performances, therefore a contrast between colours and shapes is necessary to achieve better visual results and a proper effect.

We also noted that simple colour models assume symbolic meanings from natural cycles (4) but, for more complex models, we need consensual regulations inn order to gain a precise meaning for each colour tone or shape. This field should be the subject of so-called "colour-shape grammar", as now regulated mainly by linguistics or mathematics.

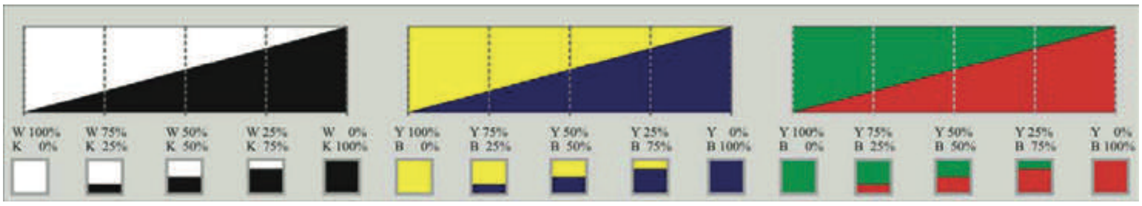

Figure 2 presents a concept based on the Gestalt theory (2) for evaluating the relationship between two colours, expressed numerically as a ratio through the cross-sections. In any case, we obtain a numerical result, which is a source of further evaluation for all other semantic elements.

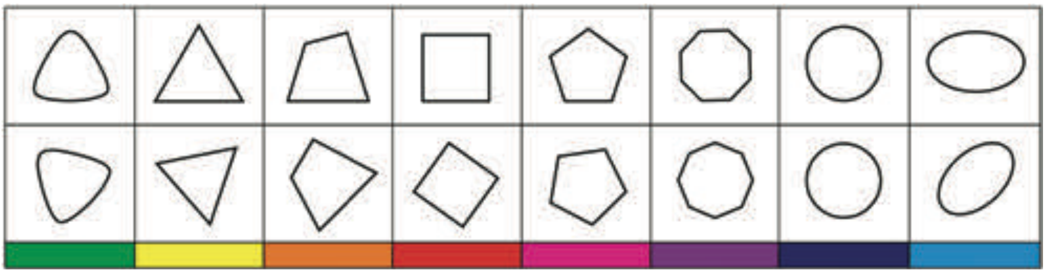

Figure 3 shows the influence of shapes' orientations on their dynamic manifestation and properties.

All the shapes are made of colours and are inseparable whilst, at the same time, contributing to the bi-semantic properties of colours (*Figure 3*). The first row of shapes are placed in stable positions. The second line all shapes are in destabilized positions, except the rounded and polygonal ones, which are perfectly symmetrical in all directions. Shapes are thus an integral part of the bi-semantic potential and properties of a colour's communication.

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5. Conclusions

The systematic exploration of colour combinations and shapes is extremely difficult, as the number of possible combinations is extremely high. However, colours can be concentrated within a reasonable number of models, using different categories. Within each category, there is a determined number of combinations, being only variations of the same model-category or colour-shape combinations (2, 1). My conclusions are that only the lower-end models within the categories of natural cycles phenomena possessing those properties, that are well-known and understood by everyone, perhaps even genetically-written. Therefore, we are somehow familiar with these simple forms and master them naturally. The models of higher categories are however too complex and our understanding is limited. It would be necessary to draft a common platform in order to learn them, just like linguistic grammar or basic mathematics at elementary schools. More complex models simply require some support for such development. In an era of advanced computer technology, it would be necessary to start with a mosaic, composed of links between colour models, shapes, and symbolic meanings.

Acknowledgments

Thanks to Dr Andreja Sinkovic for moral support and her help in finding new expressions for new non-defined categories.

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Bright fabrics: From silk to LED

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Abstract

The aim of this work is to show the methods used to make textiles capture and reflect light from ancient times to the present day. The history of textiles has been marked by an aesthetic and technical search for methods to make fabrics capture light and look bright and shiny, ranging from the processing of vegetal, animal and synthetic yarns to the study of yarn weaving structures, from ennobling and finishing processes to bright element application, and to modern technologies.
(Keywords: light, textiles, fabrics, treatments, fashion.)

1. Weaving glow

A thread of brightness

The richest and brightest fabrics are those that reflect light and convey a special bright aura to the people wearing them. Since the beginning of the textile era this role was played by silk yarn, which dates back to ancient China.

It is precisely in China that some specimens of *bombyx mori* dating back to around 3500 B.C. were discovered, making them the most ancient domesticated silk moths ever found.

Legend has it that sericulture was created by Léizǔ, the wife of emperor Huang Di, who founded the Han dynasty and reigned from 2498 to 2398 B.C.

Chinese emperors had the absolute monopoly of silk production and kept the secret of the sericulture technique for a long time. They exploited them by establishing a flourishing trade with the Western world, where rulers and influential people were dressed in silk. Silk was so much appreciated that, despite its exorbitant cost, rich aristocrats had silk garments tailored back in the Roman Empire, defying the numerous sumptuary laws prohibiting it.

In the Western world silk was first produced by the mills of Byzantine Emperor Justinian, who was given silk moths by two monks he had hired to hide silkworm eggs in their hollowed-out walking sticks. These mills produced royal fabrics and were under tight control so as to prevent production secrets from leaking and workers from escaping[1], which was punished with death. The textiles produced were used to tailor sumptuous imperial garments and as diplomatic gifts to foreign dignitaries. Even if the increased democratisation of markets has made it available to everyone, silk still has a symbolic role of preciousness and is unparalleled in terms of softness, glow and light weight[2].

Uninterrupted lustre

Glow in fabrics results not only from silk fibres, but also from their textile structure: the *satin weave*[3], which is based on large and hidden weft interlacing points on the wrong side and on long

1 From: Renata Pompas, Textile Design. Ricerca – Elaborazione – Progetto; Ulrico Hoepli, Milano, 1994.
2 Even if its tactile feel is imitated by synthetic yarns, silk still remains the only fully non-allergenic fibre. As a matter of fact, some of its amino acids are similar to those produced by the human body.
3 *Weave* is an interlacing system of weft threads and warp threads.

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floating warp threads on the right side, results in a soft and widespread lustre. Light is reflected on the surface uninterruptedly making the fabric look smooth and glossy.

Coated lustre

Nowadays the lustre of satin weave silk is reproduced by some textile surface treatments, like coating with special resins, which turns dull fabrics into reflective glossy surfaces, like *oilskin* or *patent leather*.

Iridescent glow

The application of *satin weave* (weft and warp threads of two different and complementary colours) results in an iridescent effect by which silk has the iridescence of insect wings and peafowl feathers. Based on the movement of the fabric, the angle of illumination and the angle of view[4], motion and ever-changing glares enliven the textile. This ancient technique was used to make glowing garments in different times.

Today stylists have further enriched weaving opportunities with new technologies and materials, so that they can create iridescent and kinetic effects by means of synthetic polyester yarns and flat element spinning methods that play on the different light reflection based on their position during weaving.

Deep glow

By applying pile-effect *velvet weave*[5] to silk, the resulting glow is three-dimensional, deep, sensual, and tactile.

Velvet has a mellow glow, but when its production in Italy reached its climax, from the 15th to the 18th century, playing on lights and shades became common practice, in line with the artistic expressions of those times. As a result, velvet pile was cut at different heights to convey different thicknesses to textiles. In addition, the technique known as “highlighting” was invented, which consisted in inserting additional weft golden *loops* to create flashing lights whose intensity changed based on the weft quantity added.

2. Applying brightness

Jewels for weaving

While silk alone represented splendour and attention to appearance, gold celebrated sunlight, God’s light and hence power and glory thanks to its mystical meaning of eternity and incorruptibility. Consequently, rulers, top figures of the Church, aristocrats and those who could afford it were covered in gold.

The fragments of Byzantine mosaics in the Church of San Vitale in Ravenna, Italy, show Emperor Justinian, Empress Theodora and the court dressed in sumptuous garments embroidered with a profusion of gold and decorated with twinkling gemstones (527-565 A.D.) Since ancient

4 From: Jouer la lumière, Jean Paul Leclercq, Musée de la mode et du textile, Société nouvelle Adam Biro, Paris, 2001.

5 Technique by which additional warp loops are weaved and trimmed into pile, which covers the whole textile surface, or only a part of it for decorative purposes.

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times the combination of gold and silk has represented an image of wealth, exclusivity, showing-off and luxury. Such a use has continued over centuries, turning textiles into shining jewel crafts.

Nowadays synthetic gemstones[6] made from rock crystal, glass or acrylic and known as "*rhinestone*" are sewed or heat-bonded.

The most famous rhinestones are by Austrian manufacturer *Swarovski*, which produces iridescent sequins and twinkling crystals to decorate or fully cover textiles, for a jewel-life effect.

Golden glow

The ancient technique for spinning a gold thread consisted in wrapping a thin metal sheet around a silk yarn (core). A team of experts recreated this exact method by analysing Milanese silk products dating back to the Renaissance. Golden yarn could be used for the whole textile surface, for the background of weaved decorative motifs, as a decoration or in embroidery and applications, in a "luxury philosophy whose natural breeding ground was jewel crafting"[7].

In all these processes golden yarn brought in gleams and beautiful effects depending on the angle of illumination. Pure gold threads were used until the 18th century, when French textile mills produced rich Rococo fabrics for sovereigns and Western courts.

Today pure gold threads have been replaced by synthetic materials and industrial processing technologies based on synthetic fibre threads covered with a layer of vaporised aluminium. Golden fabrics are produced not only by weaving synthetic golden yarns, but also through laminating, a treatment performed after the fabric has been produced, by which a thin metal sheet is applied at high temperatures to the whole textile or according to a pattern.

Light discs

Among the archaeological findings in the Indus Valley (in present day Pakistan) of the Kot Diji period (2800-2600 B.C.)[8], some round objects made of gold or metal with two central holes or with a series of holes along the border were identified by experts as decoration on women's clothing and paraphernalia, intended to create a twinkling, ever-changing and precious glow[9].

Many centuries later the production of the so-called "*magete" or "magette"* emerged in Europe[10]. These were small golden or silver metal rings that were applied only for decorative purposes to embellish some parts[11]. In brief, very ancient forerunners of today's sequins, which were invented in the 1960s, can be found in different civilisations. Sequins consist of small, very reflective plastic discs applied onto textiles for a lustrous effect.

At the beginning sequins were sewed on textiles through a central hole, but now they can be heat-bonded. They come in a wide range of shapes, dimensions and surface treatments. Their reflective effect is further enhanced with special treatments, like faceting, embossing (a sort of rubbing resulting in irregular glow), laminating (with reflective materials) and coating (with glossy paints and colours). Textiles fully covered in sequins have a very intense, mosaic-like and kinetic glow.

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6 From: http://en.wikipedia.org/wiki/Rhinestone. Back in 1775 Alsatian jeweller Georg Friedrich Strass had the idea to imitate diamonds by coating the lower side of glass with metal powder.

7 Op. cit.: Gold nuggets were turned into a very thin sheet (1-3 micrometres) with high-precision hammering performed by skilled craftsmen. It was then cut with special scissors into very thin stripes (170 to 360 micrometres wide). Cutting was made with scissors and the resulting sheets were then wrapped around a silk thread by means of a spindle.

8 From: http://en.wikipedia.org/wiki/Kot_Diji

9 From: http://www.harappa.com/indus5/page_392.html

10 To be precise in Milan, Italy, in the 15th century, during the Renaissance.

11 Originally these small rings were intended to protect the buttonholes of garment laces.

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Stardust

Textiles treated with glitter have a different glow, marked by a tiny and sparkling texture. *Glitter* consists of very small pieces of polyurethane plastic with metallic and iridescent colours, which are ground into sparkling powder. They are heat-sealable, available in a wide range of colours or metal effects and provide image diffraction. *Reflective* textiles result from different techniques. Two of the most popular ones are aluminising by sublimation[12] or transfer of reflective films onto textiles, mainly onto synthetic fabrics. Initially intended for heavy-duty protective clothing[13], today these textiles are employed in the fashion industry in a non-technical version enhancing their brightness.

3. Emitting luminescence

Radiating glow

In modern times light has not been captured into textiles only to make them radiate splendour, but also to highlight them visually under different visibility conditions by enhancing this light. Light-"emitting" technical fabrics have now been invented and produced: they are made of special fibres, dyed or coated with electroluminescent pigments after manufacturing.

Phosphorescent textiles emit glow even when they are no longer illuminated, but they are not much used. *Fluorescent* textiles lose any glow once they are no longer illuminated. They are widely used in technical work clothes and in sportswear. *Retroreflective* textiles, which are treated with photoluminescent pigments, reflect light rays back to their source. They are visible in low-light conditions and from any angle[14].

4. Transmitting light

As optical fibres were transformed into flexible yarns suitable for weaving or knitting (with hard-wired transformer machines or battery-powered machines), textiles started emitting light on their own, thus dematerialising surfaces and changing their perception. In 2006 Philips presented flexible light-emitting textiles named "Lumalive" made of built-in Led fibres powered by tiny batteries and ready for marketing. Since then luminous textiles have covered show business stars, lighten up ceremonies with furnishing textiles, entered the wardrobe of young people with small graphic inserts.

From empire silk…to street-style light.

In conclusion, since ancient times sophisticated technologies and materials have been used to encapsulate light into textiles, but today one can say we can "weave light".

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12 From: www.gentexcorp.com/assets/gentex/Datasheets/AluminizedFabricBrochure2006.pdf

13 "Dual Mirror" by Gentex Corporation (US) is an aluminised fabric based on a five-layer structure., that consists of an outer aluminium skin, protective film, a second layer of aluminium, a heat stable adhesive and a base fabric.

14 From: http://www.nextgenerationbv.com and http://www.3m.com/intl/ca/english/centres/safety/personal_safety/retroreflection.html

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Colour design of commercial building at Amphawa canal community using NCS colour notation

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Abstract

To repaint the commercial building at Amphawa canal community, first the original paints used on the building were investigated. We found that they were originally painted in chrome yellow and some were repainted in many other colours in later years. New schematic must create a suitable identity to the old place and from our historical background studies. Therefore, chosen colours were dominated by green hues with many nuances such as S2020-G50Y, S3010-G30Y, S1010-G30Y, S2020-G30Y whereas yellow and pink of a few subsequent nuances such as S1010-Y30R, S0520-Y30R, S1010-Y80R were selected. The experiment was carried out to evaluate the how perceived colours differ from selected colour. It shiftIt was found that the majority of observers perceived some slight colours shifts in every aspect of NCS colour notaion such as hue, blackness and chromaticness. Therefore we decided to paint the colour we selected from NCS notation.

1. Introduction

The conservation of the Amphawa Canal Community in Samut Songkhram Province was awarded an Honorable Mention in the 2008 UNESCO Asia-Pacific Heritage Awards. Amphawa is not only a significant heritage community but also a well-known tourist attraction because of the popular evening floating market. However, the commercial buildings which consist of three traffic blocks of two-storey commercial buildings built during the 1950s require new paint. Thus, TOA Paint (Thailand) and the council of Amphawa established a project charged with the responsibility of designing and donating paint colours that are appropriate to this historical place.

2. Colour design

To repaint the buildings in the whole area serves to revitalize the uninteresting buildings making them memorable tourist attractions. New paint colours ought to create an identity so that new palette blends harmoniously with the old town. Colour palette design for the facade painting of these commercial buildings was created from information which can be divided into three important structures: the Past, the Place and the People.

The past

The history of Amphawa can trace back to the 16 th B.E. when Ayutthaya Dynasty ruled the country. The community was then known as a “commercial town” (Wannasilp,2006) due to her prime location where the Mae Klong River conjunction with the canal and traveling by boats are one of the important means of transportation. Thus, water culture has long been established along both sides of the canal and river.

This community in its original form had been established for a very long time, and we can

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identify the most important person born in Amphawa "King Rama the Second of Rattanakosin Dynasty". The King was born on February 24th 2310 B.E. (A.D. 1767) which was "Wednesday", the day which represented by colour "Green" in Thai believe (Ministry of Culture Thailand). This was the reason the colour design hypothesis chosen. It commemorates the most important person of the place.

This King, considered a poet of genius had written a classic musical play "the Ramayana". The main character and hero of the play "Phra Ram" was always costumed in green to portray his green complexion. This information did support the mentioned hypothesis real well.

The place

The floating market at Amphawa has been planned to host approximately around twenty up to thirty thousand people visit on each Friday and late afternoon on weekend (3pm to 8pm). The commercial buildings are located on the western bank of Amphawa Canal which oppose to the sunset when viewed from the floating market, therefore, light and shadows at dusk enhanced green colour palette the most when daylight getting dimmer. Moreover, when the sunset and daylight is replace by artificial one, the Amphawa banks are glittering with million of tiny green light lit by flyflies.

Because of Amphawan's location surrounded by water, the irrigation is excellent. Agricultural products are abundant and the main source of the commmunities income. The place is covered with greenery of fruit orchards producing such fruits as pamelos, coconuts, lychees and mangos. The name "Amphawa" means mango forest. This meaning is on the symbol used by the Office of Amphawa Municipality. The intense greenery of the location and the mango skin which are green when raw and gradually turn yellow when ripe inspired the creation of the green-yellow palette at this hypothesis stage.

The commercial buildings which are shop houses that were built after a great fire in 2494 B.E. (1951 A.D.) Our investigation of colours on these existing buildings concluded that the original facades were painted in chrome yellow (2020-Y30R, 2030-Y30R, 2040-Y20R). Some were repainted in many other colours in later years (2030-B, 1510-G60Y, 3030-G60Y, 0510-Y60R, etc.). Therefore the yellow palette should also be considered so as to recall the memorable colour.

In Thailand there are many types of buildings painted yellow in the old days. Most of these buildings were built for government offices. Realizing that painting a large number of buildings, yellow would create an overly formal formal and rigid appearance in a region intended to be a cheerful commercial area. It wad decided to paint only on a portion of façade, particularly when it was adjacent to to the old house where Amphawa Municipality Office is located. A few other facades were selected to be painted yellow for several reasons. On occasion the choice was purely aesthetic. Sometimes, with reason, a shop owner would request the colour yellow for a particular business.

During the Reign of King Rama the fifth (2411-2453 B.E. or 1868-1910 A.D.) there were many ginger bread style or so call Victorian style houses built at Amphawa community. These houses were painted in sweet pastel colour such as light yellow, light green and pink. Therefore, some pinks were added in order to make the palette of the town more meaningful and colourful. These pink will also complement and intensified the main green palette. Moreover, many wooden Thai traditional style houses at Amphawa are painted in red (6030-Y80R, 4030-Y90R, 3050-R etc.), including pink in the designed palette will harmonize the over all colour of the community.

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The people

Designing colours for a place for living, having business and concerning the community's environment, the most important factor is "the People". TOA together with the officer of Amphawa Municipal arranged many meetings with the shop houses owner to make them understand how the main palette is chosen. They still have their own choices from the main palette and fortunately, almost all of them satisfied with the result of paint they or we selected for them.

3. The palette

When all the information from the past, the place and the people are accumulated, the decision on the palette: green, yellow, red and their nuances are selected from the NCS swatches as shown in Table 1.

Table 1. Designed NCS colour Palette

Green Palette	Yellow Palette	Red Palette
S 1020-G50Y	S 0505-Y30R	S 1010-Y80R
S 2020-G50Y	S 1010-Y30R	S 1020-Y80R
S 0505-G30Y	S 0520-Y30R	S 2020-Y80R
S 1010-G30Y	S 1030-Y30R	S 2030-Y80R
S 2020-G30Y	S 2030-Y30R	S 3030-Y80R
S 3010-G30Y	S 0502-Y	S 5020-Y90R
S 5010-G30Y	S 4502-Y	S 6020-Y90R
S 1010-G50Y	S6502-Y	S 7020-Y90R
S 1020-G50Y		S 7010-Y70R
S 2020-G50Y		
S 4010-G50Y		
S 6010-G50Y		

These colours are grouped in combinations for walls, window frames and shutters, wooden folding doors and sliding iron bars. It is known that the perceived colours will be somewhat differs from its inherent colours (Fridell Anter, 2000). To evaluate that how perceived colour differs a selected colour, by selecting some buildings as our prime experiment subjects. First, parts of exterior of the building were painted by 7 selected colours. The size of the painted wall was 1.5 x 4 meters. Then forty observers who had normal colour vision were asked to match the NCS colour patch (2.5 x 5 cm) to the painted wall under direct sunlight (5500K) and under shade (7000K). The distance of the observers to NCS colour samples was 0.5 meter and 8 meters to the painted wall.

4. Results and discussion

The painted colours were analyzed by plotting the selected colour and perceived colour in NCS colour space. It was found that the majority of observers perceived some slight colours shifts in every aspect of NCS colour notation such as hue, blackness and chromaticness. Under direct

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sunlight, colours were perceived towards more blackness and more chormaticness. Hue shift was dependent on colour hue. The green colour was perceived to have more green hue while yellow-red hue was perceived to have more red hue. Under shade, colour shifted toward more blackness for green colour and less blackness for yellow-red colour. Chromaticness is not changed in these circumstances.

The results from this experiment were part of our decision to paint all commercial buildings (Figure 1 and Figure 2). Since this market is an evening floating market and its peak activities happen after sunset. The colours of the commercial building are perceived somewhat less colourful because of the low light intensity and human vision shifts from photopic to scotopic. Experiment results shown that our selected colours change only slightly in shade. Therefore we decided to paint the colour as we selected from NCS notation.

Figure 1: Colour design of commercial building at Amphawa

Figure 2: Photographic image of commercial building in 360 degree.

Reference:

Fridell Anter, K. 2000. *What colour is the red house?* Stockholm: Royal Institute of Technology.

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Mobile sun-shading devices: Changing the colour of buildings' façades and places

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Abstract

In contemporary buildings, where large translucent façades must enable compliance with specific standards of comfort, the external mobile sun-screens have assumed a gradually more and more strategic role. Today the sun-screened surfaces can be very large according to the size of the glass panels on the façades. They are colorful and, acting in synergy with the light, they help to change the chromatic conditions of façades, of interiors and even of the surrounding environment. The objective of this paper is to summarize the result of a research for the architectural integration of mobile sun-screen devices with the façades of the buildings, according to the most common colour combinations used in contemporary architecture. In this paper the path of the research has been outlined in four phases: a brief historical introduction and a brief classification of current screening systems (summary of the state of the art); the interaction of colour and light in some emblematic case studies (central phase of the research); a short description of the obtained results.

1. External sun-shading devices in history: a brief coloured introduction

The external awnings in the architectural façades have always been a chromatic variable characterizing certain environments. Their presence or absence could completely change the look of a place: you may think about the local markets in the cities of the Eighteenth and Nineteenth centuries. When there was a market, the streets had a different colouring due to the awnings used by the sellers. In the past each city had its specific colours: in Venice there were white, blue and green awnings and white stone façades or painted with earthy colours. In Ferrara, the awnings were red and the façades were mostly brick red. Wooden louvers with adjustable blades exist since a long time, featuring the look of the façades in Bolzano such as in many other places in Italy.

In the Twentieth century the architectural industrialization has produced buildings made of steel and glass and the cultural codes that governed the colours of the façades have changed. During the Modernist period, technology has become a tool of expression for architecture and the available colours have multiplied tremendously. The need for a better living comfort favoured the evolution of the sunscreens that became larger than the past as the windows of the buildings. In some cases the sunscreens were the only opaque part of the façade as it is in some the works of sir Norman Foster.

Over the past twenty years the skins of the buildings, once static and motionless, have become increasingly dynamic, adapting to the different environmental conditions. At the same time the new cities are no longer characterized by specific colours: they have variegated and changing tones just like the people who live there. "The colour of this period is only functional to demonstrate the power of technology. It is emptied of historical and cultural significance" (Zennaro 2010: 129).

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2. The sun-screens today: types, materials and colours

According to the Italian UNI, mobile sun-screen devices can be classified into three categories: awnings, shutters and brise-soleil with adjustable blades.

The awnings have evolved in two directions: improvement of operating electromechanical systems (awnings are classified according to their operating system that may be extendable arms, little arms, drop, packet etc.) and the textile that forms the screen. In contemporary architecture synthetic technical fabrics have become popular. They are filters that allow the transition of the solar radiation within the building by transferring their colors on the internal walls. The colors are almost endless. The designers often use *screen* tissues produced by weaving yarn of different colors. The interplay of different colours produces vibrant tones. However, the most common colours are white and gray and saturated colors with high tones. There are also metal tissues.

The shutters and the panel systems can be made using any material: wood, metal, plastics etc. There are screens with sliding doors and folding doors, sometimes operated by hydraulic systems.

Even the brise-soleil can be made with any material: wood, metal, plastic, frosted glass, etc.. In some cases they can be integrated with lighting systems that create a chromatically dynamic façade even at night. Venetian blinds with adjustable strips are made of aluminium or plastic, mostly gray but available in many colours.

3. Colour and light interaction in contemporary architecture

During the research more than one hundred case studies of contemporary architecture were collected and classified. For each building, we have analyzed a series of parameters that were functional to the survey we wanted to do: shielding system, location of the sun-screen, components, materials, screen size, colour of the screen, colour of the façade, colour combinations between the sun-screens and the façade and colours of the context. Many of these cases represent only a statistical basis for the acquisition of data, but some of them are emblematic for the original solutions in the implementation of sun-screens on the facade and especially for colour relationships they create with the surrounding environment.

The GSW Headquarters in Berlin, completed in 1999, is one of the most famous work of Sauerbruch & Hutton Architects. The main façade of the building looks like a cluster grid in which each cluster has a different tone: from white to pink, from orange to red and brown. Each cluster has its own aluminium painted sunscreen. According to the different environmental conditions, each sunscreen can be opened, closed or in a mid position. This leads to a continuous changing in the colours of the façade.

The Pharmacological Research Laboratory at Biberach, completed in 2002, looks like an "inhabited painting". As the authors said, the building "consists of a simple volume with a glass skin, onto which a polychromatic pattern has been printed […]. The pattern was generated from a monumental enlargement of a microscopic image of one of the drugs produced by this pharmacological company" (from www. sauerbruchhutton.de). The skin of the building is made by vertical adjustable glass sunscreens. The glass elements are painted in group of colours: someone are white, other grey, yellow, red and brown. During the day the building skin is opaque and characterized by a static pixel pattern similar to some old computer games. By night the skin becomes transparent and the interior lights seem to bring life to the colours and to the building itself.

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In the housings the dynamics of the façades is ruled by the needs of individual residents. It many cases the sunscreens are the only opaque element of the façade. Each family can open or close their sunscreens so as to continually change the look of the building. Herzog & de Meuron Architects have designed many buildings with this feature. The façade of Rue des Suisses Apartments in Paris, completed in 2000, is made entirely of metallic black panels. These perforated panels let in a dim light inside the building, but outside they give you a feeling of a compact surface when they are closed.

The mobile sunscreens not only affect the colour perception of the façades but also the perception of the interior. The colourful awnings, once down, interacting with natural light, reflect part of their colour on the interior walls of the buildings. This phenomenon is very evident if these walls are white. Puerta America Hotel in Madrid is emblematic. The façade was designed by Jean Nouvel and completed in 2004. The architect chose to cover it all with colourful curtains with shades ranging from blue to red, yellow and orange. The saturated colours of the awnings, especially red, are reflected in the walls of the rooms, causing psychological distress to the people. In these cases, the window size is crucial. In fact, in the Social Housing on the Coast by Ofis Architects in Izola, where the awnings have many different colours (yellow, blue, brown, green, orange, pink, purple), this effect is very small.

As mentioned before, the colour of the sunscreens can affect the perception of the façades as well as the appearance of entire places. Just look at some streets, like those often found in the resorts or at the seaside. Especially in towns or places full of business. Every trader wants to stand out from the neighbour using different colours. To do that, they often use the curtains. So the streets become colourful scenarios where highly saturated colours clash with each other creating a sort of background noise.

4. Conclusions: notes for the architectural plan

Despite these colorful examples, the research results showed a clear predominance of gray and white (both outside and inside the buildings). Despite the enormous colour possibilities offered by technology, contemporary architecture that makes extensive use of sun-screen systems seems to want the dematerialization of the building envelope in the context by using these colours. We noticed that for some intended uses (offices, commercial, public buildings, places of work) the gray and white were largely favorite, perhaps because they do not create any kind of psychological stress in the population. Among the emblematic case studies, it emerged a clear research for a relationship between the colour of the non-glazed part of the facade and the color of the sun-screens. The research also showed quite clearly a relationship between the type of shading devices and the size of windows. To produce a system of guidelines, we have put the latter two aspects in connection: the size of the windows and the main material that covers the facade. In guidelines the buildings' façades have been divided in two categories: façades with small openings and façades with large openings (windows). Here's a brief selection of the guidelines.

> *Facades with small openings: plastered masonry. This kind of buildings, usually of residential use, is characterized by small and medium-sized windows and by plain surfaces in various colours. The type of sunscreens that seems more appropriate in this case are the curtains. […] You can select fabrics in white or light gray, or a monochromatic combination with the colour of the walls or a two colours-combination […].*

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Facades with small openings: brick-face view. In the facades with brick walls face-view, the contemporary architects seem to prefer vertical blinds or awnings with extendable arms in white or possibly blue and white stripes […].
Facades with small openings: stone coated. The stone claddings can have different colours. In this kind of building, contemporary architects seem to prefer vertical awnings with brackets, generally integrated in windows holes. If the stone is white you can find solutions in single colour with white curtains, or try a combination of colours with different colour curtains […].
Facades with small openings: wood panelled. In wooden surfaces the trend seems to use wooden sunscreen with slats of the same colour […].
Facades with small openings: concrete masonry. In this type of buildings you can use coloured awnings also trying to counter the gray colour of the concrete. Alternatively you can take white or gray curtains. You can also use aluminium venetian blinds or brise-soleil slatted in metal.
Facades with small openings: metal coated. In the metal surfaces, metal sunscreens seem to fit particularly well. You can use aluminium venetian blinds in gray or silver, or painted. […] The colour combinations can play on monochromatic themes or on two or three colours combinations.
Facades with large openings. In this kind of facade you can use a huge variety of different screening systems. […] In double skin facades the architects seem to prefer two separate solutions. In the first one, the outer layer consists of a glass skin that doubles as an adjustable brise-soleil. […] The second solution is the installation of brise-soleil in the technical space between the two skins. For any further detail please refer to the References. (Premier 2010: 536-537).

Acknowledgments
Professor Pietro Zennaro, head of the "Colour and Light in Architecture" Research Unit at Iuav University of Venice, Faculty of Architecture and tutor of the PhD thesis "Mobile Zone. Technologies for the architectural integration of mobile shading devices" presented in April 2010 at Ferrara University, Faculty of Architecture.

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Measuring beer haze and preference

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Abstract

A proposed technique for defining the most preferred appearance of beer (lager and bitter) in terms of colour and haze (i.e. cloudiness or translucency) has been investigated. Conventional hazemeters measure beer haze with either the detector at 90° to the light source or using forward illumination geometry (i.e. light passes straight through the liquid). Beer colour, however, is determined using a standard-specific single wavelength, e.g. 430 nm for the European Brewing Convention (EBC) standard[1].

The new method described here involves a combination of colour measurement of beer samples using a tele-spectroradiometer, measurement of turbidity using a hazemeter and visual ranking of beer samples in terms of preference via a psychophysical experiment conducted in a predefined viewing environment.

1. Sample preparation

All of the samples used here were prepared from commercially available beer. The experiment was divided into three sessions, each conducted a week apart. In the first two phases, 25 samples were prepared of which 15 exhibited variation in colour and were all very low in haze. This was achieved by adding different quantities of red and yellow soluble food colorants and different amounts of a pH 4 buffer solution to the beer[2-3]. These samples were used to determine the specific colour region which was most preferred by observers for both light and dark beers. The remaining 10 samples varied in colour and also had a large variation in haze, the latter being achieved by adding different amounts of an artificial cloudifier to the beer. Having samples with variation in haze and colour would help test the performance of different instrumental measures of haze. In the final phase, 30 samples were prepared: half were light beers and the remainder dark beers. The most preferred colours for light beer and for dark beer identified in the first two phases were used to make a more refined colour region in the third phase.

Figure 1. Some of the beer samples used in the experiment.

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2. Psychophysical experiment

Each sample was first de-gassed, poured into a highball glass and sealed with laboratory film to avoid olfactory influence and also to prolong lifetime.They were then labelled using a code at the bottom for the psychophysical experiment. In addition, a highball glass filled with mineral water and sealed and another was prepared using mineral water with 0.048 g of artificial cloudifier. These were used as reference samples for haze judgements in the psychophysical experiment.

Observers participated in all the sessions, each lasting 15-30 minutes. A total of 14 observers took part in the psychophysical experiments. Nine were Asian and five were European. Nine were males and five were females. Their ages ranged from 20-59. All were university staff or students and had prior experience in psychophysical experiments. All had passed a basic visual acuity test and also the Ishihara colour vision test. Observers were asked to sit in front of a viewing cabinet which was illuminated using a D65 simulator. The walls of the cabinet had been painted matt black and a solid white line of around 2.5 cm in thickness ran across the back wall. The room lights were turned off and all exterior light was blocked from entering the room in order to create a dark surround.

In the first section of each of the first two phases, observers made judgements of the haze seen in each of the beer samples sequentially and in a random order using magnitude estimation. Samples, presented in a highball glass, were placed in between the two reference samples. A mineral water reference was used as the anchor point for a perceived haze of 1; mineral water plus 0.048 g of artificial cloudifier was the anchor point for a perceived haze of 10. Observers were asked to judge the haze on a scale that began at zero and was open-ended, using decimals if they wished. Once all samples in a particular phase had been judged, ten were randomly selected for repetition in order to determine each observer's consistency.

In the second section of the psychophysical experiment, observers ranked beer samples according to preference. Five samples were presented to them in a random sequence and observers were asked to physically sort the beers from their most preferred down to their least preferred based on appearance. When the next sample was presented, the observers inserted this within their previous ranking before removing the least preferred of the six beers. This process of introducing a new sample, reordering and removing the least preferred continued until all of the samples had been accounted for. At the end of a single session, an observer's top five beers remained in the viewing cabinet. The beer that ranked first (most preferred) was awarded five points, the second received four points, and so on to the fifth which was given one point. None of other beers were awarded any points. At the end of the experiment, the points awarded by all observers to each sample were totalled to produce an overall score for that particular sample.

In the third phase, the ranking section was carried out twice: once for light beers and once for dark beers. The 15 light beers all had colours that lay within a refined region about the most preferred light beer from Phase 1; they also exhibited considerable variation in haze. The 15 dark beers also had colours that lay within a (different) refined region about the most preferred dark beer from Phase 2 and also showed a much larger variation in haze. The aims of this phase were to see whether any further improvement could be made to the most preferred colours from the first two phases and also to determine the most preferred haze level in beer.

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3. Colour measurement and haze measurement

The most prevalent instrument for determining haze in beer and other turbid liquids is the hazemeter, also known as the turbidimeter or nephelometer. This has a port in the centre for holding a sample of the beer, which is illuminated by a light source. Scattered light is then measured, usually at an angle of 90° from the angle of illumination (other geometries exist). Measurements are made relative to a standard suspension, typically formazin[4].

All of the beer samples were also measured using a LTP6B Dr. Lange hazemeter. This instrument measured haze by illuminating the sample and detecting the amount of light scattered at 90° to the angle of illumination. It assumes that the more light is scattered, the hazier the sample. Measured haze appeared on the display in °EBC. Before measuring samples, the hazemeter was calibrated against Formazin Haze Standard1. Three readings were taken for each sample and then averaged. The maximum standard deviation amongst each of the three readings was found to be 0.16.

Colour measurement was made using a tele-spectroradiometer in order to analyse and represent the observers' beer colour preference in a device-independent manner[5-6]. All instruments were allowed to stabilise for 30 minutes prior to measurement. A "fixed-mass" approach was used to dispense equal amounts of liquid into Petri dishes. Each petri dish was in turn placed onto a fixed position on the surface of a transparency viewer. The tele-spectroradiometer was mounted directly above the petri dish at a distance of 50 cm. Averages were again taken using three readings, however these results were somewhat more consistent than those of the hazemeter.

4. Results and discussion

For light beers, the most preferred beer according to the 14 people taking part in the experiment was one whose formulation was 500.00 g of a leading brand of lager with 0.56 g of yellow colorant. Its colour coordinates were (L*, a*, b*) = (91.73, -3.05, 63.08) when 50.00 g were presented in a polystyrene Petri dish on the transparency viewer; i.e. it was highly yellow, slightly green, very light and very colourful. Its corresponding hazemeter specification was 0.60 °EBC and the mean observer-perceived haze was 0.89 on an open-ended scale that began at 0; i.e. it had very low haze.

Cultural differences were evident between Asian and European observers for dark beers. The most preferred dark beer amongst Asian people was one whose formulation was 300.00 g of a leading ale, 200.00 g of buffer solution and 4.20 g of blue colorant. Its colour coordinates were (L*, a*, b*) = (89.86, 2.13, 42.23) when 50.00 g were presented; i.e. it was slightly red, quite strongly yellow, relatively dark and quite colourful. Its hazemeter value was 0.21 °EBC and the mean observer-perceived haze was 1.08; i.e. it had very low haze.

The most preferred dark beer according to European people had a formulation of 500.00 g of the dark ale and 0.53 g of yellow colorant. Its colour coordinates were (L*, a*, b*) = (82.63, 7.63, 75.03) when 50.00 g were presented; i.e. it was much redder, much yellower, much darker and much more colourful than the Asian observers' most preferred dark beer. Its haze was reported as 4.10 °EBC by the hazemeter and observers perceived its haze as 7.75; i.e. it had a high level of haze – much greater than that of the Asian observers' most preferred dark beer.

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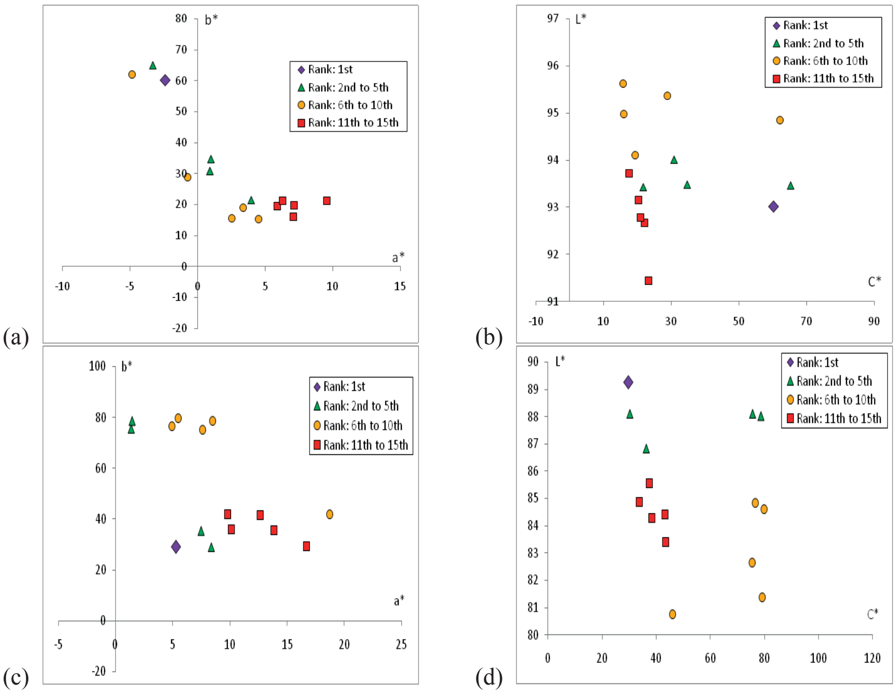

*Figure 2. Light beer colour preference for all observers in CIE (a) a*b* and (b) L*C* colour planes; dark beer colour preference for all observers in CIE (c) a*b* and (d) L*C* colour planes.*

5. Conclusion

In addition to enhancing the appearance of existing commercially available beers, the data obtained from this experiment also allowed cultural differences towards beer preference to be explored and the acceptability of various beer colours and haze levels to be determined. Such information should prove invaluable to the brewing industry, who could use it to further refine their products to attain the most preferred appearance, thereby potentially increasing sales since more consumers find their beer attractive and hence are more inclined to purchase it. It was also found that while the hazemeter is a useful tool for ensuring brewing consistency, it does to not correlate well with visual results.

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Teaching ideas and aspects for a new spacial research on the interaction between light, space, and color

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Abstract

The educational experimental work presented here, using essential structures, refers to the variability of color, light, and space, enhanced through different points of view. In these structures, the color component defines constantly changing space placements, while providing unexpected color matches with "surprise effects" as far as color perception is concerned. Color, in turn, integrates with either natural or artificial light and with space, which becomes a three-dimensional support. These studies can also be applied for teaching design, in order to develop new application opportunities, by extending perception spaces also for designed objects. You can then move further on with chromatic connotations. Natural or artificial light is then used to highlight different composition dynamics, thus promoting a real discovery of color linked to concepts of spatiality and brightness.

This method, when widely applied, extends from the object we have designed to our human landscape, our experience of shapes and the environment, by creating spaces for a new creativity, towards an aesthetic approach in which perception interferences offer a more complex and conscious vision.

The works by Verner Panton will also be mentioned as the author who has based the expression of his environments on the interaction between color and light.

1. Introduction

As part of my teaching experimental research, I continued to analyze in ever greater depth the possibilities that this topic can open up, topic which is clearly connected with my paper "Development of Intuition Skills about Light/Color", presented at the IUAV Conference on "Color and Light in Architecture", held in Venice last November.

These exercises, using essential structures, refer to the variability of color, light, and space, enhanced through different points of view. In these structures, the color component defines constantly changing space placements, while providing unexpected color matches with "surprise effects" as far as color perception is concerned. Color, in turn, integrates with either natural or artificial light and with space, which becomes a three-dimensional support.

The various constructions for teaching referred to here have been designed and produced with the collaboration of students, aged 15, 1st class of the Art High School Klee-Barabino, in Genoa, Italy.

The works by Verner Panton will also be mentioned as the author who has based the expression of his environments on the interaction between color and light.

2. Method

Method: design, intuition, creativity between color, space, and light.

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The method describes all the approach steps to the work with students in all its main design phases: namely, design, intuition, and creativity.

1st Phase

Initial construction of simple volumes followed by their composition along lines of different colors, depending on their position in space (Figure 1). Color selection is obviously intuitive, while creative discovery linked to space plays a major role in a still unexplored design experience.

2nd Phase

Color: changes of color depending on the point of view suggesting different depths or prospectives.

Color – light:

Through different points of view, different collocations in space can be suggested also with unexpected effects (Figure 2). The tone or timbre effect can be highlighted depending on the quality of light; natural or artificial light in different composition dynamics that makes color perception more complex (Figure 3).

In the context of designed plastic compositions, color itself becomes a value of luminosity; an extension of the concept of perception disconnected from preset rules.

3. Educational objectives and conclusions

Non static, undefined contents aimed at developing customized creativity and expert perceptions of the light-space-color complex (Figure 4).

For younger generations, this also means to investigate and communicate new avenues of research, which, if properly developed from an educational point of view, are likely to improve knowledge and enhance sensitivities, as well as help them better understand the environment and the motivations underlying contemporary research, also with a specific reference to future projects and a new design.

This method, when widely applied, extends from the object we have designed to our human landscape, our experience of shapes and the environment, by creating spaces for a new creativity, towards an aesthetic approach in which perception interferences offer a more complex and conscious vision.

Just like in a paper "Color and Design: between Communication and Production", I recently published, I would like to mention the works by Verner Panton as the author who has based the expression of his environments on the interaction between color and light.

4. Discussion

Focus on Verner Panton

Once again, when I speak about my experimental teaching work, I have the opportunity to refer to the work of Verner Panton for two reasons:

1. The work and research modernity of this great designer are not yet fully recognized; therefore my intention is to bring him to the attention of the large audience of scholars attending this conference;
2. Verner Panton's work and its wide and rich research have been an important reference point

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for my work presented here, in particular on the importance of rhythm, namely the modular relation of color in designed shapes. Observing the walls of his rooms that change from orange to black, and to red also by means of light sources.

It is thus possible to match different units that can also become large-sized luminous sculptures. The module keeps its serial arrangement especially through the mutation of color and light.

A message against white and gray: the cold anonymity, which is the main feature of the majority of our environments.

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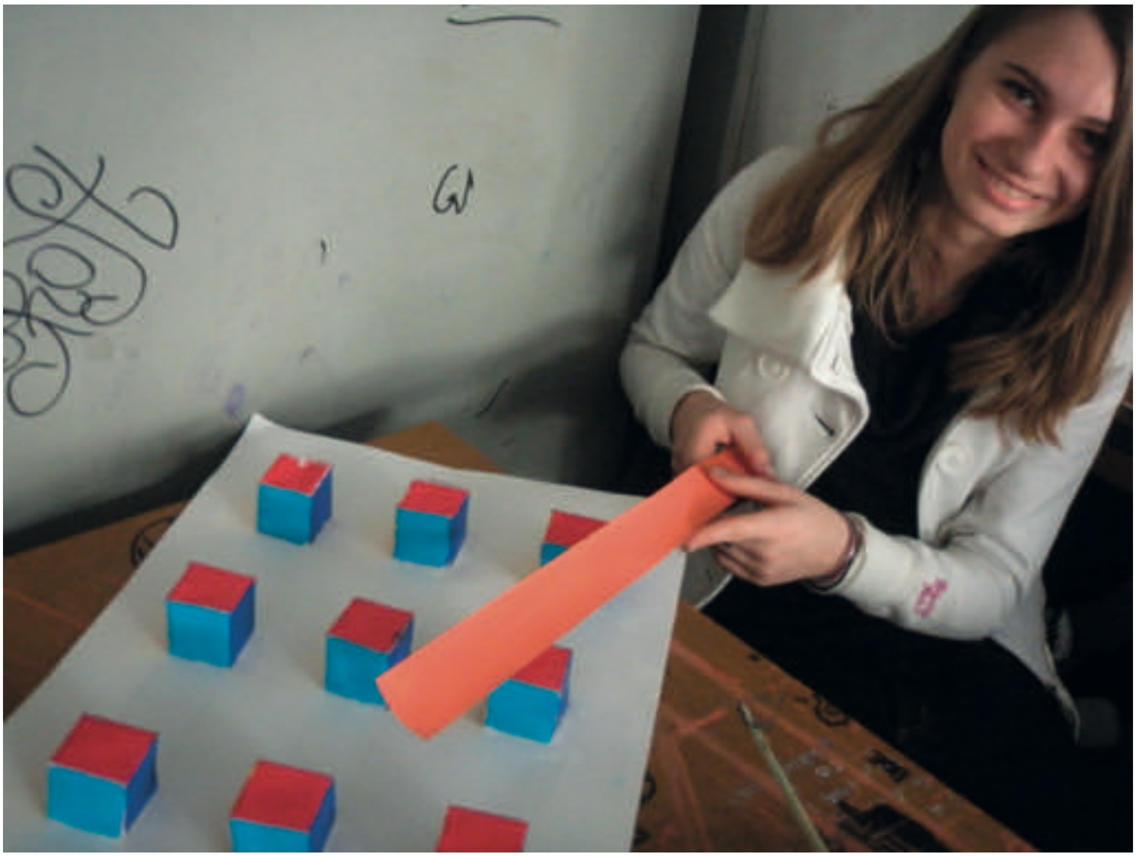

Figure 1.

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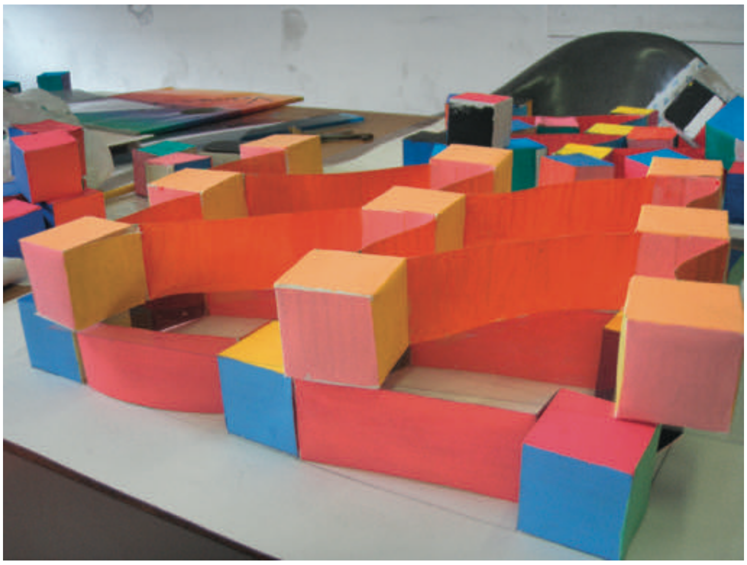

Figure 2

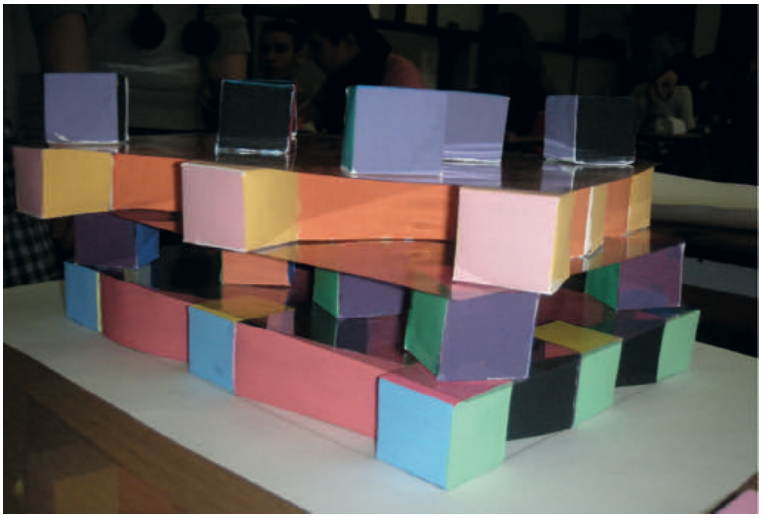

Figure 3

Figure 4

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“The Sculptural Lighting”: Applications in monumental contexts of an artistic technique based on colour-light-texture interaction

Giuseppe ROSINI
Giuseppe Rosini Scultore in Firenze Art Studio

1. “The Sculptural Lighting”

As a sculptor, my interest has been attracted by the consequences on appearance of illumination filtered by textured, coloured, translucent materials of variable thickness and chromatic strength.

Therefore I have been examining the versatility of the visual responses arising from the combination of light, colour and transparency on surfaces patterned by inlaying and carving (Fig. 1 and Fig. 2).

Figure 1. Detail of a sculpture-lamp with marquetry inspired by the caparisons of the Contrada della Tartuca.

Figure 2. Detail of a carved sculpture-lamp.

The possible uses of the multipurpose sculptures we created are:

a) in matter of lighting, with self standing independent sources, or in conjunction with existing traditional installations, by artistically filtering and modulating the output of old and new sources, e.g. LEDs;
b) decorations;
c) as displays (information, symbols).

The areas of interest and operation may be:

1. historical centres (buildings, cathedrals, indoors as well as outdoors);
2. design and furnishing private apartments and residences in modern palaces of various kind;
3. restaurants, clubs, etc.;
4. festivities, celebrations, events, private initiatives, etc.

2. Applications in monumental contexts

In historical centres the first task is to respect the constraints and restrictions of the Monuments and Fine Arts Departments. Anyhow, the main decision to take is if: to simulate and conform to the traditional atmosphere, to create new breaking solutions, or to come to a compromise? It implies that, especially in the case of creations to be permanently installed, it’s essential to make a global assessment of the environment’s appearance based on a number of elements: architectural style, building materials, prevailing colours during the alternating phases of daylight, as well as an historical investigation on the original characteristics of the environment self.

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Some examples of our applications are listed here below:

A. In various Florentine churches the traditional wax candles had been replaced by oil lamps fitted in cylindrical plastic moplen tubes. In order to improve the global environment, we installed translucent textured coloured cylindrical paraffin filters in place of the plastic tubes.

A.1. We installed 22 translucent textured coloured cylindrical paraffin filters around the choir under the Brunelleschi's Dome (Fig. 3 and Fig. 4), in the Florence's Cathedral, Santa Maria del Fiore. In order to respect the spirit of the place, we created an aged effect on filters' surface.

A.2. We installed 21 translucent textured coloured cylindrical paraffin filters around the 14th century tabernacle of Andrea di Cione called Orcagna, in Orsanmichele church. Since we were requested to use a strong white colour (symbol of purity), we added a carved texture to create a shade from shading effect in conjunction with the patterned reflections of light in the glasses and ceramics coating the tabernacolo;

A.3 We installed translucent coloured cylindrical paraffin filters on the altar of the Baptistery of San Giovanni and on the major altar of the Cathedral. In order to enrich the altars self, the filters were carved and inlayed in harmony with design and colours of the polychromed marble pavements.

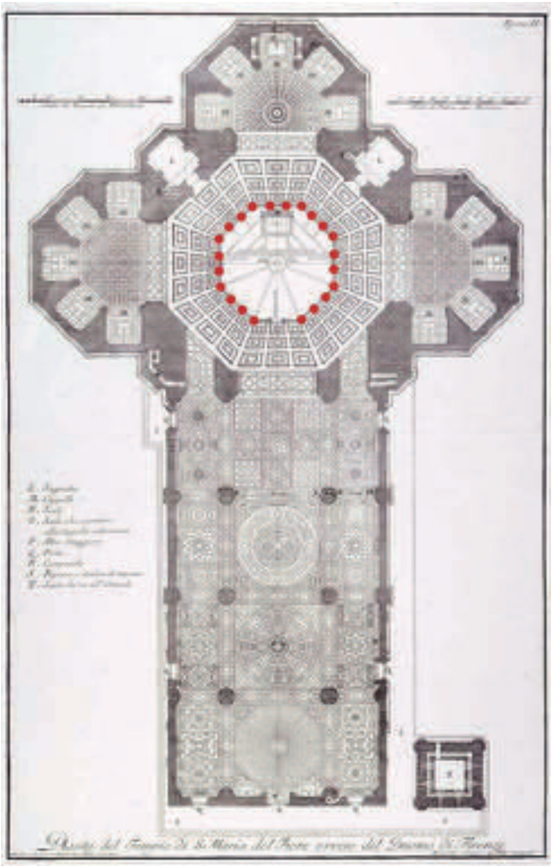

Figure 3. The collocation of the 22 sculptured filters, red marked on the Sgrilli's 18th century illustration of Santa Maria del Fiore's plant.

Figure 4. One of the 22 sculptured filters installed under the Brunelleschi's Dome in Santa Maria del Fiore Cathedral.

B. We created temporary artistic installations in various monumental contexts by using translucent coloured textured sculpture-lamps with carved and inlayed fleur-de-lis, the symbol of Florence.

B.1 Indoor: our electrically supplied light sources are placed in appropriate locations to create esthetical effects and to emphasize points of interest. Some examples of realized installations are the "Major's Christmas Wishes to the City" and the "Artisan day" in the Palazzo Vecchio (Fig. 5).

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B.2. Outdoor: our burning oil sources are placed in locations in order to create artistic effects and to obtain various purposes such as welcoming visitors, putting into evidence the architectural and sculptural details etc. Some installations are: on the Sagrade of Santa Maria del Fiore during the Christmas celebrations, at the Gala for the restauration of the Cortile dell'Ammannati in Palazzo Pitti (Fig. 6 and Fig. 7), at the opening of the art exhibition "Women in power Maria and Caterina de Medici" in Palazzo Strozzi (Fig. 8), at Orsanmichele church in occasion of "Sant'Anna's celebrations", in an event in honour of the designer Carrie Mundane at Villa Gamberaia.

Figure 5. Artistic installation with sculpture-lamps in the Salone dei Cinquecento, Palazzo Vecchio, Florence

Figure 6. Artistic installation with sculpture-lamps seen from the entrance of the Cortile dell'Ammannati, Palazzo Pitti, Florence.

Figure 7. Detail of the artistic installation with sculpture-lamps in the Cortile dell'Ammannati, Palazzo Pitti, Florence.

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Figure 8. Sculpture-lamps at the entrance of Palazzo Strozzi's court, Florence.

3. Technical data

d) materials: high melting point paraffins and polymers;
e) tools: carving and inlaying tools;
f) light intensity; chosen in relation to the factor of diffuse transmission (re: transparency), depending on both the density of the material and on the thickness of the envelope of the source;as displays (information, symbols).

Acknowledgments

The autor is greatful to Capitolo Metropolitano Fiorentino, Comune di Firenze, Museo di Orsanmichele and Opera di Santa Maria del Fiore for their advice.

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Impression differences in colour vision characteristics

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Abstract

Current colour vision simulators are originally made to simulate the colour discrimination characteristics of colour vision deficiencies. However, the users of these tools often feel insecure of the changes of the impression in their design caused by colour alteration on the simulator. The purpose of this study is to examine the changes in trichromats' impression of colour combination when using a deuteranope colour vision simulator, and evaluate whether those changes are predictable. In addition, we investigated the impression of colour of individuals with colour vision deficiencies. Thirty trichromats were asked to evaluate whether a particular three-colour combination pattern represents a particular adjective with the deuteranope vision simulator and without the colour vision simulator. Two deuteranopes carried out the same experiment as trichromats without the simulator. The results showed that trichromats' impressions tend to change significantly when the hues in the original pattern were distributed along the b* axis, and the evaluation by the deuteranopes was close to that of the trichromats under the original condition in many of the patterns. The difference in three conditions can be predicted by using the amount of colour attributes and variations, suggesting that some colour combination types which should be taken into consideration when trichromats design using a colour vision simulator.

1. Introduction

Colour designs that consider the diversity of colour vision characteristics are recommended and reflect the tendency to use more and more colours in today's society. The opportunities to design with assistance tools, such as "colour vision simulators" that simulate how people with colour vision deficiencies would see colours are becoming more accessible.

These simulators were originally made to check the visibility of colour combinations for colour vision deficiencies (e.g., Brettel et al., 1997). However, the users of these tools, trichromatic designers in many cases, often feel insecure of the changes of the impression in their colour design caused by the simulators. The term "impression" here is the feeling or image to colours or colour combinations. Few people are informed about how to design with consideration of colour deficiencies, and the impression of colour they have. There is no guideline to follow when a trichromatic designer use these colour vision simulators.

The purpose of this study is to examine the changes in trichromats' impression of colour when using a colour vision simulator, and evaluate whether those changes are predictable. In addition, we investigated the impression of colour felt by people who have colour vision deficiencies to establish a guideline to follow when trichromatic designers use a colour vision simulator.

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2. Methods

2.1 Stimuli

Three-color combination patterns from "Colour Image Scale" (Kobayashi, 1981) were used as stimuli. The pattern consists of 3 different colours, and each pattern has one or a few particular adjectives. These adjectives are defined as meaning or image of colour or colour combination. For example, a pattern with pale green, white and bright purplish blue shown in Fig.1 has an associated adjective: "refreshing". The set of pattern and adjective like this was made as follows. A conceptual space and three axes constituting the space, were extracted from various things, like colours, colour combinations, words like adjectives, design and others by analysis including SD (semantic differential) method. The three axes in each conceptual space have very similar attributes, so multiple spaces can correlate with each other. The "Colour Image Scale" used here is a set of colour conceptual space and adjective conceptual space, so the pattern in Fig.1 and adjective "refreshing" have relatively close meaning.

In our experiment, we used 30 stimulus patterns selected in a balanced manner from the "Colour Image Scale" space. The stimuli were presented on a colour monitor using the RGB scores produced by Kobayashi (2001), and one of its adjective was presented below the pattern. They were presented on a white background (x = 0.3180, y = 0.3400, 173.00 cd/m^2).

refreshing

	original			simulation		
	x	y	Y	x	y	Y
G/P	0.3020	0.4050	133.00	0.3540	0.3750	128.00
N9.5	0.3180	0.3400	173.00	0.3180	0.3400	173.00
PB/B	0.2360	0.3180	83.30	0.2730	0.2990	81.40

Figure 1. An example of a stimulus (G/P: Pale Green, N9.5: White, PB/B: Bright Purplish Blue)

2.2 Apparatus

Stimuli were displayed on 19-in EIZO FlexScan L797-U colour monitor (EIZO Nanao Corporation, Japan), and with the monitor gamma corrected. This monitor can simulate the view of colour deficient individuals in real time with the supplied software. We used 2 types of the modes: "original mode" and "deuteranope simulation mode". The Illuminance in room was 1100 lx under fluorescent lights and 1250 lx near the monitor.

2.3 Observers

Thirty trichromats (1 male and 29 females) and 2 deuteranopes (all males) participated. All observers were assessed by standard colour vision tests, which included the Standard Pseudoisochromatic Plates (SPP test) and the Farnsworth-Munsell 100-Hue Test. All observers had normal (corrected) visual acuity.

2.4 Procedures

Trichromats were asked to evaluate with a scale of 1 to 4 how much each three-colour combination pattern represents a particular adjective. They viewed the stimulus under two different conditions: "original (without using the colour vision simulator)" and "simulation (with the deuteranope simulation mode on the colour vision simulator)". The average evaluation scores were calculated and checked for homoscedasticity between the original and simulation conditions in trichromats. We run paired t-tests and Wilcoxon signed-rank tests to find whether there is a significant difference

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between the scores. For deuteranopes, we carried out the same experiment as trichromats' original condition twice. The averaged scores were compared with those of the trichromats.

3. Results

The averaged evaluation scores in each condition are shown in Fig.2. This shows that as the evaluation score is higher, the degree of match between the three-colour combination pattern and the adjective becomes higher. Thirty stimulus patterns are assigned on the horizontal axis. The results show that when the summation of colour differences ΔE*a*b* of three colours between the original and the simulation is larger, there are more significant differences between the two conditions in trichromat.

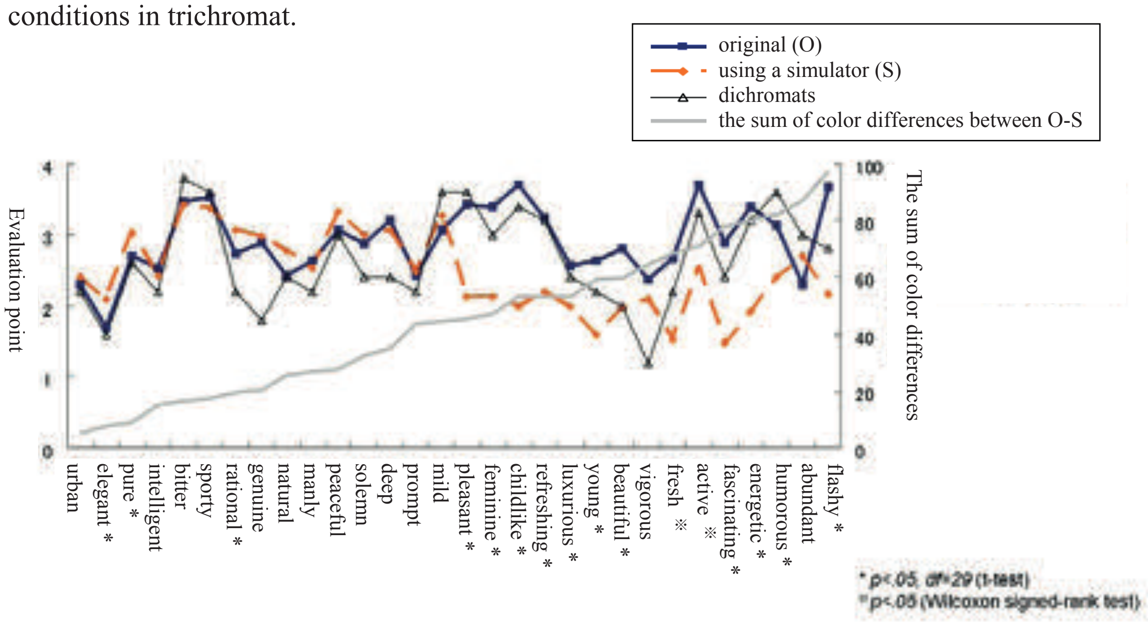

Figure 2. Results of evaluation scores (The results of thirty trichromats and two dichromats. Statical tests are used for the results of trichromats. We actually used Japanese adjectives in the experiment.)

However, there are some exceptional cases in the results depending of the value of summations. The distribution of rough colour image, that is a group of adjectives, on "Colour Image Scale" space cannot explain the results, either. So we classified the results according to the distribution of the hue of the pattern. We grouped 4 types based on the distribution of colour values a* and b* in each pattern on the a*b* plane as follows.

- *(A) Distribution in the direction of the a* axis:* being distributed in the 1st and the 2nd quadrants or the distribution in the 3rd and the 4th quadrants on the a*b* plane
- *(B) Distribution in the direction of the b* axis:* being distributed in the 1st and the 4th quadrants or the distribution in the 2nd and the 3rd quadrants
- *(C) Diagonal distribution:* being distributed in the 1st and the 3rd quadrants or the distribution in the 2nd and the 4th quadrants
- *(D) Distribution in a single quadrant:* being distributed only in one quadrant

As a result of classification, significant differences were observed between conditions in 2 out of 4 patterns in (A), 13 out of 16 patterns in (B), 0 out of 4 patterns in (C) and 1 out of 6 patterns in (D). Every pattern with significant difference, even if the total value of colour difference is small,

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can be included in (B). This results show that trichromats' impressions tend to change when the three hues are distributed along the b* axis.

The evaluation by the deuteranopes was close to that of the trichromats under the original condition in many of the patterns. The patterns where the evaluation scores varied only among the deuteranopes had low average luminance.

4. Discussion

The results showed that trichromats' impressions tend to change significantly when the summation of colour differences between original and simulation is larger, and when three hues in the original pattern were distributed along the b* axis. These patterns are the colour combination types which should be taken into consideration when trichromats design using a colour vision simulator. It was also shown that they can be predicted by using the amount of colour attributes and variations, but not a particular image word.

In many of the patterns, evaluation scores by the deuteranopes were close to those of the trichromats under the original condition. This result suggests that dichromats have possibilities to correct their lack of "warm-cool" information along the red-green (a*) axis. We should go on to an even more detailed experiment on this point.

The results suggest that current colour vision simulator cannot simulate the impression of colour or colour combination completely, but the original expression is not sufficient either. Therefore, it must be very useful to create a method of expression in such ways that simulation with annotation or providing both the view simulation mode and the impression simulation mode.

5. Conclusions

The results of this study showed that there are some colour combination types which should be taken into consideration when trichromats do colour design using a colour vision simulator. They can be predicted by using the data of colour attributes and variations, which leads to create a guideline or a method of expression using colour combination for trichromatic designers.

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Classification of fragrances by their similar psychological images with colors (1) - psychological and physiological study of harmonious color-fragrance combinations

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Abstract

In order to attempt a classification of fragrances based on their harmonious colors, the present study aimed 1) to extract matching / non matching pairs from various color-fragrance combinations, 2) to obtain their psychological and physiological effects, and 3) to derive the common and principal factors which present similar psychological impressions and feelings (mood) of colors and fragrances which might be useful for classifying fragrances. Subjects (100 female students) were asked to select matched and mismatched combinations of colors along with 16 pairs of adjective for the semantic differential method, as well as 20 mood adjectives to describe their present mood relating to each pair (matched and mismatched) to examine changes of impressions and mood. The common factors indicated by factor analysis which determined the impressions of color and fragrance were *clear* and *mild* and it was suggested that fragrances might be classified with their harmonious colors by the axes of *clear* and *mild*. In addition, the well matched color-fragrance combinations indicated responses moving in a common direction in terms of both impression and mood. In the assessment of the physiological effects, CNV measurements confirmed that matched combinations tended to sedate the emotions, while mismatched ones stimulated the emotions. Further, the indexes of the autonomic nervous system and internal secretions of Chromogranin A suggested that the mismatched combinations produced mental stress.

1. Introduction

We have five classic senses, namely vision, hearing, touch, smell and taste. Except for studies of synesthesia, these senses have been researched individually in each perceptual field of study. However, crossmodal perception or multisensory perception (or integration) has recently become a subject of current interest, especially to psychological and neuroscientific researchers. For example, Skrandies & Reuther (2008) showed that color and food words affected the human brain differently and induced electrical activity when paired with matching or non matching combination of odor or taste words.

The present study suggests one of the approaches of crossmodal studies by using the concept of color as a node for the perceptions of the senses. The first attempt is to classify smells (excluding bad smells) by similar psychological images with those of colors. Fragrances, for example, are the stimuli of smell in our daily lives. Many studies have been trying to classify the numerous smells and to establish their dimensions with which to work. While systems of color classification have already been developed, no generally accepted smell classification system has yet emerged. Kemp & Gilbert (1997) reported the correlation between smell intensity and the color values in the Munsell color system. However, no study has been attempted to either classify fragrances by their harmonious colors or to visualize the classification of fragrances by means of color, consisting of physically stable structures of three dimensions, namely, hue, lightness and saturation.

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2. Objectives

The results from the author's pilot studies show that colors and fragrances with similar psychological images are compatible with each other and are well harmonized. The purpose of this study is 1) to extract matching / non matching pairs from various color-fragrance combinations, 2) to obtain their psychological and physiological effects, and 3) to derive common and dominant factors which present similar psychological impressions and feelings (mood) of colors and fragrances that might be useful in the classification of fragrances.

3. Method

In the first step of the psychological study, 100 female student subjects were randomly assigned one of 15 fragrance stimulations (lily of the valley, moss, apple, cedarwood, musk, lavender, vanilla, spearmint, grass, clove, peach, juniper berry, pine needle, grapefruit and clary sage) and were asked to select two sets of three colors from a color chart consisting of 18 colors (15 chromatic colors and 3 achromatic colors), one that matched the fragrance and another that mismatched the fragrance, to extract matching-pair and mismatching-pairs. After the matched and mismatched pairs of color and fragrance were obtained, they were also required to rate the psychological images of those pairs using 16 adjective pairs (light-heavy, childish-adult, like-dislike, deep-shallow, ordinary-characteristic, cool-warm, manly-feminine, modern-antiquated, kinetic-static, pleasant-unpleasant, simple-complicated, stable-unstable, harsh-gentle, muddy-clear, bright-dark, wet-dry) for the SD method (semantic differential method) along with 20 adjectives for mood assessment (joyful, serious, nervous, active, calm, jittery, refreshing, gloomy, happy, tense, downhearted, relaxed, bored, feeling at ease, concentrating, cheerful, irritable, tired, carefree, vigorous) under exposure to the given fragrance-color combination within a booth. As for the physiological experiment, the assessment of physiological effects established by the measurements of CNV (contingent negative variation) brain waves, electrocardiographic monitoring (ECG measurements) and Chromogranin A (CgA) levels in saliva to estimate the mental stress were provided.

4. Results and discussion

4.1 Extraction of matching/non matching pairs

The matchings for fragrance were found to be more strongly biased for the tone of colors than for hue in an analysis of residual variance for the contingency table analysis which indicated that there appeared to be close relationships between fragrances and color values (tones). Moreover, the matched combinations of color and fragrance were confirmed to elicit responses moving in a common direction in terms of the impression and mood. The results suggested the possibility of the classification of fragrances by means of similar impressions and mood with colors. Moreover, some outstanding matching pairs (pale red + peach, pale red + vanilla, vivid blue + spearmint, dark yellow + cedarwood) and non matching pairs (vivid blue + vanilla, dark yellow + vanilla, dark yellow + spearmint) were obtained.

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4.2 Physiological analysis

Physiological assessments by the measurements of CNV (contingent negative variation) brain wave, electrocardiographic monitoring (ECG measurements) and Chromogranin A (CgA) levels in saliva were provided to obtain the physiological effects, with special attention to stress. The CNV brain wave measurements were taken by the international 10/20 system for electrode placement. Subject's emotions moved towards a sedate state when color and fragrance were matched, and a stimulated state when they were mismatched. For instance, pale red decreased the early CNV shift when combined with vanilla and peach, and increased the CNV when combined with spearmint and cedarwood. HF fluctuations are said to be mediated solely by the parasympathetic nervous system. HF components in R-R interval variability showed the mismatched color-fragrance combinations induced stress. The CgA level in saliva has been demonstrated to respond sensitively to mental stress. The results showed that elicited CgA levels in saliva were higher with the vivid blue + peach combination (mismatched pair) than with the vivid blue + spearmint combination (matched pair). Consequently, the results suggested that the mismatched pair induced more mental stress than the well matched color-fragrance combinations.

4.3 Factor analysis

Factor analysis was applied to the data of both SD evaluation and mood assessment of combined color and fragrance data. Table 1 shows the main components of the adjectives of SD evaluation for the five extracted factors (*clear, preference, mild, quiet, ordinary*) along with colors and fragrances which gained high or low factor scores, respectively. The first factor, named *clear,* is closely related to the lightness of color; i.e. light colors obtained high factor scores whereas dark colors obtained low scores. The fragrances which elicited a fresh image scored high on the *clear* factor, showing that the factor determined whether a fragrance was clear or muddy. *Mild* was an important factor as it was influenced by hue and was active in classifying warm colors and cool colors, as well as in classifying whether the fragrances have the images of feminine or masculine.

4.4 Multiple regression analysis

Using the factor scores of the extracted factors of mood assessment; i.e. *pleasant, calm, serious, anxious,* and *gloomy* as dependent variables, and those of *clear* and *mild* factors of the SD evaluation data as independent variables, a stepwise multiple regression analysis was conducted to establish the relationship between the results from SD evaluation and mood assessment. Except for *anxious,* all factors of mood assessment indicated a positive correlation with both *mild* and *clear*. The positively higher the factor scores of *clear* were, the higher became the scores of *pleasant* ($p<.01$). In other words, bright and clear impressions of color and fragrance brought about a vigorous, cheerful and happy mood. On the other hand, their dark and muddy impressions (negatively high scores in *clear*) brought about a downhearted and tired mood ($p<.0001$), namely, positively high scores in *gloomy*. In addition, heavy and wet images from *clear* with cool and manly images from *mild* produced the moods of concentration and tension (*clear* $p<.01$; *mild* $p<.0001$). Moreover, when color and fragrance had feminine and warm impressions (a *mild* factor), relaxed and calm feelings were raised ($p<.05$). As a result, the main factors which determined the impression of color and fragrance were suggested to be *clear* and *mild*. The stronger the bright and clear impressions from *clear*, and the warm and feminine images from *mild* were, the more the positive feelings increased. It is also suggested that the effect of mood might be predicted or determined according to those two factors.

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5. Conclusion

The common factors which determined the impressions of color and fragrance were *clear* and *mild*. The results that *clear* corresponds to the lightness of colors with fresh fragrances, and *mild* corresponds to the hue with sweet fragrances, suggested fragrances might be classified with their harmonious colors by the axes of *mild* and *clear*. In addition, the well matched color-fragrance combinations performed responses moving in a common direction in terms of the impression and mood. The results from physiological assessment suggested that the matching color-fragrance combinations tended to impart an emotionally stable state, and the matched combination cumulatively strengthened the psychological effect of the impression. On the other hand, the complexity of the impressions of the mismatched combinations elicited mental stress and anxiety, as well as physiological change.

Table 1. Result of factor analysis

name of factors	main components	score of stimuli>0.5	score of stimuli<-0.5
clear	deep-shallow light-heavy bright-dark muddy-clear wet-dry childish-adult	pR/pG/pB/pP/vY/W/ moss/spearmint	dkR/dkY/dkG/dkB/dkP/ Bk
preference	like-dislike pleasant-unpleasant stable-unstable harsh-gentle	vB/W	dkY/Gy apple/cedar wood/ juniper berry
mild	cool-warm manly-feminine modern-antiquated	dkB/W/Gy/Bk/ apple/lavender/spearmint	pR/pY/pB/pP/vR/dkR/dkY/ grass/pine needle
quiet	kinetic-static	vR/vY/vG/vB/ moss/musk/spearmint/ pine needle	pY/pG/pB/pP/dkY/dkG/ dkB/dkP/W/Gy
ordinary	ordinary-characteristic simple-complicated	pY/vB/W/Gy/Bk	vP/dkP/lily of the valley/apple/ cedar wood/ lavender/ grove

Acknowledgments

The author expresses appreciation to co-workers from Kanebo Cosmetics Co. for their cooperation in determining physiological assessments.

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Software to examine and improve legibility of colored documents for protans and deutans

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Abstract

This paper describes our developed software to improve legibility of colored texts in the electronic documents for the people with color vision deficiencies, particularly protanopic and deuteranopic vision (red-green color blindness). The aim of the software is to help color deficient people distinguish and separate out colored texts from their background and to use accessible colors in the documents. The proposed software examines the electronic image of a colored document whether the font colors in the document is accessible to the color deficient people by the use of dichromatic simulation and legibility evaluation. If the examined document turns out to be inaccessible, inadequate colors are replaced automatically with accessible ones by means of proposed color replacement methods: color optimization method, color mapping method or image processing method. Each of them has both advantages and disadvantages on the effect of legibility improvement, the number of available colors, the execution speed, and so on. Thus they should be chosen in accordance with the type and the purpose of colored document.

1. Introduction

The people with congenital color vision deficiency feel something inconvenient to distinguish colors, because certain colors appear similar or the same to them. These inconvenient effects are called color confusion and every accessible document for the color deficient people must be taken such effects into account. If you have normal color vision and you have a chance to create accessible documents, it is difficult for you to consider the effects of color confusion in your documents, because you cannot judge which colors are confusable or not for the people with the color vision deficiency.

One of possible means for solving above mentioned problem is to use software that can judge colors confusable or not on behalf of color deficient people. Such kinds of software and algorithm have been developed and reported by Ichikawa et al. (2004), Nakauchi and Onouchi (2008), Meguro et al. (2009), etc. They can replace confusable colors with distinguishable ones automatically. Each of them works on the basis of different computational principles but realizes the optimization of color combinations.

The color confusion is brought about by interaction of two or more colors. The optimization of color combinations eliminates such color confusion and also maximizes color differences. However, the optimization of color combinations generally faces two problems as follows: The first problem is on color categories. If the optimization algorithm only maximizes color differences, it may change original color categories to the others and replaced colors may look different. As for the second problem, it is desirable to reduce execution times of optimization algorithm.

This paper proposes three methods as solutions to the above-mentioned problems: color optimization method, color mapping method and image processing method. Color optimization method we proposed in this paper can take account of original color categories by making use of

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a categorical color database. The latter two methods can omit the process of optimization and also take color categories into consideration. Using these three methods, this paper describes software to improve legibility of colored documents for the people with protanopic and deuteranopic vision (red-green color blindness).

2. Objective

Our research objective is to develop and examine software that makes use of proposed three methods. The aim of the software is to help color deficient people distinguish and separate out text colors from background colors and to use nonconfusable colors in colored documents.

Such kind of software is mostly used by the non-professional people who don't have technical know-how to create color barrier-free documents for the color deficient people. Even though it is difficult for the non-professional people to consider color vision deficiency carefully and to select nonconfusable colors in the documents, the software can help them select appropriate colors easily.

3. Methods

The proposed software examines the images of colored documents whether the font colors in the documents are accessible to the color deficient people by the use of dichromatic simulation and legibility evaluation.

The dichromatic (protanopic and deuteranopic) simulation is done on the basis of colormaps by Vienot et al. (1999). The legibility evaluation of colored documents is performed according to W3C accessibility guidelines (WCAG 2.0). The W3C guidelines are mainly designed for webpage construction, but their principles and frameworks for legibility evaluation are applicable to general electronic documents.

If the examined document turns out to be inaccessible, inadequate colors are replaced automatically with adequate colors according to any of three methods as follows:

[1] "Color optimization method" proposed in this paper can maximize color differences between text colors and background colors from the viewpoint of protanopic and deuteranopic simulation. It also can choose replacement colors from the same color categories of original colors, by making use of a categorical color database. The database is consists of categorical color data obtained from color-naming observations by normal trichromatic subjects (e.g. Sakamoto (2005)).

[2] "Color mapping method" chooses replacement colors according to the color set assembled by Ito et al. (2009). The color set consists of twenty two colors that can be identified by the color deficient people (protans and deutans). These colors have been determined through color-naming observations by several dichromats. The color mapping method has limitation of the number of colors that must be less than twenty two colors. But, beyond that, it can run faster and more reliable than the color optimization methods previously mentioned, because the color mapping method doesn't need so much CPU power and avoids the complexity of solving optimization problem of color combinations.

[3] "Image processing method" has no limitation on the number of colors and can process any full-colored image of the document. This method enhances the edge of colored fonts in the document by means of unsharp masking. Unsharp masking is one of technique to sharpen images.

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Proposed method uses the modified unsharp masking for the protans and deutans. It can visualize the edge between fonts and background, even if they are composed of confusable colors. But it is difficult for this method to make clear separation between colored texts and their background.

As mentioned above, each of these three methods has both advantages and disadvantages on the effect of legibility improvement, the number of available colors, the execution speed, and so on. Thus they should be chosen in accordance with types and purposes of colored documents.

4. Results

Computer implementation of proposed three methods was done by Microsoft C# and GNU C++. These methods were examined by several color replacement tests. One of examples of color replacement tests and comparison of their results is shown in Table 1.

As seen in Table 1, color optimization method made font's color lighter, but it didn't change color categories of the original image. Color mapping method turned the bluish-red (nearly pink) color into the yellowish-red (nearly orange) color and slightly made the background gray bluish. The said yellowish-red and the bluish-gray colors are constituents of the color set that is composed of twenty two colors. Image processing method didn't change original color without the edge between a font and background. All these three methods enabled people with protanopia to distinguish confusable colors as seen in Table 1 (see images of the protanopic simulations).

Table 1. Comparison of color replacement results obtained by proposed three methods.

	Original image	**Color optimization method**	**Color mapping method**	**Image processing method**
Trichromatic appearances				
Protanopic simulations according to Vienot et al. (1999)				

5. Conclusion

Software to improve legibility of colored documents were developed and examined. Proposed three methods had adequate effect to visualize fonts and to distinguish them from their background.

In order to evaluate the quantitative effect of legibility improvement by the proposed three methods, visual psychological experiments applied to protanopic and deuteranopic observers must be done. It is also our future work to do detailed comparative studies of color

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replacement methods from the viewpoint of visual effects, error rates, computational costs, versatility, and so on.

It is the authors' hope that barrier-free documents will become more common and many same kinds of software will come into wide use in the near future.

Acknowledgments

This work was partly supported by grants from JST, A-STEP (AS2121336F); City of Yokohama, Yokohama Version of SBIR (2009); and JSPS, KAKENHI (19500490).

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Conceptual metaphor and the interaction between color and light: LIGHT IS COLOR, SEEING IS RECEIVING LIGHT, SEEING IS COLOR

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Abstract

How do humans conceptualize color experience in language? What is the interaction between color and light in the crossmodal processing of visual perception and linguistic expression? My objective is to describe a complex conceptual metaphor that is at the basis of human primary conceptualization of color, and to give examples of how humans develop a network of metaphors in color perception and language use. Identifying a color through language is a perceptive act that tells us what 'ground' is associated with the 'figure' of color. The process of identification is codified through conceptualization that allows us to identify what color code the entity (either abstract or concrete) should have. The conceptual interpretation of our embodied experience of LIGHT as COLOR includes the implicit processing of color dimensions. The conceptual metaphor LIGHT IS COLOR represents the transfer of information: photons, particles and wavelengths, between the environment, the human visual system and linguistic identification. An individual can see a color light and give it a color name. To explain this perception and integration process there are a series of concepts that form what is known as a complex metaphor.

1. Objective: conceptual metaphor mapping

The objective of this paper is to employ the conceptual metaphor model to identify the abstract crossmodal mapping humans use to cognize color terms in language. The theories of conceptual metaphor and embodiment in the cognitive linguistics approach are relevant tools to operate a semantic analysis of chromatic terms and dimensions in natural language. The mapping that is generated reveals how the the signification of color is accessible through the distinguishing of light. By concentrating on the domain of LIGHT and the interaction with the domain of COLOR our conceptualization of color terms in language emerges.

The lexical frame of COLOR still lacks complete and in depth conceptual mapping. This is due to the complexity of interaction between color-light and color-substance and its polysemic nature. Humans project embodied experience of color onto different conceptual domains depending on the association with the color and the specific surround. How do humans conceptualize color experience or the interaction of LIGHT and COLOR?

Conceptual metaphor phrasing is indicated as: TARGET DOMAIN 'A' IS SOURCE DOMAIN 'B', projecting from the more concrete SOURCE onto the more abstract TARGET. This paper follows the convention of using SMALL CAPS for conceptual metaphors (Gibbs 2007, Kövecses 2010, Lakoff 1990, Lakoff and Johnson 1999), and italics for the metaphorical linguistic expressions. For example, She is really up today, is a metaphorical linguistic expression that realizes the conceptual metaphor HAPPINESS IS UP. The more concrete or embodied physical experience of directionality **UP** is the SOURCE DOMAIN used to describe the more abstract emotion **HAPPINESS**, the TARGET DOMAIN, or that which is modeled through the conceptual operation called metaphor.

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1.1 Past color mapping proposals

I presented an initial part of my conceptual color mapping at AIC 2009, in Sydney-Australia, where I discussed how COLOR is a source domain in the entailment of the *primary* conceptual metaphor target domain of SEEING: KNOWING IS SEEING, which motivates SEEING IS COLOR (Sandford 2009). The second part of my conceptual color mapping places color as part of a complex metaphoric system: GOOD IS THE RIGHT COLOR, GOOD IS COLOR, BAD IS THE WRONG COLOR, BAD IS (COLORLESS) LACK OF COLOR. Color is also activated as a sub-systemic metaphor of the THE EVENT STRUCTURE METAPHOR system- ATTRIBUTES (COLORS) ARE ENTITIES/POSSESSIONS, STATES (COLORS) ARE LOCATIONS (Sandford, in press).

2. LIGHT/COLOR mapping proposal

Color is a result of our perception of the spectrum of light as it is transmitted or reflected. To explain the conceptualization of this process in language there are a series of conceptual metaphors that form a 'primary complex metaphor'. The conceptual metaphors under analysis that identify our ability to give meaning to light are: PERCEPTION IS RECEPTION or SEEING IS RECEIVING LIGHT, LIGHT IS COLOR, SEEING IS COLOR [LIGHT]. It is necessary to specify that LIGHT is understood as in the form of PACKAGES OF INFORMATION such as PHOTONS, PARTICLES, WAVELENGTHS. Examples of metaphorical linguistic expressions follow each conceptual metaphor presented here to illustrate how the network of metaphors in language use and color perception is realized[1].

2.1 PERCEPTION IS RECEPTION or SEEING IS RECEIVING LIGHT

In the master metaphor list perception is indicated as a mental event. THE MIND IS A BODY (Lakoff 1999: 248) is the underlying concept that allows us to map from the body experience to the mind. The CONDUIT METAPHOR (Lakoff 1990: 104, Kövecses 2010: 84) is a generic set of interrelated metaphors that characterize the mind and human communication. It also specifies THE MIND IS A CONTAINER. It allows us to represent how we receive messages that are 'transmitted' to our minds by our senses through our bodies. When we 'receive' the message 'perception' takes place, **PERCEPTION IS RECEPTION** (Lakoff 1999: 339). This further entails that IDEAS ARE OBJECTS and that COMMUNICATION IS SENDING IDEAS FROM ONE MIND-CONTAINER TO ANOTHER: (1) *Sally **gave** the **idea** to Sam*. IDEAS ARE PERCEPTIONS[2] entails IDEAS ARE LIGHTS [COLORS] where the type of PERCEPTION is visual LIGHT: (2) a. *present it in a favorable **light**; b. in this **light,** mitigation.* Other examples of LIGHT as a source domain are: IDEAS ARE LIGHT SOURCES: (3) a. *What a **bright** idea!* b. *That idea really **illuminates** the problem*; and INTELLIGENCE IS A LIGHT SOURCE: (4) a. *He is very **bright**;* b. *I thought he was a little **dim***.

SEEING then is the perception that happens when we receive light signals, hence **SEEING IS RECEIVING LIGHT**. LIGHT reaches us in the form of PACKAGES OF INFORMATION, which are interpreted in our minds. The embodiment of this process entails the metaphor UNDERSTANDING IS RECEIVING [THE MESSAGE] or UNDERSTANDING IS SEEING (Lakoff 1999: 541), SEEING has moved from the target domain to the source domain: (5) a. *I **get** what you mean.* b. *He **sees** only what he wants to **see**;* c. *He's not **seeing** things **clearly**.* There are two important specific conceptual entailments with the shift between target and source domains. First, LIGHT entails SEEING: AIDS TO GAINING AWARENESS ARE

1 All of these examples are used in natural language and have been selected from the *Corpus of Contemporary American English,* from Google (by inserting the chain of lexemes), and from the Master Metaphor list, see references.

2 http://web.archive.org/web/20050426053443/cogsci.berkeley.edu/lakoff/metaphors/Ideas_Are_Perceptions.html IDEAS ARE PERCEPTIONS, last accessed 11/02/2011.

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AIDS TO VISION or LIGHTNESS IS MAKING VISIBLE, and UNDERSTANDING IS SEEING WHAT IS IN THE LIGHT: (6) a. *He spot**light**ed the issues that were important;* b. *Can you shed more **light** on this issue?*. And second, the opposite, DARKNESS entails NOT SEEING: IMPEDIMENTS TO AWARENESS ARE IMPEDIMENTS TO SEEING or DARKNESS IS A COVER: (7) a. *Under the **cover** of **darkness**;* b. ***Darkness closed** in over us*. These further combine with LIGHT in the target domain metaphors, LIGHT/DARK IS A LOCATION: (8) a. ***in** this **light**;* b. ***in** the **light** of new developments;* c. *They were totally **in the dark** about everything*; and when physical detail is ascribed with LIGHT IS A FLUID: (9) a. *Sun**light poured** into the room;* b. *He **soaked up** some **sun**;* and DARKNESS IS A SOLID (SUBSTANCE): (10) a. *The **darkness** was **palpable**;* b. *We had to feel our way **through** the **darkness**.*

2.2 LIGHT IS COLOR and SEEING IS COLOR [LIGHT]

Therefore, our embodied experience of LIGHT realizes the conceptual metaphor **LIGHT IS COLOR**, with LIGHT in the target domain and COLOR is the source domain; with the effectuation of utterances such as: (11) a. The sky ***is blue***; b. ***Red** at night sailors delight. c. Orange **light glows** in the lodge's windows*. We identify LIGHT as being COLOR; as in the experience of a summer day, when the sun approaches the horizon, we know that LIGHT is RED. By indicating the color, the act of seeing is implicit, hence **SEEING IS COLOR [LIGHT].**

Taking the interaction of LIGHT with COLOR into consideration, the entailment of abstract light and concrete substance is represented in the conceptual metaphor LIGHT IS A SUBSTANCE (Lakoff and Turner 1989: 70-71), as in the examples: (12) a. *Night **takes** the **light away**;* b. *The **light made** a brilliant moving arena in front of me;* c. *A **soft light fell** in from the window;* d. *under a blue sky and the **heavy light** of summer.* To *take away*, *make*, and *fall* are clearly verbs that indicate actions and interactions with things, or substances. *Soft* and *heavy* are adjectives that are used to identify texture or weight. Expressions such as: (13) a. ***a bit** of light;* b. ***some** light;* c. ***a** light;* d. ***lots** of light;* e. ***measure** the light,* refer to quantities, which are referable to substances or objects.

2.3 LIGHT IS HEAVY/LIGHT/SOFT/HARD and COLOR IS HEAVY/LIGHT/SOFT/HARD

Duly to be able to conceptualize LIGHT or COLOR, which are both IDEAS, individuals use concrete or more tangible domains to describe them. Ergo, if LIGHT IS COLOR and LIGHT IS A SUBSTANCE, then COLOR IS SUBSTANCE, further LIGHTS ARE ENTITIES and COLORS ARE ENTITIES; as 'attributes' refer to STATES and PROPERTIES. The conceptual metaphor ATTRIBUTES ARE ENTITIES yields knowledge structure of objects. This conceptualization allows us to pass from COLORS ARE ATTRIBUTES to COLORS ARE ENTITIES. This type of projection is evincible in the examples **LIGHT [COLOR] IS HEAVY/LIGHT** and **LIGHT [COLOR] IS SOFT/ HARD**: (14) a. *It wasn't a **heavy light**. It was **light** and **soft**;* b. ***Hard light** sources cast shadows*. These are embodied conceptualizations of LIGHT and COLOR as an object/ substance in the dimensions of value: lightness or brightness (HEAVY is to DARK, as LIGHT is to LIGHT), and saturation (HARD is to DENSE/VIVID, as LIGHT is to THIN/DIM): (15) a. *a **heavy red***; b. *a **light green***; c. *the **hard blue** of her concern*; d. *a **light dim grey***.

3. Conclusions

Color is interpreted through perceptual embodied experience and through association and the resulting connotation of this integration may be negative or positive. I argue that light and color perception involves the development of conceptual metaphors and, therefore, the establishment of a process of mapping between the interaction of the domains of color as a substance/object and as

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a light/object. This interaction happens through a series of parallel processings that then result in the use of the color term. The theory of embodiment is crucial in understanding how these cognitive mechanisms work. This research is based on linguistic and neuro-physiological considerations. Identifying color through language is a perceptive act that tells us what ground is associated to the figure of color. The process of identification is codified through conceptual metaphor, which allows us to identify what color code the entity should have. This process begins with light and our conceptual interpretation of light as being the essence of the beginning for us as human beings LIFE IS LIGHT (Kövecses 2010: 50). The linguistic expression *to see the light* means 'to understand' and 'to come into existence or being'. All 'life' as we know it is based on the process of interaction with light known as *photosynthesis*. Nearly all life either depends on light directly as a source of energy, or indirectly as the ultimate source of the energy in their food. Seeing light triggers seeing color, which allows us to interpret our surroundings.

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The *colourlessness* of the Zener diode

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Abstract
Science challenges the limits of the imagination just as well as art does, and they may set their way in curiously opposite directions, and yet somewhere we may find the realm of mathematics "between" them or "inside" both or "connecting-disconnecting" them. Mathematics arose powerfully *deus ex machina* giving world a new colour free picture. And yet my hand moves and galaxies move: all move in a colourful *space-time* whose colours help me to understand its hidden secrets.

Colourlessness
Xenophanes' *Apeiron*, one of the most impressive intellectual creations in the history of science, (Popper 2001: 33-40) was simply colourless and yet sustained our colourful world. Science challenges the limits of the imagination just as well as art does, and they may set their way in curiously opposite directions, and yet somewhere we may find the realm of mathematics "between" them or "inside" both or "connecting-disconnecting" them. The notions of c*olour* and *colourlessness* have definitely arisen at the trial of our understanding.

During the early Enlightenment a serious problem arose within our colourful world when Newton put forward the idea of *gravitation*. That is, here finally was a mathematical law that simultaneously explained why my coffee has just dropped down to the floor and why the Earth, moon and other planets move around the sun keeping their relative distances stable. This fact appeared as a product of a long walk in humanity towards universality, but it arose and endured in a quite surprising way. The infinitesimal and the infinite seem close relatives. As Nigel Calder (2003: 1) puts it: "The difference now is that you'll understand stars better if you know about atoms, and vice versa. It's the same with fossils and climate. Everything connects, not by sentimental holism, but in physical processes that gradually reassemble dem dry bones of Mother Nature."[1] And thus the huge and the very small appear intricately connected, as is everywhere starting at our bodily existence and proceeding through the unbound universe.

Newton's mathematics was able to visualize fundamental unseen forces in nature. And it seemed a miracle to *see* the *ghost* forces of the world we fashion. Mathematics arose powerfully *deus ex machina.* Abstraction has taken command, and we recognize a greater sense in Xenophanes because the *unseen* seems a greater challenge than what we see.

Curiously, it seems that all that is visual and colourfully presented to our bodily experience is legitimated by colourless laws that determine our experience and understanding. Our colourful world seems easily understood under the shape of colourless laws and to some extent it remains

1 And Lewis Wolpert (2008: 88) stresses a similar view, in that we notice that this approach has invaded our bodies at the core of their being: "We are nothing than a society of cells, every one of us is just a collection of cells. So cells really are terribly important. They are the basis of life and we need to understand how cells actually function."

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so. But all this may make profound sense because human perception seems to extend through the "technology" of mathematics into both the colourful and colourless secrets of nature. Mathematics unites. Thus, we may even think that *only* colourless laws would give sense to colour.

The new logic of science finally brought about non-territorial science supplied by non-territorial mathematics.[2] Such an advanced phenomenon increased a profound abstract rational character, and which was only systematically questioned with the arrival of Edmund Husserl's *Krisis* (1970).[3] The visibility of functions working according to variables on a Cartesian axis was impressively clear, leaving colour behind. Newton's *gravity* seemed to hide the springing colour of his prisms.

The rise of a new colourful *abstract-machine-based-architecture* seemed hard to accomplish during the Enlightenment. But some architects could combine mathematics and colour.[4] And it is important to stress that the romantic artist's struggle for colour needed an "anti-mathematical" base despite the sense of "mathematical" composition that we find later in the highly "natural" gestures of Jean-François Millet's *The Gleaners* (1857) that move into some kind of "natural order." And arriving at Renoir and Cézanne we may reflect on *a mathematical-free art* or, in opposition, on a fully mathematical colour structure that legitimates the colourful pigments replaced by, or superimposed by, numbers and proportions. And thus we also have other painters, such as Van Gogh, supported by the miracles of French chemistry technology.

In this context one could hardly imagine a close future development of painting. Malevich's various *white-and-black* compositions seemed more a case of art searching for its own essence away from *mimesis*. And thus, the mathematical bases of art have moved away from canonic shapes into "colourless" pigments. Single colour statements seemed to have arrived as art *per se*, which Lucio Fontana literally cut *into* "spatial concepts" at a time when colour had definitely invaded space. Yet, returning to Malevich, we may ask if it was not his *black* and *white* compositions that really superimposed *black and white photography*, opening a definite way to colour in painting and in art in general. Painting seemed to have won the fight against its direct challenger, *photography.* And the former came into the field of the latter and used its tools, its own "colours" that could be reduced to an absolute *mathematical* substance.

My hand moves and galaxies move: their colours move. My fingers have the strength to hold my cup of coffee preventing it from falling. But far more important, my hand, my body, my cup, the universe – all move in a colourful space-time whose colour helps me to understand its hidden secrets.

We have just entered the path that will bring our attention to the fact that the beautiful yellow gold created by the impressive and rare explosion of a supernova somewhere in a distant galaxy was found somewhere else on this colourful Earth, and it was turned into art at the hands of a goldsmith. But before proceeding to our colourful outer space, we may not forget a particular efficacy of colour in science that has been created anew. Regarding the division art-science, one can certainly assert that other kinds of scientific work were receptive to colour, such as Charles Darwin's *The Zoology of the Voyage of H. M. S. Beagle* (1838, 1841). As he moves from *Fossil Mammalia* to *Mammalia to Birds,* we see the role of shape combining with colour in order to make clear

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2 As Saloman Bochner (1981: 114) puts it: "Before 1600 there had been an Egyptian mathematics, a Babylonian mathematics, an Indian mathematics, a Chinese mathematics, etc.; a Greek physics, an Arabic physics, etc."

3 In fact, major works, such as Lord Kelvin's *The Elements of Natural Philosophy*, (2002) needed no colour.

4 e.g. Such as Ange-Jacques Gabriel at the *Salle de l'Opéra* (Versailles, 1748-70), Robert Adam at *Kedelston Hall* (Derbyshire, 1760-70) and *Syon House* (London, c. 1765), William Kent at *Holkham Hall* (Norfolk, c. 1734), or James Wyatt at *Heaton Hall* (Lancashire, 1774).

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a scientific record, and such a necessity was already found earlier, in works such as Maria Sibylla Merian's *Insects of Surinam.* If nature was speaking through colour, the role of the latter on science had not been forgotten.

But the new age demanded the efficacy of a machine that could be understood by mathematical laws and designed by colourless lines and shapes. Besides the classical enduring struggle against chaos – which argued that there was a nature[5] (*natura naturata*) divided into two, a visible nature (*summa rerum*) and an invisible nature (*origo rerum*), seemed to have brought to a zenith the impressive role of mathematics. "What makes mathematics so effective when it enters science is a mystery of mysteries." (Bochner 1981: 114). But such a mystery has a long art-science history.

Tambora-Krakatau records appeared at a time when the relativistic *space-time* had not yet arisen in a promissory chaotic nature (Bronowsky1978: 40) and Mandelbrot' colourful fractals (1977) were a long way away. But as far as science walked its own path, we may return to Duchamp and Carrà and realize that they gave colour to the universal laws of the outer universe in the straight way we fashion them in everyday life.[6]

It seems that colour came to endure within the art-science realm and yet it was finnaly brought up through some *colourless* paradoxes. Xenophanes' *Apeiron* seemed to have moved into a lattice motion inside semi-conductors. The interesting behavior of the Zener diode is clear under the mathematical shape of a colourless mathematical function that shows "unexpected behavior" from the conventional understanding of electrical behavior. What colour could replace such an effective understanding? Perhaps it would be senseless to think about colour when a new miracle of mathematics came under a new shape: Boolean logic. The digital age had arrived.

Antony Hewish, the 1974 Nobel laureate in physics, has explained that the Palomar optical telescope was successful in discovering first radio galaxy, and yet it was only the radio telescope that could transform cosmology from a fight among theoreticians into an observational science, something that we can really study (Hawking 1992:72-73). Suddenly we come to a surprising zenith in the long art-science history. Mathematics at the core of semi-conductors was not abstract enough because it needed to proceed into a 0-1 logic based on full controlled matter infused into *logical doors* and other similar devices that, nonetheless, have shown to be the only tools that were able to bring to us the most impressive colours of the universe and thus we may combine them with this colourful based world we construct. The most impressive colourless devices one can imagine have brought us the most impressive colourful universe that no one could imagine to be there beyond the dark night sky.

Acknowledgments

Architect Patrícia Canelas and Professor Isabel Braz de Oliveira at the CITAD/UL
UL, Universidade Lusíada, Lisbon, Portugal
CITAD, Centro de Investigação em Território, Arquitectura e Design at UL.
FCT, Fundação para a Ciência e a Tecnologia, Lisbon, Portugal.

5 *φυσις* translated into Latin as natura combines all visible things – summa rerum – and the hidden force that produced them – origo rerum (Tatarkiewicz 1980: 293).

6 The move from Expressionism into abstraction should also not be forgotten. Our deepest states of mind or spiritual moods could be expressed through forms and shapes and both entailed the use of colour. Both our internal and external worlds look similar, in a way that Husserl would appreciate and similarity was right there living upon colour.

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Last but not least to Architect Gareth Griffiths, editor of DATUTOP, at the Department of Architecture, Tampere University of Technology, Tampere, Finland.

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Perception of contrast on different backgrounds

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Abstract
We quantify the effects of background on perception of contrast. For this, we compare pairs of colour differences using the method of constant stimuli. The influence of room illumination is quantitatively measured and discussed.

1. Introduction
How do humans perceive contrasts? How is contrast related to colour difference?

The answers to these questions have many implications for creative professionals. It influences for example how image transformation algorithms should be conceived. We are interested to know, which colour difference in one condition corresponds to a colour difference in a different condition. Such situations can occur, if creative professionals use displays to design objects that are then compared in a light booth. The same holds for images edited using a display with a white reference that does not match the white of the paper used in print. Image transformations designed to match device limits (gamut mapping) are another example where relative contrast perception matters.

With the help of psycho-visual experiments, we want to determine the relative size of two colour differences in different conditions. Takasaki showed in 1966 that the contrast between two gray patches is enhanced if the background has brightness close to these patches (crispening effect). Wittle (1993) and Moroney (2001) used simultaneous equisection to find equidistant spacing of greys on different grey backgrounds. Unlike these studies, we compare given *pairs* of patches at quite different places in colour space, not isolated patches. Chen et al. (2010) compare pairs, but for a single background only. In this paper, we restrict ourselves to measure contrasts between pairs of uniform patches on the grey axis and to three backgrounds without texture (black, white and a middle grey).

2. Experimental setup
For our experiment, we use an EIZO CG220 display with baffles. Stimuli were presented using a web browser. Sprow et al. (2010) showed how to display colour differences to a high precision this way. Observers made their comparisons in illuminated rooms and a white reference was always on the screen.

Table 1. Spectroradiometric measurements with Minolta CS2000, opening 1°: influence of background.

Room illumination (x-rite i1)	<20 lux	>400 lux	>400 lux	>400 lux	>400 lux
Patch p (RGB)	0	0	0	0	255
Background bg (RGB)	0	0	128	255	255
Luminance (Minolta CS2000)	0.3 cd/m^2	1.22 cd/m^2	1.34 cd/m^2	1.80 cd/m^2	120 cd/m^2

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For stimulus specification, we measured spectra of a centred, quadratic, achromatic patch with 8cm edge length with a Minolta CS2000 spectroradiometer (380-780nm, 1nm steps). The instrument was positioned in 40cm distance perpendicular to the middle of the measured patches. While room illumination and background had almost no influence on values and differences between bright greys, the measured spectra of darkest patches were biased (Table 1). When applying the CIE1931 normal observer model, the difference of what the calibrated output, measured directly at the display surface, would be and what effectively reaches the spectroradiometer can differ up to more than 8dL* in dark image areas – even as in our case in dim, indirect, diffuse illumination in a room with neutral surfaces and using baffles to prevent direct illumination of the display surface. As the bias enhances brightness of both patches of a pair, the small differences we measured were altered by less than 4dL*. Differences in the dark areas were affected most.

We will express results relative to the dark room reference with black background. But we based stimulus selection on measurements in the illuminated room, setting the background *bg* to the same RGB value as the patch *p* (see Figure 1, leftmost).

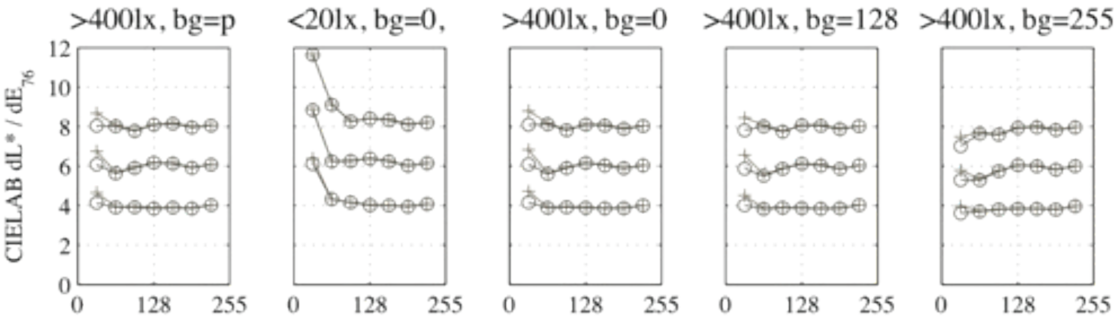

Figure 1: Spectroradiometric measurements of grey pairs -identical in RGB values- map to quite different dL (○), respectively dE_{76} (+), under different conditions. Lines connect small, middle and large differences respectively around seven locations on the grey axis. We ignored the chromatic part and used dL*.*

3. Experiment

Observers were asked 41 times per session, which of the two pairs presented had the larger lightness difference. Observers were given three answer options: ‘Upper pair has larger lightness difference’, ‘Both pairs have equal lightness difference’ and ‘Lower pair has larger lightness difference’. During each session, the background remained at a fixed RGB value. Most observers passed three sessions a day (each on a different background) on at most three different days. All observers passed the Ishihara test for normal colour vision.

The spatial separation between stimuli, as well as the size of the stimuli was kept constant. Edge length of patches was 1.8cm. The patches within a pair were adjacent, but there was a distance of the edge length of patches (1.8cm) between upper pair and lower pair. The order of presentation and spatial arrangement were randomized.

We used grey pairs around seven different lightness locations; around each location, we chose three pairs of about 4, 6 and 8dL* respectively (figure 1, leftmost), setting all three RGB components of a patch to the same value. We refer to the respective differences as small, middle and large pairs. Those pairs around each location were constructed in such a way that RGB values of the smaller difference pair were contained in the RGB interval defined by the larger difference pair (e.g. [28,35] in [25,39]). The measured colour differences varied due to quantization errors,

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and due to the surface reflections discussed before (see Figure 1). We did not compare large and small pairs, since we expected that all observers could agree on the ranking in these cases. Complete agreement on some pairs can lead to situations where no transformation of the ranking to an interval scale is possible.

4. Results

Table 1. Summary of comparisons.

Stimulus description		Comparisons	Answer "tie"	
Pairs around same location	Same pairs (real ties)	60	45	75.0%
	Different pairs[1]	242	59	24.3%
Pairs around different locations		1912	170	8.9%
Total		2214	284	

1 From 242 comparisons of two pairs around the same location, but with different RGB intervals, 183 answers described the pair with larger RGB difference as larger, 59 were ties and only 2 answers described the pair with larger RGB interval as smaller.

We transformed the frequencies of answers to scale values using an extension of the Bradley-Terry model incorporating ties, proposed by Davidson (1970). Each scale value in a Bradley-Terry model defines the expected score in a tournament, expressing relative size of a colour difference in this population.

A logistic regression transforms the scores to dL*-units for the respective background. Regression functions are computed using the large, middle and small difference pair around each location (One example is marked with fillings in Figure 2).

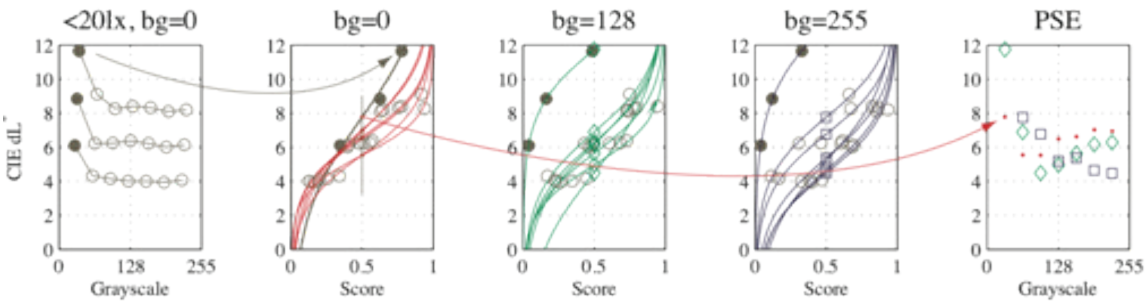

Figure 2: Regression from scores to colour differences using points of subjective equivalence (PSE).

In the three middle panels of Figure 2, the score associated with each pair is plotted on the horizontal axis versus measured colour difference on the vertical axis. The intersections of the regression functions with the vertical at 0.5 define points of subjective equivalence (PSE) in dL* units. PSE values are understood as colour differences around the respective location that would be perceived equal on the respective background. PSE are plotted in the rightmost panel of Figure 2 versus the respective location in RGB-coordinates. Figure 3 compares our results to dE_{00}. Error bars in Figure 3 show the 1%-99% quantile of 100 times subsampling 50% of the original sample size.

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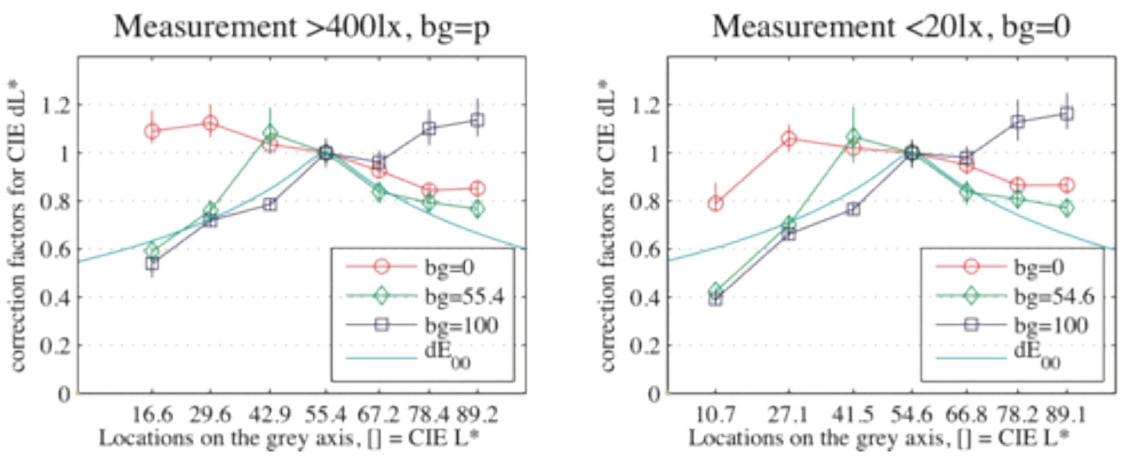

Figure 3: Correction factors to apply to dL units in order to account for background (left), respectively background and room illumination (right). The difference around a middle light grey is chosen as a unit.*

5. Discussion and conclusions

We showed how contrasts on the grey axis change on different backgrounds. Quantitative results of the influence of room illumination and background luminance in a realistic working environment using LCD are reported. The model of dL* applied to spectroradiometric measurements needs to be corrected for influence of background up to a factor of 2 in order to fit our visual data. The model of dE_{00} does qualitatively match our data, however only on the grey background for which it is specified. The model proposed by Moroney (2001) predicts similar, but more pronounced effects.

These results are promising enough to continue in the direction of a finer discretisation, chromatic stimuli and spatially more complex stimuli.

Acknowledgments

This work was partially funded by the Swiss National Science Foundation (SNF), project #200021_129964.

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Enigmatic search: Light and colour in today's urbanscape. A pleasurable paradox

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Abstract

This paper explores ways of introducing daylight into architectural environments in an everyday manner as well as theoretically in the context of contemporary architectural discourse. Architects and artists, often in collaborative works, e.g., the Barcelona Forum, use traditional or innovative surface textures and specific material qualities in order to deal with daylight and colour in a dynamic way. Seemingly paradoxical means – transparency and opacity, glossiness and roughness, reflection and superposition – shape daylight and make colour emerge, space appear and appearance change. In contrast to the relatively rare investigations exploring daylight, research and projects developing and applying new technology and understandings using artificial colour-light environments, e.g., so-called 'interactive' installations are becoming a major trend, commercial tool and media-driven obsession. However, some contemporary architects, e.g. Jean Nouvel in collaboration with lighting designer/artist Yann Kersalé or artists, e.g., James Turrell are calling for more subtle ways of using the newly developing lighting techniques and technologies.

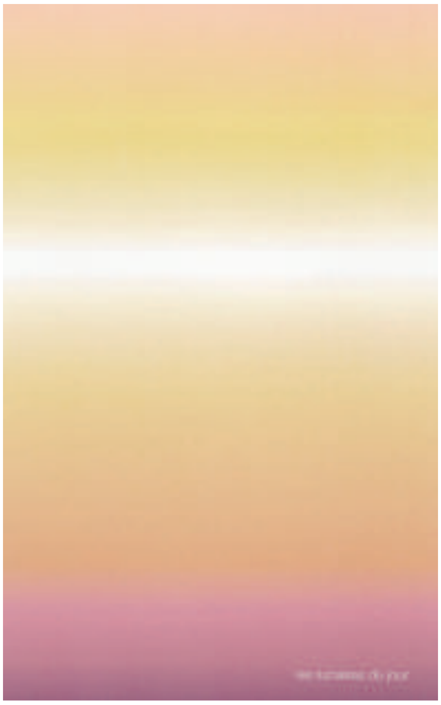

Fig. 1 Daylight colours. France Cler © Atelier Cler, Paris

1. The colours of natural light

Unlike artificial lighting daylight causes subtle colours and complex shadows to appear. Its cyclical course and daily and yearly rhythms produce a rich variety of intensity in hue and saturation, brightness and darkness. Such resulting ephemeral and transient aspects lend the architecture and its environment ambiguity, fragility, evanescence and uncertainty. Daylight can be used to great effect in architecture expressively activating and energizing the colours of materials. Both inside and outside the variable play of sunlight and shadow performs upon surfaces. (Yonge, 2009) Daylight also renders visual comfort and imparts a natural atmosphere to a place. Artificial lighting also has the ability to reveal colours, but it can distort them to the extent that they are no longer recognizable. Dependent on the intensity and orientation of sunlight, daylight or so-called natural light is best in capturing and modulating illumination and its shadows, in contrast to artificial lighting whose effects are more uniform and static.

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2. The magic of the real

Daylight reveals colour appearance and produces comfortable environments, both psychologically and functionally. Speaking in general of the nature of colour appearance in terms of perception, it can be said that colours emerge through an on-going process of structuring and de- and re-structuring the visible.

Fig. 2 Colours, shadows, artificial lights in the Japanese urbanscape. Photo: Melanie Yonge

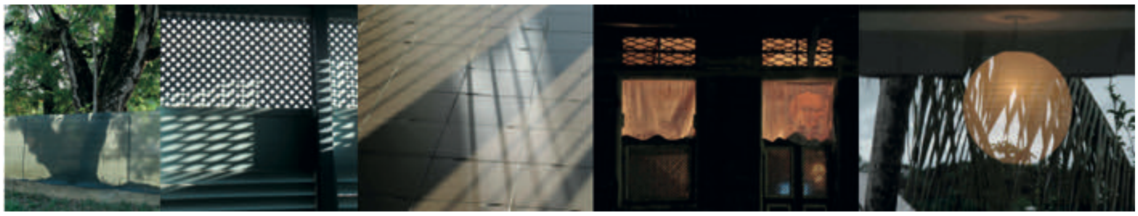

Fig. 3 Artificial light casts static shadows while natural light changes and transforms shadows constantly. Photo: Jean-Paul Leclercq

Some examples from Japan and La Guyane show recent efforts in the search for enigmatic expressions of colour and light in architecture and urban space.

However, what touches us most? Raising the issue of this often neglected subject, we ask the Swiss architect Peter Zumthor: Is it the atmosphere, the magic of a place, the energy of colours and lights that affect and put people in a particular mood? In the words of Zumthor: "Everything! Everything! Things, people, the quality of the air, the light, the sounds, tones and colours." (Zumthor, 2003: 19) Everything together constitutes the living human environment, human habitat. However, a place, colours and lights are only magic if they are able to enhance and inflame human sensations, as he states: "For me, the magic of the real is this 'alchemy' of transforming real substances into human sensations, this specific moment of emotional appropriation or seizure of material, matter and form in architectural space." (Zumthor, 2003: 20) Indeed the magic of the real is closely related to a feeling of well-being, coherence and harmony.

3. Enigmatic search

Dealing with daylight in architectural environments has always been a main objective of architectural practice: however, in contemporary architecture this seemingly everyday concern has become underscored by the expectation of novelty and innovation. Architects and artists, often in collaborative works, e.g., the Barcelona Forum, the Quai Branly Museum in Paris or the Novartis Campus Forum 3 management headquarters building in Basel, use traditional or innovative surface textures and specific material qualities in order to deal with daylight and colour in a dynamic way. Seemingly paradoxical means – transparency and opacity, glossiness and roughness, reflection and superposition – shape daylight and make colour emerge, space appear and appearance change. The skylights of the Barcelona Forum show how traditional techniques (rough coating) combined with new ways of dealing with materials and fine-tuning colour nuances can produce unique an enigmatic atmosphere. Combinations of smooth glass cladding and rough

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coatings, glossy and matt materials, plain and fragmented surfaces enhance or soften the pleasurable play of light, shadow and colours in space.

Fig. 4 Skylights change and transform space according to material surface and colours. Herzog & de Meuron's Forum, Barcelona. Photo: Verena M. Schindler

4. Visual complexity

Contemporary architecture is far from the premises of Le Corbusier, one of the most influential thinkers about natural light in modern architecture, who thought architecture to be "the masterly, correct and magnificent play of masses brought together in light." (Schindler, 2003). At the same time it is equally distant from the technology-inspired desire to dematerialise architecture with light, as in Jean Nouvel's ingenious Arab World Institute of 1987. Its southern façade is designed with diaphragm-like sun-shading elements that function like the internal mechanisms of a camera lens sensitively opening and closing depending on the intensity of the sunlight. This kind of performance generates a kinetic play of light and shadow dissolving the interior spaces in a spectacle of fragmented light.

Fig. 5 Superimposition of colours and reflections creates a visual complexity. Museum Quai Branly, Paris (left). Sunlight dissolves colours and forms while colours and reflections become visible in the shadows. Novartis Office Building, Basel. Photo: Michel Cler (left), Verena M. Schindler

As Nouvel states in his Louisiana Manifesto of 2005 his aim is to discover 'unknown colours' through "…shifting from assertion to allusion, from positioning to super-positioning, from clearness to nebulousness." (Nouvel, 2005) In Nouvel's Museum Quai Branly of 2006 a palette ranging from dense browns and warm earthy reds to light ochre yellows applied in the middle of limestone-white Paris are combined with fully glazed infill walls covered with translucent "jungle-green" sheet films. Another example is provided in Basel by an architectural façade wrapped by a structure of hundreds of superimposed coloured glass panels. The artist Helmut Federle in collaboration with the architects Roger Diener and Gerold Wiederlin created a sophisticated composition of shiny glass panels. Overlapping and coloured in different hues these panels reflect the landscaped surrounds and the sunlight, whereby the direct illumination causes the colours to completely dissolve under the blurring white light; at the same time the colours and reflections of panels in the shade appear mysterious and emphasize the complexity of the façade's intricate structure.

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5. Pleasurable paradox

In contrast to the relatively rare investigations exploring daylight, research and projects developing and applying new technology and understandings using artificial colour-light environments, e.g., so-called 'interactive' installations are becoming a major trend, commercial tool and media-driven obsession. Often irritating the senses such applications are now commonly experienced as part of urban life in the form of commercial actions and temporary event-oriented installations, e.g., White Nights, Festivals of Lights, New Year's Eve celebrations and other mass events performed in public space. The commercial – or entertainment – touch calls for rapid change effects and intense, short interventions: slick advertisement and fashionably fun are combined in the tradition of Las Vegas.

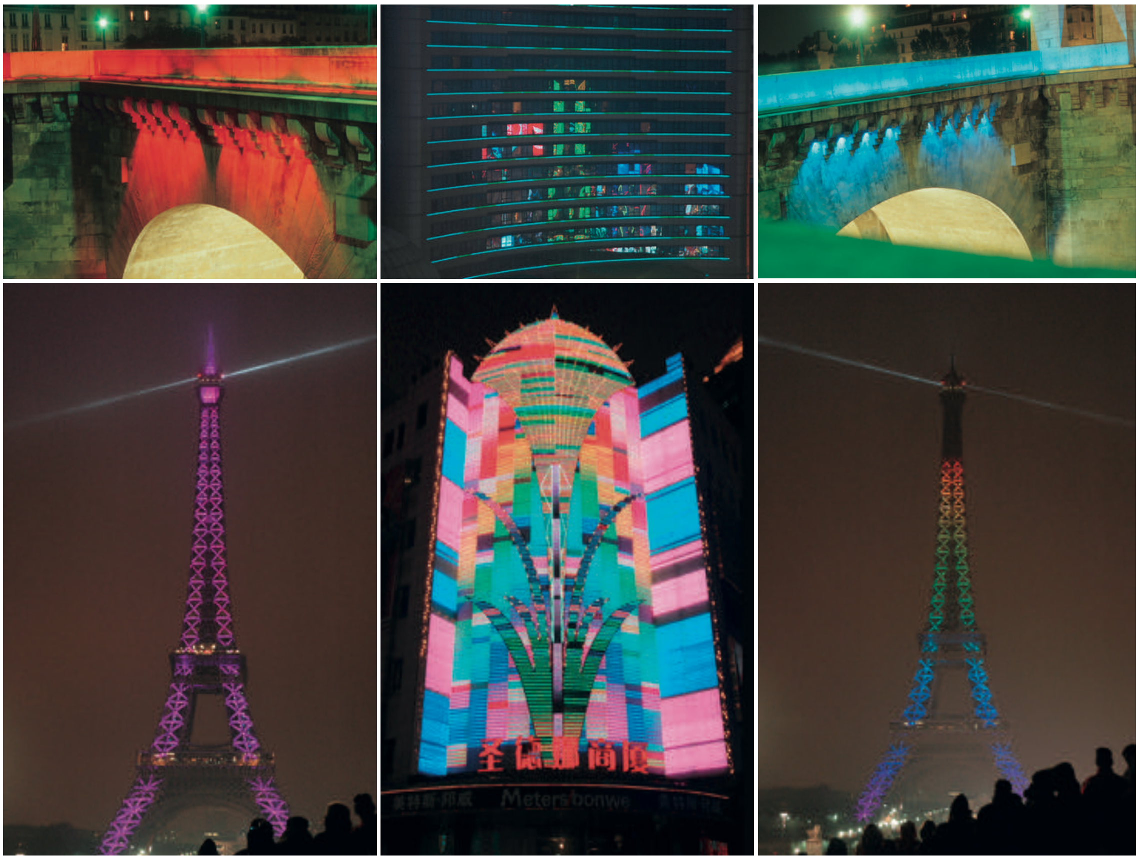

Fig. 6 Temporary coloured lighting on bridges, Paris, 2006, and kinetic coloured performance on the Eiffel Tower on New Year's Eve, 2009 (right and left). Kinetic digital performance on eight stories of a building's façade (centre, bottom) and colour-light reflections on a glass wall façade (centre, top), Shanghai, 2007. Photo: Verena M. Schindler

As a result urban space is de-constructed visually to the extent of annihilation as a media-imposed stage for fluctuating screens rather than background and platform for human presence and exchange. Often architecture façades are used as huge screens for gigantic performances.

However, some contemporary architects, e.g. Jean Nouvel in collaboration with lighting designer/artist Yann Kersalé or artists, e.g., James Turrell are calling for more subtle ways of using the newly developing lighting techniques and technologies. One of the main ways that artificial lighting affects colour and shadow is to radically reveal – and transform – the relationship between volume and void, both enhancing and blurring contrasts. Understanding and dealing with a range of human senses are essential in artistic light-colour installations, some of which

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elude boundaries between the real and unreal to establish a disturbing ambiguity, a paradoxical consolidation of the two states that can surprisingly even sometimes produce a pleasurable spectacle.

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Painters judging brightness of coloured samples under chromatic illumination

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Abstract

This paper focuses on an experiment the objective of which is to examine the appearance of coloured surfaces and the mood variation under several chromatic lights. To anticipate the appearance of the surface colours, different light conditions are of importance for painters and colour-designers, whose task is to design and apply colours in the built environment. One of the aims in painter training consists of raising the awareness of the impact of light conditions on the perception of colours. The tested colour conditions were of rather extreme nature, featuring saturated chromatic lights. The experiment described here below was performed with apprentice craftsmen painters and colour designers and took place in a classroom equipped with fluorescent tubes covering a variety of spectral power distributions. Achromatic as well as chromatic lighting conditions were provided. The task requiring to assort four colour swatches according to their apparent brightness was repeated seven times under different lighting conditions. As expected, the impact of lighting on the appearance of the colour swatches was mainly confirmed. Additionally, it was indicated that working under coloured light conditions could cause mood swings and hence should to be examined in more detail.

1. Introduction

Light plays an essential part in the visual perception of space. Altering light conditions significantly influence the way of experiencing a spatial situation and convey a certain atmosphere. A room flooded with light seems clear and well-arranged, it expands in front of you. When filled with colours and different luminances, you can see a perspective in it and you can estimate distances; Bollnow (1997). By altering the lighting conditions the spatial impression and the visibility of things changes. The human eye and its perception need to adapt to the situation. As a consequence of the altered lighting conditions (e.g. achromatic / chromatic conditions) the experienced space also transforms itself in its appearance (e.g. narrow or wide, light or dark, warm or cold). The knowledge of the characteristics how surface colours under different lighting conditions can change is of particular importance for architects, colour designers and craftsmen painters in its practical use. As the built environment is strongly influenced by architects and colour designers, the impact of light and colour should already be dealt with during apprenticeship to allow them to see the big picture. This is especially relevant for apprentice colour designers, because they theoretically have the possibility to work under such conditions.

For this reason a group of apprentice colour designers was chosen for the test series. It could be assumed that this group was apt to choose colours accurately, moreover, the participants showed interest in colour as well as responsibility and were involved in the process of implementation. In the context of spatial design the choice of colours in chromatic light spaces was supposed to be reviewed by test subjects. The choice of colour application was subsequently

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compared with the measured values. Since it was assumed that colours also have an emotional impact, the subjects were interrogated under chromatic lighting conditions.

2. Description of spatial conditions and lighting

The experiment was carried out in a classroom with the measurements of 8,1m x 5,8m. The room height was of 2,8m (see Figure 1). The equipment consisted of common classroom facilities with 10 desks und 20 chairs made of light wood. The walls and the ceiling were painted in white, the floor in anthracite. The three windows in the room were completely darkened for the experiment. The luminous ceiling was equipped with 120 luminaires (58 watt T26) to demonstrate different achromatic and chromatic lighting conditions with 20 fluorescent tubes each in the colour temperatures of daylight 6500K, warmwhite 3000K and coolwhite 4000K with a colour rendering index of 90. Furthermore, fluorescent lamps in red, green and blue colour were used. The seven lighting situations, which were applied in the experiment, were daylight 6500K (500lx), yellow (630lx), green (400lx), cyan (max.380lx), blue (max. 91lx), magenta (max.37lx) and red (180lx). For the creation of cyan, magenta and yellow colours, the complementary chromaticity coordinates of the already existing chromatic light red, green and blue were selected with the corresponding filter foils.

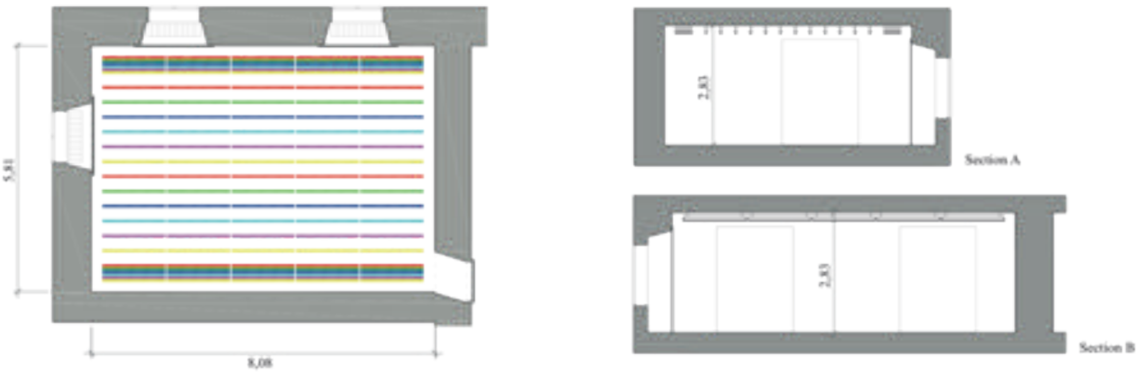

Figure 1. Spatial conditions and Lighting in plan view and two sections (A and B)

3. Design of the experiment

The test subjects were pupils of a higher technical education institute specialising in colour and design. The common precondition of the pupils was the interest in colour and a possible experience through regular handling of colour. The experiment took place in the context of a course lasting seven weeks. All in all, 35 pupils between 15 and 21 years of age participated in the experiment. The pupils were previously screened for colour deficiency by means of Ishihara colour charts and made colour attributions under different chromatic lighting conditions. Depending on the task, the probands were provided with NCS colour swatches. Additionally, by means of a questionnaire carried out before and after the trial, the mood state of the participants was evaluated.Each of the probands remained 90 min in the chromatic lighting condition and was asked to fulfill various tasks. The subject of the depicted exercise was „brightness“. 12 colour swatches in various shades of light grey (reflection factor between 75 and 5) and four NCS colours (S 0580-Y, S 1565-G, S 1565-B, S 1080-R) were provided. The directives required to sort out the given chromatic and achromatic colour swatches according to their apparent brightness, from light to dark. For the

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purpose of comparison, the luminance of all colour swatches was measured under achromatic light 6500K TL as well as under six chromatic lighting situations.

5. Results and discussion

The grey values were constantly rated from light to dark in the correct order. The brightness values measured under different chromatic lighting conditions were compared to the subjective ratings of the probands (Figure 2). Under the same illumination and swatch colour, the colour was subjectively rated darker than the measured brightness. The comparison of the swatches with the complementary coloured light condition resulted in a good conformity . In general it could be observed that the yellow colour swatches were well rated under all light situations with minimal deviations, the green colour swatches, however, showed the biggest differences within the coloured illumination and were subjectively rated too dark (Figure 3).

Another part of this study dealt with the probands' state of mood while remaining in chromatic light. A mood state questionnaire on this subject was filled out before and after the experiment; Steyer et al. (1997). It turned out that cyan light seems to make the probands more awake than white light and that green light has a mood lighting effect.

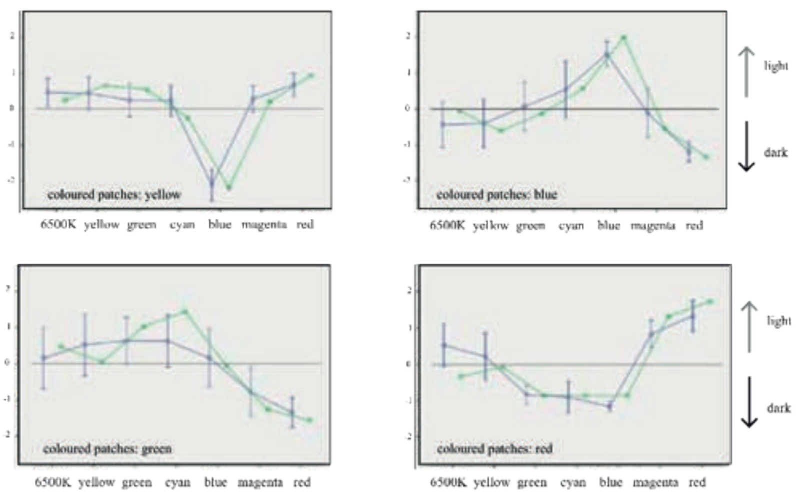

Figure 2. Comparison of the rated apparent brightness of the 4 colour swatches under seven light conditions with measured relative luminance values

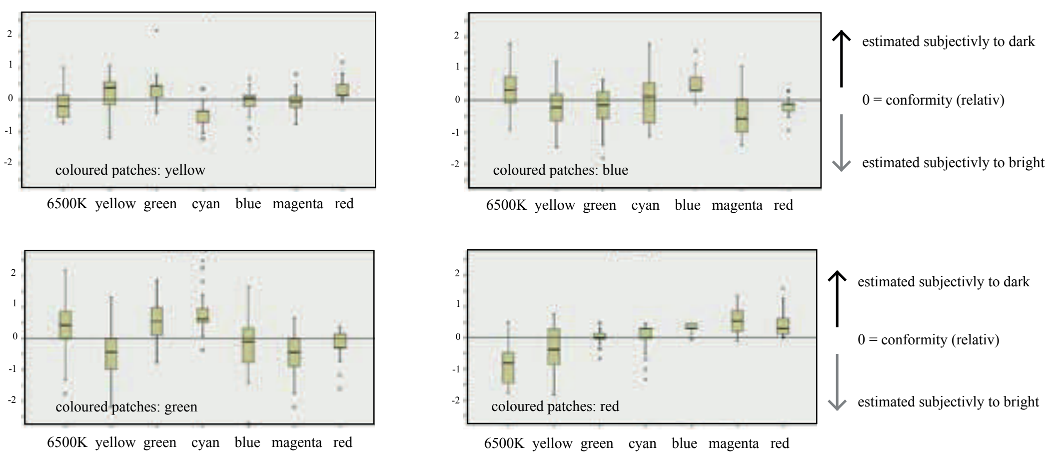

Figure 3. z-value difference of measured minus rated values for the four coloured swatches under seven light conditions

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Sessions with cyan and yellow light the task was considered easy. Under red light the task was considered difficult. The sessions with red and magenta were perceived less comfortable and more exhausting than the session featuring yellow light.

A training effect was observed showing that with an increasing number of repetitions the task could be finished in shorter time.

In general, the experiment confirmed the expected impact of coloured light on the appearance of surface colours and offered the students a realistic support for colour designing and building inscriptions under chromatic lighting conditions. Furthermore, it was observed that mood swings resulted from staying under chromatic lighting conditions, which shall be referred to in detail in a further study.

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Chromatic enlightenment: Color and light in modernist religious architecture [a spiritual journey in two buildings]

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Abstract

This paper develops a case-study comparison of the implications of the manipulation of color and light in two modernist religious spaces: Annunciation Monastery (formerly Annunciation Priory) | Bismarck, North Dakota. Marcel Breuer, 1959-1963 [AM] and Mount Zion Temple | St. Paul, Minnesota. Erich Mendelsohn, 1950-1954 [MZT]. Here, we examine how a color and light experience can help to convey the ideas, attitudes, and emotions underlying devout practices. The paper exposes techniques of use of color and light for **advertising**, **awe**, **direction** (both literal as wayfinding and metaphysical as conduit to higher powers), **grounding**, **intimacy**, and **intimidation**. The paper identifies how the use of light and color as design elements can significantly sway the meaning of the experience of the religious practice in the identified spaces. Furthermore, the paper illustrates how areas, as “color containers”, hold and convey ideological thoughts and attitudes and explores the methodologies of the modernists (as a gateway to contemporary innovations in use of color and light in religious spaces).

1. Note to the reader | Excessively gratuitous disclaimer

One of the difficulties in discussing buildings with a religious objective in an intellectual, scientific, and/or artistic crowd is the assumption that you and/or your topic are likely being dubbed as weak and myopic and the certainty that you and/or your topic appear soft, hokey, and/ or downright judgment impaired to your staunchly informed academic peers. This is NOT to say that those of the religious ilk automatically fall into that camp. It IS to highlight the shortcomings of the academic and artistic milieu (in which - for better or worse - I firmly reside) in relation to things holy (but NOT in relation to things aesthetically divine!) Let it be said, so that the content of this paper can come through with ultimate honesty, that, while I was raised a Lutheran church-going child, I politely write this paper as a secular, non-religious member of the world. It must also be said (and will likely appear quite obvious in the coming minutes) that I do consider myself spiritual. This differentiation may have been the harbinger of my interests in this topic and may, in fact, be the primary driver in my ongoing fascination with color in modernism and minimalism and my adoration for atmospheric color spaces. [Think Luis Barragan, Donald Judd, and James Turrell. Ahhh, bliss!]

As an innately nice and firmly polite person, people can assume that I am “churchy”. While their false assumption tethers (in their minds only) my floating freedom, I find the supposition quite amusing and societally revelatory. In fact, in response to a question of the meaning and concept of a religious space in an interview article titled “Marcel Breuer: On Religious Architecture”, architect Breuer amusingly contested,

> *‘… I am not a religious man. I have the feeling, and this is not a very clear-cut program or idea, that any space which is larger than necessary and higher than necessary, and in which the structure and the whole building of the space is visible*

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as it is in all churches and this type of architecture, that this space created is simply automatically religious . . . The monks at St. John's Abbey used to say, ''Breuer is a religious man, only he does not know it.' (Howarth 1979: 260)

It seems clear that many artists, architects, designers, and creators actively cultivate a spiritual embrace or rely on a celestial experience in their viewers. In fact, a priest, after walking through Donald Judd's installation of 200 pristinely milled aluminum boxes reflecting the hot West Texas light in a former military compound, said, " 'You and I are in the same business.' (Judd 1994: 70) As we explore the experiential toolkits of two renowned modernist architects, I pray that you find inspiration, humor, and triumphant joy in the heavenly color and light moments in these two works.

2. A visual analysis of the manipulations of color and light

Figure 1: Color and light for advertising. Voids, relief, and changes in materiality affect shadows, colors, and light qualities calling attention to sites and to design details. From left to right: light wells emit light as a dayglo sign (MZT) and light wells soak in natural light to mix with artificial light within as the reflective surface of the Holy Ark kicks the light back to the congregants (MZT). In the four images on the right, the hyperbolic paraboloid bell banner from multiple vantage points at various times of day recruits from far and near (AM campus).

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Figure 2 at left: *More advertising. From top to bottom: sun highlights light well facades (MZT), lights in W motif reference a Hebrew word for God (MZT large sanctuary), the W motif repeats on the Holy Ark (MZT large sanctuary), and darker colored Christian cross connection pieces for sidewalk pavers remind walkers of the sanctity of the site (AM campus) (Some items may not be part of the original modernist works.) (Mount Zion Temple Pamphlet 2011: 6)* ***Figure 3 at right:*** *Grounding. Original textured mat provides patterned ground for clergy while red cantilever creates a sandwiched space (AM small sanctuary), dark edging of stairwell keeps nuns rooted to the earth (AM former nun lodging), and photograph of original section drawing by Breuer outlines the change in levels to nestle congregants on lower plane (AM small sanctuary).*

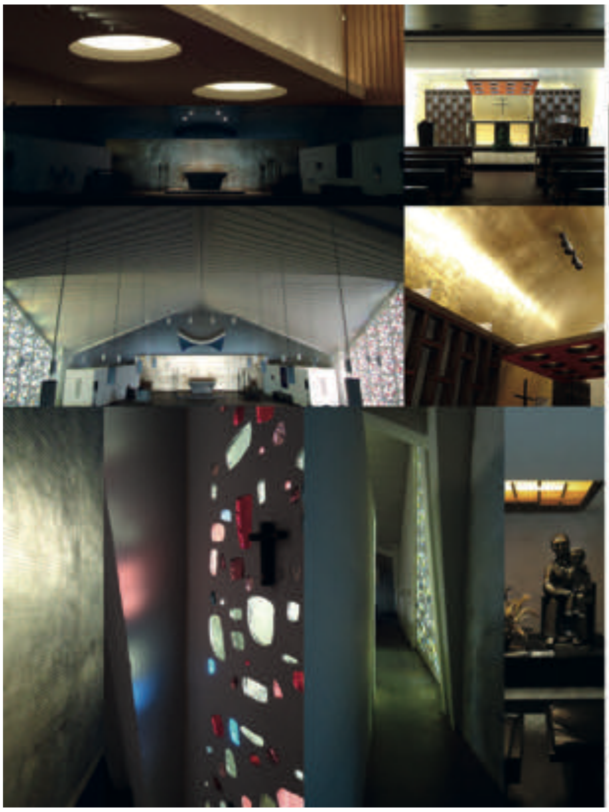

Figure 4 at left: *Awe. From left top to middle: light licks sanctuary walls like flames (MZT large sanctuary), otherworldly color behind altar and illuminated hull of concrete structure near altar (AM large sanctuary). From right top to middle: light well caked in gold creates aura of grandeur from above. Bottom from left to right: gold tiles behind altar, colored glass sheds light around stations of the cross, side passage to main sanctuary, warm light from above glows in side chapel (AM large sanctuary).* ***Figure 5 at right:*** *Breuer perforates surfaces to maintain visual connections and spiritual continuity throughout the complex (AM).*

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Figure 6 at left: *Direction. From top to bottom: concrete formwork leaves colored striation around walkway (AM campus), light marks the way out of the dark sanctuary hull (AM large sanctuary), light marks more heavenly zones (MZT small sanctuary), ceiling color morphs from more greenish with presence of natural light at left of image to a more sacred golden by altar (MZT large sanctuary).*

Figure 7 at right: *Intimidation. From left to right: Establishing boundaries with translucent layers between the people and the Torah (MZT large sanctuary), elevating the choir to a higher reddish ground plane (AM large sanctuary), changes in level + light signify areas of leadership (AM large sanctuary), edge of sanctuary space coated white to denote holier space (AM large sanctuary) (Private Communications with S.G.), the congregants sit lower in a darker hollow (AM small sanctuary) [it quite literally feels like you are the lowly trudging through mud!], and a change in paver color and direction marks the entry to the sanctuary (AM large sanctuary).*

Acknowledgments

Sincere gratitude to Sister Gemma and the Benedictine Sisters at Annunciation Monastery and Executive Director Larry Solomon and the Mount Zion Temple community. Your generosity of time and space, your insight, and your spiritual connection were nothing short of remarkable.

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Unsupervised colour segmentation of textile fabrics constructed by coloured yarns

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Abstract

As the normal colour measurement method of using a spectrophotometer is impossible to measure colours of multi-coloured textiles woven or knitted using coloured yarns, commonly termed as 'yarn dyed' fabrics, colour measurement method based on the multispectral imaging technique is a viable alternative. To do this, a colour segmentation step is necessary. This study presents a novel approach of reconstructing colour images of yarn dyed textile sample in the perceptual colour space of CIELCH from spectral data captured by a narrow-band multispectral imaging system. The new method firstly constructs a segmentation tree by the unsupervised image content self-learning method. Secondly, all colour regions in the image are segmented followed by a step of merging similar colour blocks to avoid over-segmentation. Finally, the spatial locations of the colour regions are established by the Hough Transform. Comparison was made to other image segmentation methods, i.e., region growing method and quadtree methods and shows that the new method is superior in terms of colour segmentation efficiency.

1. Introduction

Most of the image segmentation techiques deal with general purposes images, such as those published recently by Ohta et al. (1980), Ohlander et al. (1978), and Bleau and Leon (2000). However, the segmentation techniques are commonly used to solve specific problems, and thus task-oriented approach are normally adopted to improve the effectiveness and accuracy of the image segmentation. This paper describes a colour segmentation algorithm for the purpose of measuring colours of yarn dyed textiles. The approach involves characterizing colour information derived from a multispectral image data and the statistical features of the histogram distribution in each colour channel of the CIELCH colour space. These features in the CIELCH colour space are then used in an unsupervised histogram segmentation algorithm to find regions of uniform in the image.

2. The proposed method of colour segmentation of yarn dyed textiles

In this study, a multispectral imaging system consisting of a monochrome digital camera and 16 narrowband filters was used to capture the image of yarn dyed textile fabrics. Spectral reflectance data for each pixel in the image are recovered from the response values of the camera based on the Wiener method by Shen et al.(2007). Due to the high correlation of reflectance data among the wavelength range, all spectral data were transformed into the CIELCH colour space, which possesses perceptual uniformity and meets the psychophysical need for a human observer.

The histogram of each channel of the CIELCH colour space is calculated and all local inflection points in the histogram are evaluated to segment the histogram distributions that can be used to differentiate the dominant colour regions in each colour channel of the original image. A

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set of certain features of segmented histogram distributions are calculated to estimate the segmentation cost function $f(x_i, \beta)$ between the segment in histogram and the dominant colour regions in each colour channel. These features include the spread range of segment in the histogram, the area ratio of segment in the whole image, the kurtosis and the standard derivation of the segment in histogram distribution. The estimation $f(x_i, \beta)$ can be calculated:

$$f(x_i, \beta) = \sum_{j=1}^{m} \beta_j \phi_j(x_i) \qquad (1)$$

Where $\Phi_i(x_i, \beta)$ is the j-th feature in i-th semgent. β is the parameter estimated by the least square method.

The segmentation tree can be constructed by sorting the sum of weighted segmentation cost function of the segmented regions in each colour channel.

$$F = \sum_{i=1}^{m} f(x_i, \beta) * N_i \qquad (2)$$

Where F is used as colour criteria to effectively segmented colour regions in each colour channel and N_i is the effect number of segments in the histogram of each channel of colour space. In the proposed method, the value of F at the first level in the constructed tree is the greatest. And then, the value of F decreases along with the increase of tree level. In the constructed tree, the root represents the original image. The nodes of the tree are segmented regions of the image in each colour channel. The level represents segmentation in a particular channel. Thus, all the segmented regions in the image can be obtained by tree traversal. Figure 1 shows the segmentation tree of an image.

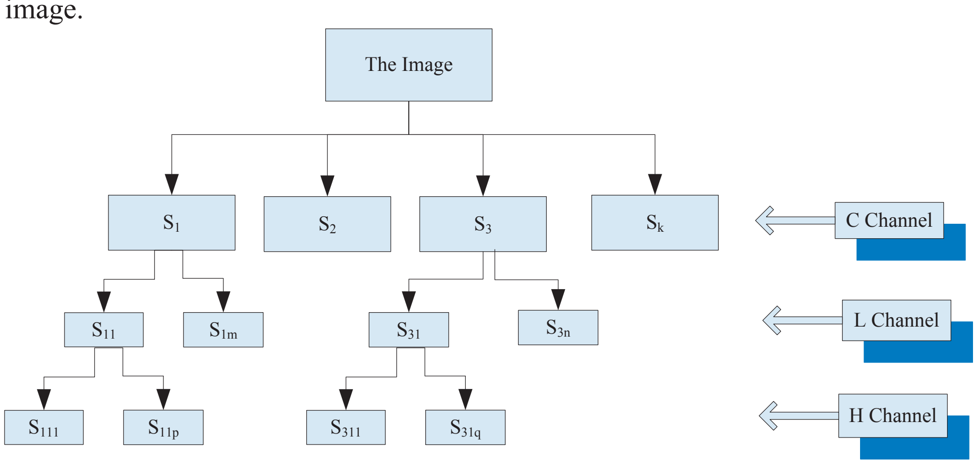

Figure 1 Tree structure of segmentation

Using the above method, it may lead to the over-segmentation. Hence, it is essential to merge these over-segmented regions based on their colour similarity. The similarity of blocks in each level of the segment tree structure is calculated to prepare for merging. For a similarity matrix A, in which the element a_{ij} is the i-th feature of j-th block. The similarity of blocks can be represented as follows:

$$S_{ij} = \frac{A_i^T * A_j}{|A_i| * |A_j|} \qquad (3)$$

where A_i is the i-th column of A.

For a yarn dyed fabric, single yarn is often used to separate the neighboring colour regions. It can be viewed as outline in the boundary of two segmented colour regions in the image. To

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segment these outlines, edge detection method is employed. To complete the segmentation of the image, it is essential to locate the pattern of the yarn dyed sample and then fill any holes in the image, which are the regions heavily influenced by noise. Hough Transformation by Hough, P. V. C(1962) was applied in our study to locate the pattern of the sample.

3. Experiment and results discussion

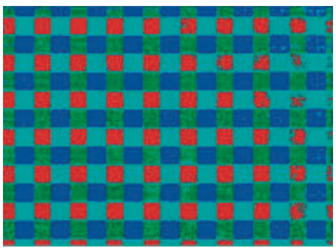
As showed in Figure2 (b), the dominant colour regions in the image can be found in the segmentation of the first level of the tree structure. The finer sub-regions can be obtained in the second and third levels segmentations. Figure2 (c) shows the final segmentation result by the tree structure. Following that, Hough Transformation is applied to locate the pattern of the image, as showns in Figure2 (d).

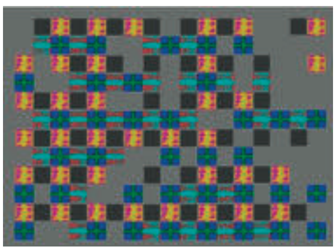
We compared our method with other image segmentation methods, such as region growing method and quadtree method. Figure2 (e)-(g) and Figure2 (h)-(j) show the segmentation results by region growing and quadtree methods respectively. As Figure2 (e) shows, the region growing method in C channel of CIELCH colour space can achieve similar segmentation result compared to our method (Figure2 (b)). But the drawbacks of region growing method are the selection of seeds and the criterion to stop growth. In the comparison experiments, the seeds were chosen manually. And the criterion of growth stop is the same as the segmentation threshold used in our method. Comparison between

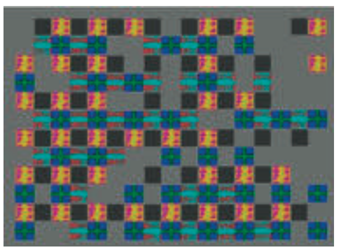
4. Conclusion

In this work, a new approach based on the construction of unsupervised segmentation tree is proposed to fully segment the colour regions of yarn dyed textile fabric samples combining with edge detection method. The segmentation process consists of three stages. A colour criterion to effectively segment colour regions based on the histogram distribution in each colour channel is also presented. By comparing with two other segmentation methods named region growing and quadtree methods, results from the new proposed method clearly indicate a superior performance. The new colour segmentation method can be further applied to measure colours of the yarn dyed samples based on their digital images.


(a)


(b)


(c)


(d)

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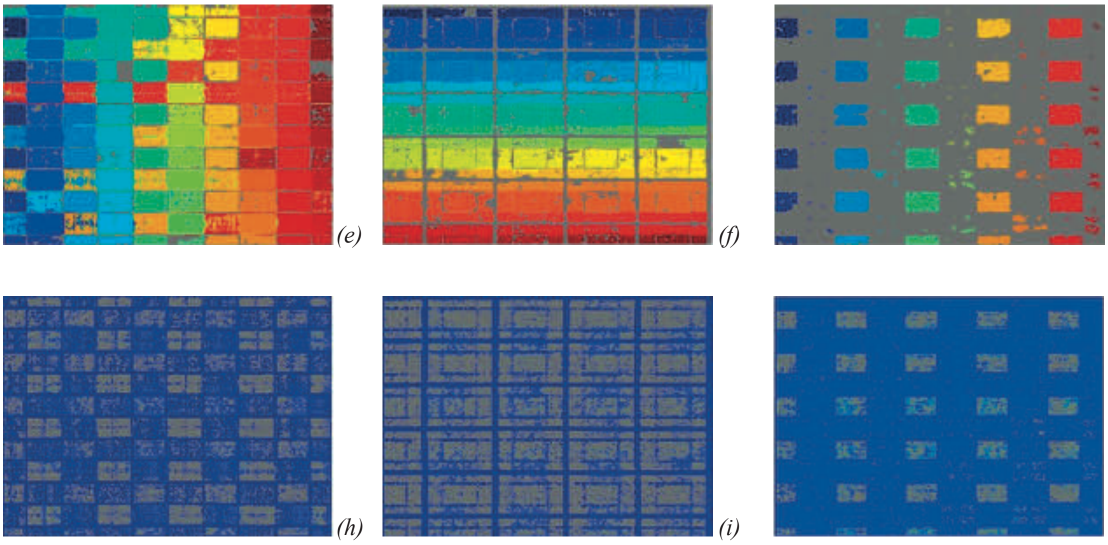

Figure2 (a) the original image in RGB colour space,(b)the segmentation result by the first level of the tree structure, (c)the final segmentation result by the tree structure, (d)the result after post-processing,(e)the segmentation results in the Chroma channel of region growing method,(f)the segmentation results in Lightness channel,(g)the segmentation results in Hue channel,(h)the segmentation results in the Chroma channel of quadtree method, (i) the segmentation results in Lightness channel,(j)the segmentation results in Hue channel.

Acknowledgments

This work was supported by the HKRITA project ITP/001/10TP of the Innovation and Technology Commission of the Hong Kong SAR Government.

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Estimation of spectral reflectances of an art painting using a multispectral camera and evaluation of their accuracies

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Abstract

The digital archive of art paintings is a promising technology to leave them as our human heritages to the future as if they were painted at the present time. The impression of an art painting changes largely with illuminations. In order to reproduce realistic color images of it under various illuminations, the spectral reflectances must be accurately recovered at the spatial resolutions of a camera pixel. Usually colors in a painting are not uniform in the two dimensional space, which is quite different from that of color charts, thus colors are not uniform within the area used to measure a spectral reflectance by a spectrophotometer and the area contains many pixels within it. This paper describes the experimental results on the comparison between the measured spectral reflectance by a spectrophotometer and the mean spectral reflectance recovered by all pixels within the area used for measurement. It is shown that the accuracies of the recovered spectral reflectances of an art painting must be evaluated by averaging the spectral reflectances recovered by the pixels within the area used for the measurement.

1. Introduction

Colors in an art painting fade as time passes and the impression of it changes largely with illuminations. The digital archive of art paintings is a promising technology to leave them as our human heritages to the future as if they were painted at the present time (Berns (2010)). In order to reproduce realistic color images of the paintings under various illuminations (Nayatani (1995) and Hunt (1991)), the spectral reflectances of the paintings must be accurately recovered at the spatial resolutions of a camera pixel. The author already proposed a model to recover spectral reflectances of an art painting without the prior knowledge of it (Shimano (2006), (2007), (2010)). Usually colors in a painting are not uniform in the two dimensional space, which is quite different from that of color charts, therefore colors are not uniform within the area used to measure the spectral reflectances by a spectrophotometer even though a uniform color region is used for the measurement and the area contains many pixels within it. Thus it is very difficult to evaluate the accuracy of the recovered spectral reflectance of an art painting. This paper describes the experimental results on the comparison between the measured spectral reflectance by a spectrophotometer and the mean spectral reflectance recovered by all pixels within the area used for the measurement. It is shown that averaging the spectral reflectances recovered by all pixels within the area used for the measurement is the right method for evaluating the recovery performance.

2. Model

Figure 1 shows pixels and an area S used for a measurement. Let S be the area used for the measurment by a spectrophotometer. A spectral reflectance vector $\mathbf{r}_{ij}$ recovered by a pixel $\mathbf{p}_{ij}$ in S is expressed by

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$$\hat{\mathbf{r}}_{ij} = W\mathbf{p}_{ij} \ , \qquad (1)$$

where W is the Wiener filter that estimates a spectral reflectance. Since a spectral reflectance $\mathbf{r}$ measured by a spectrophotometer can be considered as the mean spectral reflectance of all points within the S, thus the $\mathbf{r}$ is approximated by

$$\mathbf{r} \cong \frac{1}{n}\sum_{i,j\in S} \hat{\mathbf{r}}_{ij} = \frac{1}{n}\sum_{i,j\in S} W\mathbf{p}_{ij} \ , \qquad (2)$$

where n is the number of pixels in S (all pixels on the circumference of the circle S were excluded in this experiment). Equation (2) shows that the mean spectral reflectance recovered by the pixels in the area S must be used for evaluating recovery performance.

The Wiener estimation is widely used to recover the spectral reflectances of imaged objects by using image data. However the recovery performance of it depends on the noise present in the image acquisition system and on the spectral reflectances used for the autocorrelation matrix. And more it is very important to recover spectral reflectances of an art painting at a the spatial resolution of the camera pixel withougt the prior knowledge of the painting (i.e., withought prior knowledge of the spectral reflectances of the painting or materials used to paint it). The author already proposed a model to recover spectral reflectances of the imaged object withougt the prior knowledge of it (Shimano (2006), (2007)). The training samples of the Macbeth ColorChecker was used to estimate the noise variance of the image acquisition system and the spectral reflectances of the samples were also used for the autocorrelation matrix. For more detail, see reference Shimano (2006). The accucacy of the estimates is greately improved by use of the adaptively selected spectral reflectances for the autocorrelation matrix of the filter (Shimano (2010)).

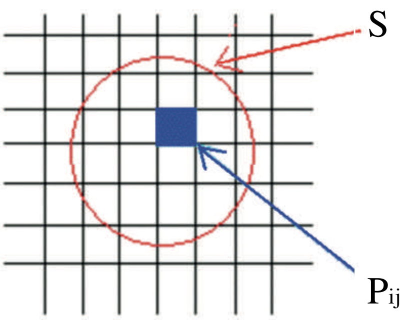

Figure 1 A measurement area S and a pixel within S.

3. Experimental procedures and results

2.1 Experimental procedures

The Wiener estimation with the noise variance estimated by the previous proposal and with the autocorrelation matrix of spectral reflectances of the Macbeth ColorChecker were used for W in Eq.(1). The seven channels multispectral camera, in which spectral sensitivities of the channels were optimized by a colorimetric evaluation model of the sensors (Shimano (2005)), was used for image acquisition under the illumination of the Solax which simulates daylight illumination.

Three different types of art paintings, a watercolor painting, an oil painting and a Japanese painting drawn with natural mineral pigments, were used for image acquisition and their spectral reflectances were recovered at the pixel resolution. Figure 2 shows Japanese art painting with 18 selected points used to evaluate the recovery performance. Each spectral reflectance was measured by the spectrophotometer (Minolta CM2022). The diameter of the instrument was about 3mm. The spectral reflectances were recovered by the Wiener filter for all pixels in the diameter.

3.2 Experimental results

Table 1 summarizes the recovery performances, in which MSE represents the mean square error between the actual spectral reflectances measured by the spectrophotometer and recovered spectral reflectances over the 18 points, and ΔEab* is the color difference in the CIELAB color space under D65 illumination. We searched each measured point which gives the minimum Euclid norm of the difference vector between a measured and a recovered spectral reflectance vector. We selected one pixel within each area S which gives the minimum error in the recovered spectral reflectance and the MSE was obtained by averaging the minimum errors over the 18 points, and it is denoted as "One pixel". "Mean" shows that the average spectral reflectances recovered by all pixels in the area were used for calculating the MSE. The table shows that the mean spectral reflectance is more accurate than that of one pixel and this result means that averaging spectral reflectances recovered by all pixels within the measurement area is the right approach for evaluating the recovery performance for the art paintings. This result was also hold for other paintings. Figure 3 shows a typical example of the two types of the recovered spectral reflectances from the pixels in the point 3 in Figure 2 (to discriminate the difference, the spectral reflectances are enlarged by limiting the wavelengths and reflectances regions).

Figure 2 A Japanese painting used for the evaluation.

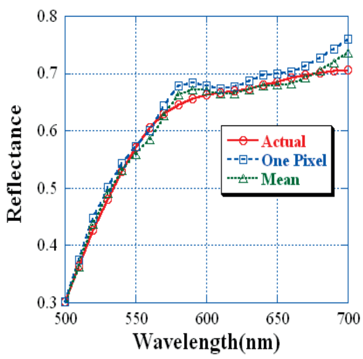

Figure3 Typical exaples of the recovered spectral reflectances.

Table 1. Results on the evaluation by two methods

Method	MSE	ΔEab*
One Pixel	0.0154	1.67
Mean	0.0123	1.29

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4. Conclusion

We addressed the evaluation method of the recovery performance of art paintings. It is shown that averaging the spectral reflectances recovered by all pixels within the area used for the measurement is the right approach in order to evaluate the accuracies of the recovered spectral reflectances of the paintings.

Acknowledgments

N. Shimano was supported in part of his work by the Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (C) 20500173, 2010.

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The real and the ideal fashion image type and the color image favored by contemporary Korean women

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Abstract

The purpose of this study is to classify the real fashion image and the ideal fashion image favored by Korean women in their twenties and thirties, and to find out the standards and color features that divide such a classification. For this study, we used the Q method, which is regarded as an effective way to assess subjectivity. The analyzed materials were divided into two real fashion frames and two ideal fashion frames, and classified into 12 fashion image types in total. That is, six real fashion images and six ideal fashion images. We then named each type of fashion image and analyzed the features and color images of each fashion image type through an in-depth Q workshop in which 14 professionals participated.

1. Research procedure

We used the Q method, which is regarded as an effective way to assess subjectivity, for the collection and analysis of materials, in order to objectively classify the perception of and response to the fashion image. The subjects of this study were 60 women in total, 30 in their twenties and 30 in their thirties and all of them resided in Seoul. For the survey, fashion image excitant are composed of 88 fashion images which best reflect Korean women's fashion in their twenties and thirties. These images were selected from 56 books of 5 magazines having the highest market share were published between May 2009 and April 2010. We collected the Q response materials by showing the 88-page Q sample to the subjects, and performed a Q factor analysis using the PC-version of the QUANL program and SPSS 15.0 statistics program. The analyzed materials were divided into two real fashion frames and two ideal fashion frames, and classified into 12 fashion image types in total. That is six real fashion images and six ideal fashion images. We then named each type of fashion image and analyzed the features and color images of each fashion image type through an in-depth Q workshop in which 14 professionals participated.

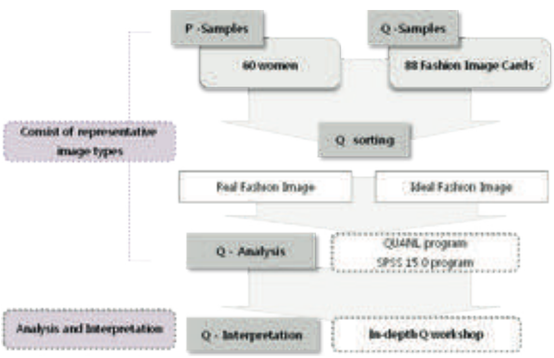

Figure 1. Research procedure

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a) b) c)

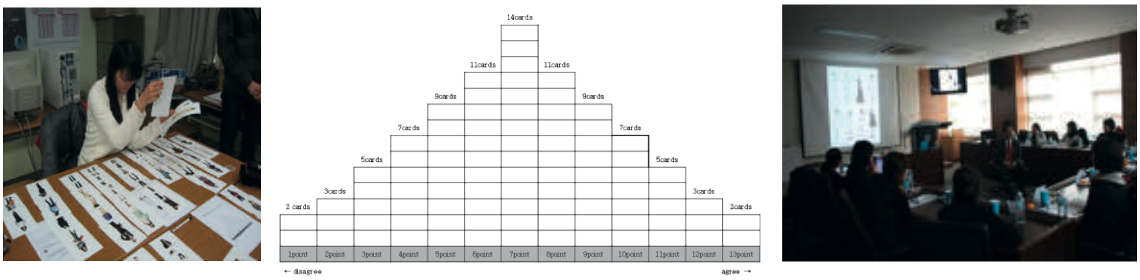

Figure 2. a) Q-sorting *b) Q- Allocation table* *c) Q- Workshop*

2. Results

2.1 The real fashion frame of Korean women in their twenties and thirties

The real fashion frame of Korean women in their twenties and thirties was largely divided into 'Fashion Gold Girl,' the mainstream fashion frame and 'Indi-idol,' the subculture fashion frame. It was minutely divided into six fashion image types, these are, 'Basic Casual', 'Vintage Performer,' 'Easy Chic,' 'Ladies' Look,' 'City Office Girl' and 'Club Mania'. The 'Basic Casual' type is a lively, casual and popular image; the 'Vintage Performer' type reflects the image of strong individuality and artistic sensibility; the 'Easy Chic' type is the image of an attractive and fashionable woman; the 'Ladies' Look' type is the image of an ordinary and conservative housewife; the 'City Office Girl' type is the image of a professional and refined office girl; and lastly the 'Club Mania' type is the image of a dynamic rebel. Each type has key common characteristics: 'Basic Casual' and 'Vintage Performer' types pertain to individuality; 'Easy Chic' and 'Ladies' Look' types pertain to style and composure; and 'City Office Girl' and 'Club Mania' pertain to practicality. Such key common characteristics - individuality, style, composure, and practicality - are interpreted to be the determining factors of the realistic fashion frame for Korean women in their twenties and thirties. They also work as the standard to divide the fashion image type.

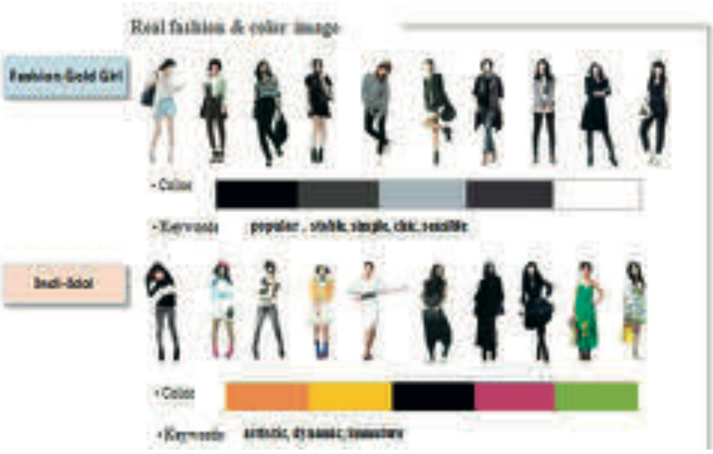

Figure 3. Real fashion frames & color image

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2.2 The ideal fashion frame of Korean women in their twenties and thirties

The ideal fashion frame of Korean women in their twenties and thirties was divided into 'Urban Refinement,' the fashion frame of the mainstream and 'Mismatched Style,' the fashion frame of subcultures. It was also divided into six fashion image types, that is, 'Power Fashion', 'Fashion Conservative', 'Semi-culture', 'Fashion Otaku', 'Sweet Darling' and 'Fashion Panic'. The 'Power Fashion' type portrays the image of a stylish trendsetter with strong individuality; the "Conservative Fashion" type presents the image of a stubborn housewife; the 'Semi-Culture' type presents the image of someone who pursues culture which represents the casual "missy" look; the 'Fashion Otaku' type is an improvisatory and showy image; the 'Sweet Darling' type is a lovely and soft image; and lastly the 'Fashion Panic' type is an image whose concept is obscure and awkward. The 'Power Fashion' and 'Fashion Conservative' types are those who lead and are indifferent to trends; The 'Semi-Culture' and 'Fashion Otaku' types portray different perspectives of culture: popular culture and minority culture, while the 'Sweet Darling' and 'Fashion Panic' types are divided into open and closed types due to the characteristic of outsider. Such key common characteristics - fashion presentation, culture and outsider status - are interpreted as decisive factors for the ideal fashion frame of Korean women in their twenties and thirties and the key common characteristics work on dividing the fashion image type.

Figure 4. Ideal fashion frames & color image

2.3 Color image of fashion image types

Each type is represented by a certain color; in the mainstream and the subculture fashion frames, respectively. We can see common colors emerge within the real and the ideal images, though there are clear differences between the mainstream and the subculture themselves. The mainstream frame consisted mostly of monotones, like black and white. The frame's main colors are cold, and vivid red and red purple are presented as its accent colors. In contrast, the subculture frame consisted mainly of vivid warm colors and black was presented among monotones. When we combine all these factors, the mainstream fashion frame of Korean women in their twenties and their thirties is the image of an urban and refined professional woman. The image is represented by modern black and refined cold colors. Also, the fiercely individual, unique, striking and mismatched image of the subculture fashion frame was represented by vivid red, yellow, yellow red, green yellow and green colors.

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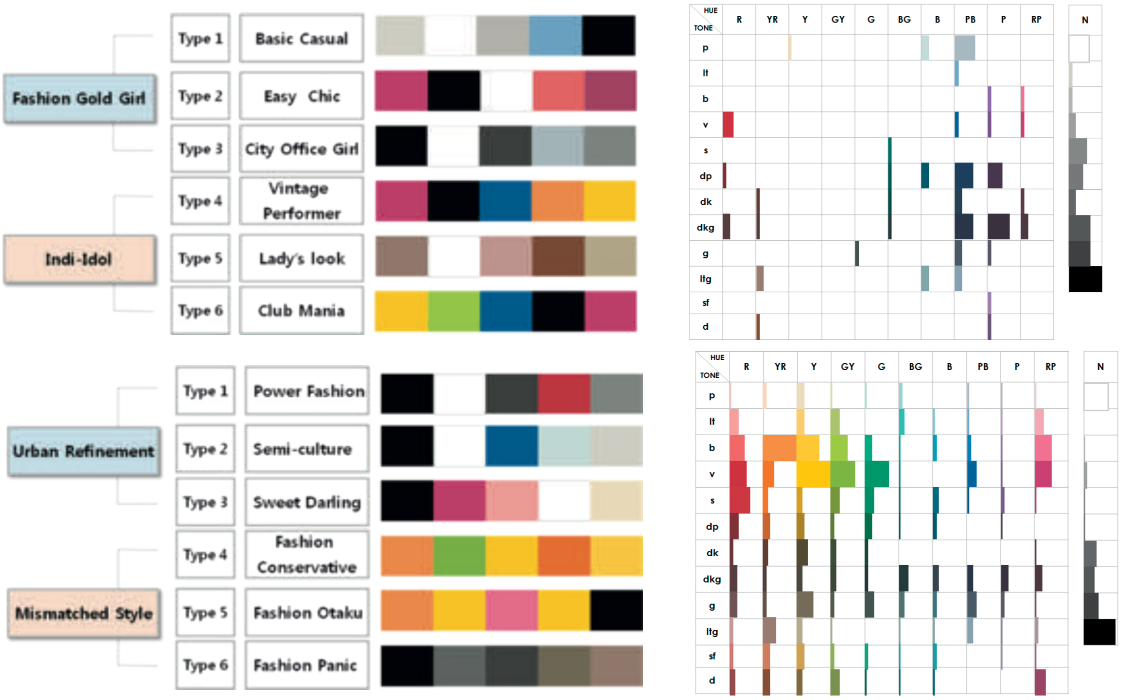

Figure 5. Color image of fashion image types

3. Conclusion

This study clarified that the real fashion image and the ideal fashion image favored by Korean women in their twenties and in their thirties were classified into types that can be objectively perceived. Through more, it can be seen that color is a medium of common sensitivity with which human beings perceive and express images because the recognizable features of color images were distinctively divided by each fashion image type. This study is meaningful in that it used the Q-method instead of the adjectives which had been used before to express images, so that the 'subjective' estimation was analyzed into 'objective' types.

Acknowledgments

This study was supported by the National Research Foundation of Korea(NRF) grant funded by Korea government(MEST)(No.2009-0077523).

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Observer metamerism potentiality of a metameric pair

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Abstract

Observer Metamerism is defined as a property of a pair of spectrally different stimuli having the same color sensation for an individual (reference) observer. Frequently, samples in this pair no longer match if the observer is changed. In this article a linear approximation formula is developed, which predicts a metameric effect (ΔL^*, Δa^*, Δb^*) caused by small changes $\Delta\vec{x}=\Delta\vec{x}(\lambda)$, $\Delta\vec{y}=\Delta\vec{y}(\lambda)$, $\Delta\vec{z}=\Delta\vec{z}(\lambda)$ of observer's color matching functions $\vec{x}=\vec{x}(\lambda)$, $\vec{y}=\vec{y}(\lambda)$ and $\vec{z}=\vec{z}(\lambda)$. This approximation formula enables us to define a general metric of observer metamerism, OMP (observer metamerism potentiality), which is independent of any particular deviated observer but it still provides a close link to "metameric" color difference. The results of numerical experiment are presented in which we investigated the correlation between OMP and the maximum of 20 metameric color differences caused by the change from the color matching functions (CMFs) of CIE standard 10-degree observer to the CMFs of 20 real 10-degree observers. The most important subject of our research was to determine an upper-bound for "observer-metameric" colour difference $\Delta E_{observer}$ that can be exhibited by a given metameric pair under any particular from the set of considered test observers. The inequality to calculate such upper-bound is presented.

1. Approximation of color shift caused by observer's CMF-change

Recently, a new general metric of illuminant metamerism, the quantity Illuminant Metamerism Potentiality (IMP) of a metameric pair was introduced and analyzed (Peyvandi S. et. al., 2009). In the present paper a similar approach is used for defining the Observer Metamerism Potentiality (OMP) of a metameric pair, and to calculate its value. The concept will be presented for the case of 16 considered wavelengths (20-nm steps) within the visible spectrum [400nm, 700 nm]. The generalization to any other number of considered wavelengths is quite straightforward. Let's have a metameric pair: two metameric samples, standard and ist match, having different reflectance curves $\vec{R}_{std}=(R_{std,1},R_{std,2},\ldots,R_{std,16})$ and $\vec{R}_m=(R_{m,1},R_{m,2},\ldots,R_{m,16})$, respectively. Let both samples match in color for certain reference viewing conditions: for the illuminant SPD $\vec{S}=(S_1,S_2,\ldots,S_{16})$, and for the observer (say, standard 10-degree) defined by color matching functions $(\bar{x}_1,\bar{x}_2,\ldots,\bar{x}_{16})$, $(\bar{y}_1,\bar{y}_2,\ldots,\bar{y}_{16})$, $(\bar{z}_1,\bar{z}_2,\ldots,\bar{z}_{16})$ (in short: CMFs). A small change/deviation of observer CMFs $(\Delta\bar{x}_1,\Delta\bar{x}_2,\ldots,\Delta\bar{x}_{16})$, $(\Delta\bar{y}_1,\Delta\bar{y}_2,\ldots,\Delta\bar{y}_{16})$, $(\Delta\bar{z}_1,\Delta\bar{z}_2,\ldots,\Delta\bar{z}_{16})$ can be written also in the form:

$$\Delta\vec{T}=\left(\Delta\bar{x}_1,\Delta\bar{x}_2,\ldots,\Delta\bar{x}_{16},\Delta\bar{y}_1,\Delta\bar{y}_2,\ldots,\Delta\bar{y}_{16},\Delta\bar{z}_1,\Delta\bar{z}_2,\ldots,\Delta\bar{z}_{16}\right)^T .$$

When the observer's sensitivities

$$(\bar{x}_1,\bar{x}_2,\ldots,\bar{x}_{16}),\ (\bar{y}_1,\bar{y}_2,\ldots,\bar{y}_{16}),\ (\bar{z}_1,\bar{z}_2,\ldots,\bar{z}_{16}),$$

are slightly changed/perturbed from $\vec{T}=\left(\bar{x}_1,\bar{x}_2,\ldots,\bar{x}_{16},\bar{y}_1,\bar{y}_2,\ldots,\bar{y}_{16},\bar{z}_1,\bar{z}_2,\ldots,\bar{z}_{16}\right)^T$ to $\vec{T}+\Delta\vec{T}=\left(\bar{x}_1+\Delta\bar{x}_1,\ldots,\bar{x}_{16}+\Delta\bar{x}_{16},\bar{y}_1+\Delta\bar{y}_1,\ldots,\bar{y}_{16}+\Delta\bar{y}_{16},\bar{z}_1+\Delta\bar{z}_1,\ldots,\bar{z}_{16}+\Delta\bar{z}_{16}\right)^T$, then

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the color position (L^*, a^*, b^*) of a particular sample $\vec{R} = (R_1, R_2, \ldots, R_{16})$ changes to color position

$$(L^*, a^*, b^*) + (\Delta L^*, \Delta a^*, \Delta b^*) .$$

The resulting small color-position change is approximately:

$$(\Delta L^*, \Delta a^*, \Delta b^*)^T = \mathbf{J}_O \cdot \Delta \vec{T} \ , \tag{1}$$

or written more elaborately as:

$$(L^*_{\mathrm{II}} - L^*_{\mathrm{I}}, a^*_{\mathrm{II}} - a^*_{\mathrm{I}}, b^*_{\mathrm{II}} - b^*_{\mathrm{I}})^T = \mathbf{J}_O \cdot \left(\Delta\bar{x}_1, \ldots, \Delta\bar{x}_{16}, \Delta\bar{y}_1, \ldots, \Delta\bar{y}_{16}, \Delta\bar{z}_1, \ldots, \Delta\bar{z}_{16}\right)^T$$

where the indices I and II indicate reference observer $\vec{T}$ and deviated observer $\vec{T} + \Delta\vec{T}$, respectively.

The matrix $\mathbf{J}_O$ is the matrix of partial derivatives:

$$\mathbf{J}_O = \begin{bmatrix} 0 & 0 & \cdots & 0 & \dfrac{\partial L^*}{\partial \bar{y}_1} & \dfrac{\partial L^*}{\partial \bar{y}_2} & \cdots & \dfrac{\partial L^*}{\partial \bar{y}_{16}} & 0 & 0 & \cdots & 0 \\ \dfrac{\partial a^*}{\partial \bar{x}_1} & \dfrac{\partial a^*}{\partial \bar{x}_2} & \cdots & \dfrac{\partial a^*}{\partial \bar{x}_{16}} & \dfrac{\partial a^*}{\partial \bar{y}_1} & \dfrac{\partial a^*}{\partial \bar{y}_2} & \cdots & \dfrac{\partial a^*}{\partial \bar{y}_{16}} & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & \dfrac{\partial b^*}{\partial \bar{y}_1} & \dfrac{\partial b^*}{\partial \bar{y}_2} & \cdots & \dfrac{\partial b^*}{\partial \bar{y}_{16}} & \dfrac{\partial b^*}{\partial \bar{z}_1} & \dfrac{\partial b^*}{\partial \bar{z}_2} & \cdots & \dfrac{\partial b^*}{\partial \bar{z}_{16}} \end{bmatrix}_{3x48} \tag{2}$$

Using the approach similar to that of Wang et al. (2005), the partial derivatives, which appear in the matrix $\mathbf{J}_O$, can be calculated:

$$\frac{\partial L^*}{\partial \bar{y}_i} = \frac{116}{3}\left(\frac{Y}{Y_0}\right)^{-2/3}\left(\frac{Y_0 R_i - Y}{Y_0^2}\right)E_i \tag{3}$$

$$\frac{\partial a^*}{\partial \bar{x}_i} = \frac{500}{3}\left(\frac{X}{X_0}\right)^{-2/3}\left(\frac{X_0 R_i - X}{X_0^2}\right)E_i \tag{4}$$

$$\frac{\partial a^*}{\partial \bar{y}_i} = -\frac{500}{3}\left(\frac{Y}{Y_0}\right)^{-2/3}\left(\frac{Y_0 R_i - Y}{Y_0^2}\right)E_i \tag{5}$$

$$\frac{\partial b^*}{\partial \bar{y}_i} = \frac{200}{3}\left(\frac{Y}{Y_0}\right)^{-2/3}\left(\frac{Y_0 R_i - Y}{Y_0^2}\right)E_i \tag{6}$$

$$\frac{\partial b^*}{\partial \bar{z}_i} = -\frac{200}{3}\left(\frac{Z}{Z_0}\right)^{-2/3}\left(\frac{Z_0 R_i - Z}{Z_0^2}\right)E_i \tag{7}$$

A similar manner can be applied to calculate the elements of the Jacobian matrix $\mathbf{J}_O$ when the values X/X_n, Y/Y_n and Z/Z_n are lower than 0.008856, respectively. In such cases the formula $L^* = 903.29(Y/Y_n)$ for L^* should be used, and the formula $f(X/X_n) = 7.787(X/X_n) + 16/116$ should be used instead of $f(X/X_n) = (X/X_n)^{1/3}$.

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2. Definition and calculation of OMP

Eq. (1) can be re-written for the standard sample and its match, then the obtained approximations of corresponding colorimetric shifts can be substracted to get:

$$\begin{bmatrix} L^*_{\mathrm{II},s} - L^*_{\mathrm{I},s} \\ a^*_{\mathrm{II},s} - a^*_{\mathrm{I},s} \\ b^*_{\mathrm{II},s} - b^*_{\mathrm{I},s} \end{bmatrix} - \begin{bmatrix} L^*_{\mathrm{II},m} - L^*_{\mathrm{I},m} \\ a^*_{\mathrm{II},m} - a^*_{\mathrm{I},m} \\ b^*_{\mathrm{II},m} - b^*_{\mathrm{I},m} \end{bmatrix} = (\mathbf{J}_{O,std} - \mathbf{J}_{O,m}) \cdot \Delta\vec{T} \tag{8}$$

Left-hand side in Eq. (8) is (the approximation of) the metameric CIELAB color-difference vector $(\Delta L^*, \Delta a^*, \Delta b^*)^T$, and $\Delta T = (\Delta\bar{x}_1, \Delta\bar{x}_2, \ldots, \Delta\bar{x}_{16}, \Delta\bar{y}_1, \Delta\bar{y}_2, \ldots, \Delta\bar{y}_{16}, \Delta\bar{z}_1, \Delta\bar{z}_2, \ldots, \Delta\bar{z}_{16})^t$ is a (small) change of the observer's CMFs. An important consequence of Eq. (9) is the following estimation for the trully metameric effect caused by a small change $\Delta T = (\Delta\bar{x}_1, \Delta\bar{x}_2, \ldots, \Delta\bar{x}_{16}, \Delta\bar{y}_1, \Delta\bar{y}_2, \ldots, \Delta\bar{y}_{16}, \Delta\bar{z}_1, \Delta\bar{z}_2, \ldots, \Delta\bar{z}_{16})^t$ of observer CMFs:

$$\Delta E = \left\| (\Delta L^*, \Delta a^*, \Delta b^*)^T \right\| \leq \left\| (\mathbf{J}_{O,std} - \mathbf{J}_{O,m}) \right\|_2 \left\| \Delta\vec{T} \right\| \tag{9}$$

The *Observer-metamerism potentiality* of a metameric pair can be defined as the biggest rate of varying the „observer-metameric" color-difference vector $\Delta\vec{V} = (\Delta L^*, \Delta a^*, \Delta b^*)^T$ of matched samples across all possible directions
$\Delta\vec{T} = (\Delta\bar{x}_1, \Delta\bar{x}_2, \ldots, \Delta\bar{x}_{16}, \Delta\bar{y}_1, \Delta\bar{y}_2, \ldots, \Delta\bar{y}_{16}, \Delta\bar{z}_1, \Delta\bar{z}_2, \ldots, \Delta\bar{z}_{16})^T$ of small variation in color matching functions (observer sensitivities $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$) over wavelength spectrum:

$$\mathrm{OMP} = \max_{\Delta\vec{T} \neq \vec{0}} \frac{\left\| \Delta\vec{V} \right\|}{\left\| \Delta\vec{T} \right\|} = \max_{\Delta\vec{T} \neq \vec{0}} \frac{\left\| (\mathbf{J}_{O,std} - \mathbf{J}_{O,m}) \cdot \Delta\vec{T} \right\|}{\left\| \Delta\vec{T} \right\|} = \left\| (\mathbf{J}_{O,std} - \mathbf{J}_{O,m}) \right\|_2 \tag{10}$$

Remark 2. The CIE $L^*a^*b^*$, CIE L^*C^*h and CMC$(l:c)$/CIE94 versions of observer-metamerism potentiality of a metameric pair can be calculated as well.

3. Numerical experiments

In order to study how reliably the OMP of a metameric pair can describe the magnitude of observer metamerism, let us consider a set of metameric pairs, a set of metameric spectra that are numerically generated for an individual target color stimuli under a reference condition. The metameric reflectance curves of this particular target color satisfy the matching condition under a CIE 1964 standard observer and D65 standard illuminant. The Spectral database containing the reflectances of 1269 chips in the Munsell Book of Color Matt Finish collection (University of Joensuu Color Group, http://spectral.joensuu.fi/) was considered as the set of standard samples. For each particular standard sample, a large variety of metameric stimuli was generated by the metameric black method; each of these stimuli would match the corresponding standard under illuminant D65 and 1964 standard observer. In this research, the color matching functions of 20 different real observers in the 10-degree visual field (Wyszecki G. & Stiles W.S., 1982) were considered as the deviated test observers. The Munsell color chip 5GY 4/2 was selected to illustrate a typical results of this study. In the right-hand side diagram the set of reflectance curves is presented that

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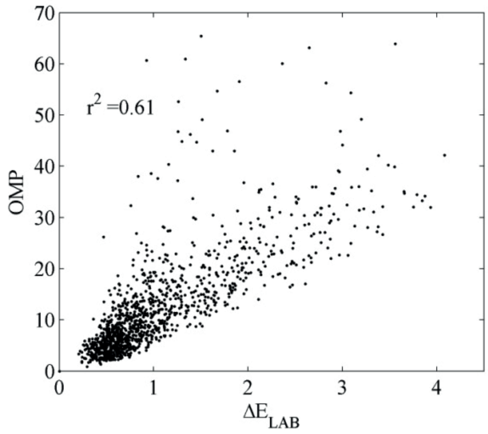
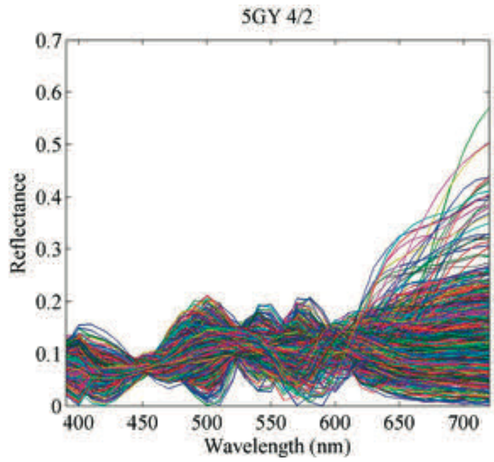
are metameric match for CIE 1964 standard observer and D65 standard illuminant. In the left-hand side diagram bellow the scatter-plots of OMP versus maximum of 20 "observer-metameric" colour differences is presented.





4. Conclusions

A linear approximation formula was developed which links an arbitrary (small) observer CMF-change to the colorimetric shift of a reflecting sample. The application of this formula to a metameric pair of reflecting samples gave another linear approximation formula, which transforms an arbitrary observer CMF-change to the truly-metameric effect – the color-difference vector between the color positions of metameric samples after the observer's CMFs had been slightly changed. The Observer Metamerism Potentiality of a metameric pair (OMP) was defined. This is a new general metamerism index for describing and predicting the total degree of observer metamerism, it is independent of any particular small observer's CMF-change but it still provides a close link to color difference. In numerical experiments we investigated the correlarion between OMP and (maximum of 20) metameric color difference(s) ΔE caused by particular changes from CIE Standard 10-degree Observer's CMFs to the CMFs of the 20 real 10-degree observers. In most cases, medium to high correlation between the OMP and the maximum of „observer-metameric" color differences was found. As the most important goal in this reseach was to determine an upper-bound for "observer-metameric" colour difference $\Delta E_{observer}$ that can be exhibited by a given metameric pair under any particular from the set of considered test observers; the inequality to calculate such upper-bound is presented.

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Color configurations of Jaipur palaces

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Abstract

Color is a vital element in architecture and design. It informs and speaks to us in various ways, gives expressions to the space and enhances its visual language. The study aims to identify colour shades on the exteriors and in the courtyards of the palaces in Jaipur. The exterior color is a gesture of a building and courtyards are the most interactive and festive spaces. The hot and dry climate of Rajasthan with its architectural style comprising of open and semi open spaces receives optimum stark daylight. Its political capital Jaipur is an example which has creatively used colour in the parched landscape which is elaborately demonstrated in its traditional palaces. The premise of the study is confined only to the assessment of perceived colors of the palace buildings and does not include the study of inherent colour or the application techniques and methods. In this paper, the focus is to unfold the attributes of its use in the palaces that have created the resulting color configurations completely studied under natural lighting conditions. It creates a rationale of colors and factors governing the relation between hues, expounding their play in the palaces of Jaipur. This can be used in today's context for the purpose of conservation and for the architectural colorations, art and other fields of design as an essence of colors in the palaces of Jaipur.

1. Introduction

India portrays a wide range of colors in architecture which is governed by the regional, climatic and cultural diversities. The state of Rajasthan and its political city Jaipur is a hub for traditional crafts and its polychromatic display of color which is known internationally. The palaces belonged to the royal clans where they used the best possible features of aesthetic representations, through the fine workmanship of the use of color. Assesment of color is done for the important space making elements in the courtyards such as walls, columns, gates, doors and openings, semi open spaces comprising of pavilions inside courtyards. Colors in the palaces are seen as kaleidoscopic visual mix. They show a strong traditional background and are related to traditional Indian treatise which explains their existence. These colors show strong relevance with the local crafts in Jaipur, where they portray their metaphor in architecture. Textiles and paintings are the major contributors to the life style in Rajasthan and it has been like a trigger to the development of the tradition of color. The surface colorations in palaces have brought out the metaphors of the traditional crafts in architecture. All these colors are best sensed as a visual display than described but to understand their interactions, there is a need of a system that will break down the components of colors and help in a systematic analysis. There are several colors that human eye perceives and it is difficult to describe the color verbally. Hence, NCS has helped in plotting the exact color shades which has helped in analyzing them along with a set of parameters derived out of observations.

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2. Methods

The palaces are identified and assessed as a visual match with a NCS fan deck of 1,950 colour shades in the natural light in the month of March 2010 in between 10.00 a.m to 5.00 p.m. Extensive photographs have been taken as a part of the documentation. The color pigments and influences for the use of colors have been identified. The interaction of color and natural light creates variation in their appearance in the morning, afternoon and evening. Further the analysis parameters are derived out of overall observations, finally performing a comparative analysis.

3. Color pigments and influences and associations

Color pigments in Rajasthan have a strong traditional origin and have governed the schools of painting. In the Vedic tradition, the transformation of mineral stones and metals into colour pigments is seen as an inherently alchemical journey. They have been identified as primary colours and secondary colours. The surface colorations show direct influences of the color shades and designs seen in the crafts of blue pottery, mandana paintings and the colours in the textiles of Sanganer and leheriya fabrics. They are specific to Jaipur and are flourishing sectors. These crafts are seen as objects, but their replicas on the buildings are an overall manifestation of colors on the horizontal and vertical planes experienced in the natural light. This play of light and shadow on the architectural form is an interesting aspect noted.

Mandana painting *Blue pottery* *Leheriya(wave patterns) textiles*

Figure 1. Series of pictures showing colors in crafts and in architecture. The terracotta brown color, bluepottery and wave patterns on the textiles of leheriya

4. Analysis parameters

There are two sets of analysis parameters which are clubbed together. The first set is the one that is derived out of the NCS plotting, where the colors are segmented in their singular components of hue, chroma, nuance, blackness and whiteness. The analysis parameters derived out of the observations are categorized as color as massing and color as decoration. These further are governed by two sub parameters – firstly geometry, motifs and patters and secondly the relation between hues.

5. Analysis

The palaces selected for the study are – City Palace complex Jaipur comprising of the main palace building, Hawa Mahal, Jantar Mantar, and other palaces like the fort of Amber and Samode Haveli.

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Figure 2. City Palace Jaipur: Peacock gate and the facade of the palace.

Figure 3.Amber fort

Figure 4. Samode haveli

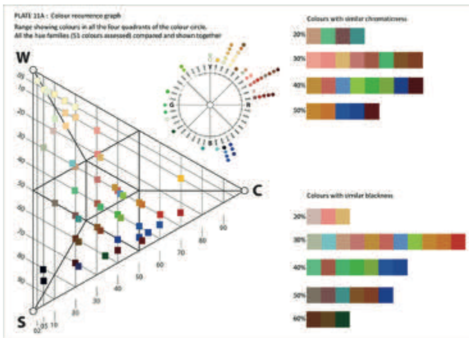

Figure 5. Plotted NCS graph

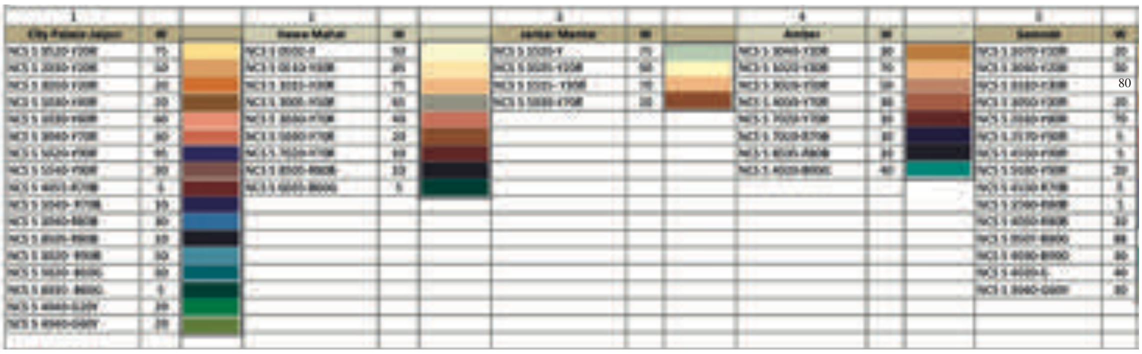

Figure 6. Enitre color palette of the palaces describing the rationale of colors as a comparitive

The most prominent color families seen for massing are in the range of Y70R, Y20R, Y30R. The connotations show the details of the colors as per the plotting done in NCS. The colour families of all the palaces demonstrate that most of the colours have their blackness in the range of 30-50% and whiteness in the range of 20-30%. This quantifies the pastel character of the colours. The colour as massing and as decoration highly falls in the range of off-whites. The other colour families identified fall between: R70B, R80B, B10G, B90G and G60Y. The layering and revealing of architecture is enhanced due to the modulations in the use of colors.

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6. Outcome

The colors used are not many, but the kaleidoscopic display is an outcome of the geometry and color compositions. The color summary of all the palaces show strong coherence. Also the exterior colours of the palaces are in harmony with the ochres seen in the city. The study can be used further for the conservation of the palaces in Jaipur in the present time as well as in the future. Colorations with such a sensitive approach on the basis of precise interpretation of color shades and color interactions can be imbibed in new contemporary spaces. Palaces are not very prevalent in today's context, but the essence of colors extracted from them has a wide range of applications. They have the potential to give a new dimension to colour usage for designers and craftsmen in the fields of art, design and interior architecture.

Acknowledgments

School of Interior Design, CEPT University, CEPT and NID libraries, gamut of people in Jaipur including the craftsmen and resource persons.

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The psychological and physiological effect of 'Cool Down Pink' on human behavior

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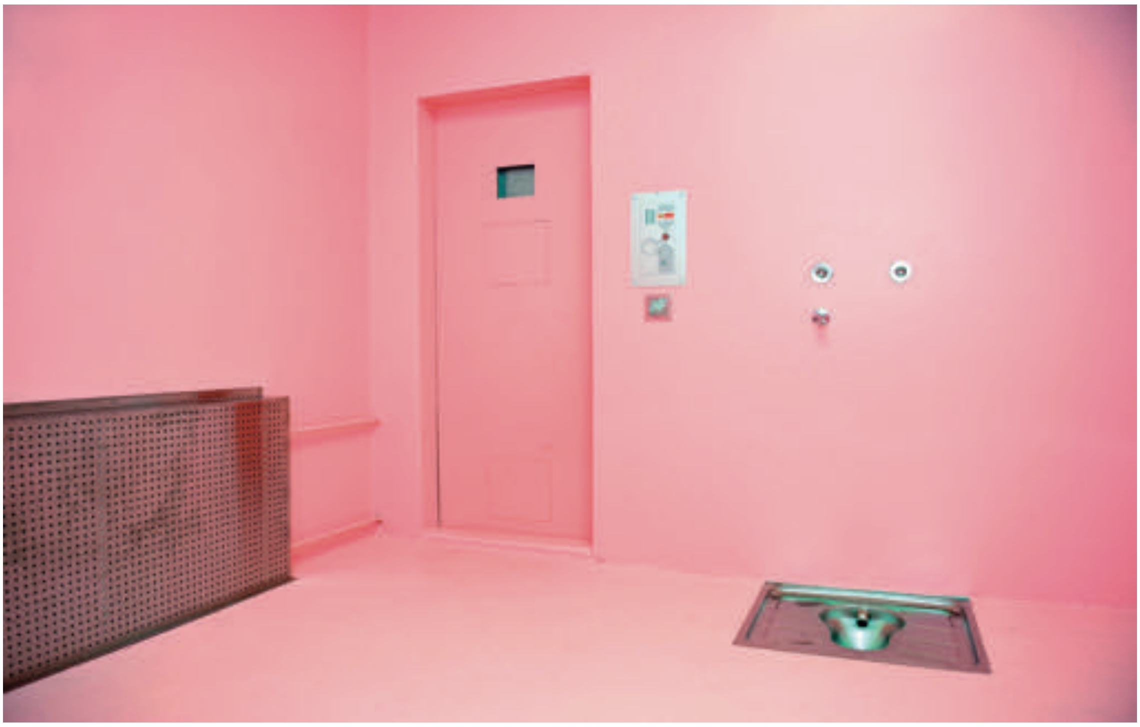
Abstract

The relaxing effect of Cool Down Pink is not only scientifically highly interesting but also includes effective solutions for a social problem: the increasing aggressivity in many domains, ranging from the penal system to schools, medical institutions and public security zones (airports, state borders, stations etc.).

After four years the application of Cool Down Pink in the penal system in Switzerland has shown positive results. According to the statements of the prison directors, the prisoners aggressive behavior has been greatly reduced. Even the aggressive prisoners are relaxing in a significantly shorter period. This means there is an efficient improvement in situations of arrest as well as an optimization of security.

Cool Down Pink has also been employed in various schools, psychiatric hospitals and institutions for mentally handicapped peoples. The evaluation is not yet completed.

Especially remarkable with the Cool Down Pink is that the effect becomes effective after only a few minutes and that it is based on an unconscious action and hence can be converted into an inconspicuous intervention measure.



Calming prison cell, Police Biel, Switzerland

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1. Methods

As security for the results a methodic triangulation of the subtypus across-method with a normed colour (Cool Down Pink) has been used.

- Measurement of the change of blood pressure and pulse rate before entrance and after the departure of the cabin.
- Observations of aggressive prisoners behavior change in Cool Down Pink cells in form of an unstructive, hidden and notparticipating observation as knowledge generating evaluation method.

1.1 Test situation in the colour cabin

The colour cabin has a base of 1 m^2 and a heigh of 2 m. Three walls as well as the ceiling are painted with Cool Down Pink. Illumination is with Osram Biolux full spectrum light. The cabin has been placed in various shopping centers. The participation was voluntarily. The duration was optional because some people react very strongly and violently to colours. Therefore a normed period of the time in the cabin has not been possible to establish. On average the duration of stay (period) ranged between 1 to 5 minutes. Before going into the colour cabin some particulars were noted (age, sex, state of health, favourite and refused colours). No detailed explanation of the test progress was provided to avoid influencing the probant. The blood pressure and pulse rate has been measured and noted. The probant entered the cabin and sat down facing the coloured wall. After leaving the cabin the blood pressure and the pulse rate measured once more and he or she was asked after his or her health.

There were no comparison measurements with a white cabin, because the probants has already been in a normal daily situation (shopping center) before entering the colour cabin. It is scientifically proven that within a socio-psychological evaluation already the observation leads to a behavioural change. Therefore a comparing research to a white colour cabin would not have been provided any information because it has not been established that the white colour works physiologically and psychologically neutral.

1.2 Evaluation procedure in the penal system

The evaluation has been used as an explorative method to research the interventional process. It is also usable as a hypothesis proving method to support the efficiency. The observations in the penal system (approximately ten prisons in Switzerland) were taken by the penal institution officers during their normal work. As a comparison the behaviour in white cells was also noted. Beside the aggressive behaviour (verbal attacks, violent attacks, damage to property, screaming, staining the walls with eces) it has been observed how quickly the prisoners relax.

Studies on the effect on drunken persons in cells and how quickly they become sober as well as in other spheres (schools, social institutions, psychiatric institutions, hospitals, security) are still currently being evaluated.

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2. Results

The validity of the common results were based on the used methodic triangulation of an objective measuring method (blood pressure and pulse rate measurement) and an evaluation measurement in the praxis transfer (observations). The results obtained from the different methods for the Cool Down Pink effect showed correlation to the validity of the research.

2.1 Results of the Cool Down Pink colour cabin

Table 1. Change in blood pressure

	Systolic blood pressure	**Diastolic blood pressure**	**Pulse rate**
Figures before	121 ± 28.9	87 ± 24.1	89 ± 17.5
Figures after	117 ± 28.5	83 ± 21.3	89.4
Significance P	**0.02***	**0.01***	0.83

Values as average values ± S.D.
Number of test persons: 193
statistical very significant, because P<0.03

The statistical shows highly significant results. As well as the systolic blood pressure the diastolic blood pressure sank in the Cool Down Pink cabin within 1-5 minutes with the above mentioned average values. Subanalysis concerning the sex, age or medical diagnose (blood high pressure) has not been carried out.

2.2 Preliminary results of the evaluation in the penal system

In the high security section of the prison Pfäffikon ZH, Switzerland four cells are since 2007 in Cool Down Pink installed. These cells are especially reserved for prisoners with a specially high aggression potential. According to the statement of the prison's director the aggressive behaviour of the concerned prisoners has greatly decreased. In police station cells it has been observed that the aggressive prisoners become quick much more relaxed than in the white cells and that they can return earlier to the normal police prison. The evaluations are finished in many places not yet. The interim findings support the present evaluation. Negative behaviour changes or side effects have not been observed. Based on the evaluation lasting four years the high security tract of the prison in Pfäffikon ZH the aggression depression effect of Cool Down Pink in the penal system can be confirmed.

3. Hypothesis and conclusions

The short reaction time (1-5 minutes) on the decrease in blood pressure and the fundamental blood pressure depression are indicators of a vegetative, hormonal steering mechanism which becomes activated by Cool Down Pink. Connections of the fiber structures in the visual route to the Hypothalamus (Nucleus suprachiasmaticus) as well as from the nucleus to the Epiphyse are today scientifically proven. The Epiphyse sets melatonin free and controls the endocrinical hormone system and regulates the essential activities. That means that the functions of vision go beyond the pure visual realisation. Connected with the hormonal system they influence directly our feeling of well-being. The hypothesis that the decrease in blood pressure due to Cool Down Pink becomes directly released in the interbrain is proven by this statement. Cool Down Pink

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primarily reduces the blood pressure. This is a pure corporal effect which leads in sequence to a psychological relaxation.

The realisation of colours is regarded as a multi-layer in the brain research: the physiology of the optic vision, the network with the hormonal system as well as the cognitive realization process.

The cognitive psychology concerns the process of realization and the question if and how human behaviour is conciously influenced by colours. Here we can observe complex behaviour phenomena, which are influenced by cultural or individual learning experiences.

In individual cases this can mean that a probant, who learned that pink is a female or gay colour (social influence), will not relax and that the blood pressure decrease will not occur. In connection with an intervention in the penal system this phenomenon has not been observed, because the prisoner cannot decide his handling by himself.

The blood pressure sinking effect proves Cool Down Pink to be an efficient and low threshold intervention instrument in the fight against aggression..

Acknowledgments

Dr. A.Paula Simões-Wüst, Head of Research, Paracelsus-Spital, Richterswil, Switzerland for scientific support

Dold AG, Lacke und Farben, Wallisellen, Switzerland for the technical support in the development of the product

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Misconceptions about HDR photography

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Abstract

The research was conducted, using a questionnaire, to get some actual information about how Croatian photographers see the HDR photography and how they employ it. The results of the questionnaire proved that indeed a great interest exists in the technique, but that many photographers are scared away from HDR photography because of the misconception that the artificial look is an unavoidable side effect of the HDR processing. However, the fact is that the final HDR image is a result of the tone mapping process and post-corrections and adjustments, entirely dependent on photographer's intent and vision, as well as his understanding of various adjustments available. The results of the questionnaire have also pointed out other widely spread misconceptions which are discussed in this paper.

1. Introduction

A general problem in photography has always been how to capture real world scenes which contain the range of luminance that considerably exceeds the dynamic range capabilities of camera (i.e. film or sensor) and output media (monitor, print). Conventional photographic materials, as well as digital image sensors cannot match the dynamic range of a scene, and can only capture a subset of luminance present (Reinhard 2010). In most situations photographers face the dilemma: how to capture details in the shadows without obtaining blown-out highlights and vice versa. By choosing the right combination of aperture and exposure time, photographers control the amount of light reaching the sensor (or film) and actually select the subset of the scene luminance they wish to capture. When the dynamic range of the scene is too large, it is not enough to simply adjust the exposure; something always had to be sacrificed – either you give up the details in shadows or those in the highlights. Photographers tried to resolve this problem, which exists since the advent of photography, by means of a handful of innovative methods and techniques, such as various darkroom techniques for film (e.g. dodging and burning), graduated neutral density (GND) filters for in the field use and a variety of digital post-processing techniques – one of which is the High Dynamic Range processing.

High Dynamic Range is a set of techniques which allows a greater dynamic range of luminance between the darkest and the lightest areas of an image by merging several different exposures of the same scene (Asla 2007). The idea is not new; its wider usage started just a few years ago with the rising popularity of digital cameras and the increase of computers processing power. Now this technique is widely spread and used, but more often - misused. The problem HDR technique faces nowadays is not a technology problem, but the problem of misconceptions and bad public impressions of it. It is a solid technique, but often used for wrong reasons and in a bad manner.

This paper deals with the impressions of HDR photography among photographers. It seems that all those involved in photography – both amateurs and professionals, have a certain attitude towards HDR photography. It is a highly debated topic on web blogs, photo club panels and round tables. Titles such as: *"Photorealism vs. surrealism"*, *"Is Velvet Elvis in the building"*, *"Exciting*

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new frontier or gimmick to avoid", *"Photo technology porn"* can be found on the Internet and in photo magazines. When typing HDR into Google, it brings out huge amounts of surreal, overly coloured, crazy looking photographs, photographs becoming illustrations. There is a very large Flickr group for HDR which sets the trend of "the over the top the better". Currently it has 75067 members, according to the Group Trackr (Taraborelli 2011). From all those discussions and photographs one can get the impression that the use of the HDR technique is out of control. Instead of using it with the purpose it is supposed to have, it is in most cases used just to show off. The technique became the foundation of an image and its sole purpose.

2. Method

The research was conducted, using a structured non disguised questionnaire, to get some actual information about how Croatian photographers see the HDR photography and how they employ it. Adequate questionnaire construction is critical to the success of a survey (Trochim 2006), so special care was taken in preparing appropriate questions, their order and scaling, according to the research objectives. Types of questions used in questionnaire was closed ended questions with multiple choice responses. Only last question, which was not mandatory, was open ended question (*"what is your opinion about HDR photography"*), where the respondent supplies their own answer without being constrained by a fixed set of possible responses.

The questionnaire was e-mailed to the respondents using the mailing lists of professional photographers from the Croatian Association of Artists of Applied Arts (ULUPUH) and the three largest photo clubs in the country. More than a hundred replies arrived and were later classified into professional and amateur group.

3. Results and discussion

The first question was: *"Do you know what the HDR technique is?"* There was a set of three possible responses: *Yes; No; Roughly*. Most respondents (89%) answered that they know what the HDR technique is, while only 9% respond that they roughly know, and 2% that they do not know what the HDR technique is. About the technique they learned through the Internet (45%), books and magazines (29%), fellow photographers (12%), photo club (9%) and expert lectures (5%).

On the question about employing the technique in their work, it was interesting to see that around half of the photographers respond that they use this technique occasionally (44%) and the other half (43%) that they have try out this technique, but do not use it in their work. Only 2% of the respondents state that they always use this technique in their work and, on the other side, 11% have not tried this technique.

For the question: *"For what field of photography do you think HDR is most applicable technique?"* there was the largest difference in the responses of amateur and professional photographers. It is interesting to notice that only amateur photographers (7%) were stated that HDR could be used for every scene and subject, while professional photographers thinks that it is best suited for photographing architecture and interiors (48%), landscapes (35%) and advertising (17%). Figure 1, shows the overall responses obtained from all photographers (professional and amateur).

On a question: *"When comparing HDR photograph with conventional (single exposure) photograph of the same (or similar) subject"*, only 4% of the respondents state that it looks more

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realistic, 27% responded answered that it looks more attractive, while other respondents had a negative impression of it (26% it looks artificially, 24% unrealistic, 19% exaggerated).

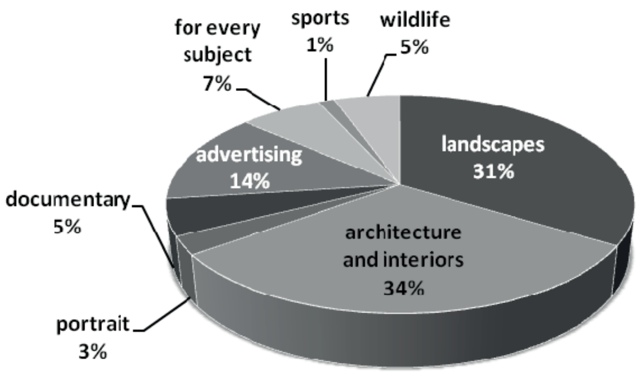

Figure 1. Responses on a question: "For what field of photography do you think HDR is most applicable technique?"

Except that there is a great interest in the HDR technique, the results of the questionnaire have also pointed out widely spread misconceptions about HDR photography.

The most common misconception is that the artificial look is an unavoidable side effect of the HDR processing and that the HDR photography always looks fake. It is generally believed that HDR images have a certain "Look" – the shadows full of detail and usually more colour then we would expect, unnaturally dark skies with stormy clouds and saturated colours, etc. However, the fact is that the final HDR image is a result of the tone mapping process. The aggressive tone mapping can produce extreme local contrast with halos, very saturated colors, noise and muddy textures. But this process of tone mapping and other post-corrections and adjustments, entirely depends on photographer's intent and vision, as well as his mastery and understanding of various adjustments available. HDR photography hence does not have to look exaggerated and fake. It is a matter of taste and measure.

Another widely spread misconception is that HDR technique can be used in any situation and for every scene and subject. For low contrast scenes there is no need for HDR technique. Also, the moving subjects are not suitable for HDR capture, because one takes several photos of the same scene with varying exposures. Capturing moving subjects with this technique can cause problems in post processing known as ghosting. This technique proved to be useful for architecture photography, where it is possible to balance wide range of luminance, e.g. when shooting interiors with windows, without using complex lighting equipment. It can be used to solve lighting problems, rather than to provide unreal effects that distort tonal values. It is also useful for taking photographs of landscapes in cases when the GND filter cannot fit the scene, and when it is not possible to get it right from only one RAW photograph. Another example of useful application of HDR technique is when it is necessary to enhance the texture of objects, or when the main purpose of photographs is to illustrate a service or a product, like often needed in advertising.

One of the misconceptions is that converting a single RAW, TIFF or even a JPEG image into a 32-bit HDR file will create a HDR image. The truth is that it is possible to make a conversion, but it does not create a greater dynamic range that the file already contains. The process will not add details in shadows that were not there already, or recreate highlights that were blown out.

Belief that the HDR technique is automatic is yet another common misconception. To get a good HDR image takes a lot more than just process it with keeping everything at its default

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settings. Each image needs to be custom processed. This could be very time consuming, but also rewarding, if done properly.

4. Conclusion

One of the respondents, who fill up the questionnaire, gave a nice comparison regarding the use of HDR technique. He said: *"It's like driving a fast car. No use of 500 kw if you didn't go to the driving school"*. Creating a good HDR photography is a technique that has to be learned. As with all new methods and techniques, there is an evolution of use. Photographers first experiment (often use to extreme) and eventually, with time, gaining the experience and knowledge how to settle on a more subtle and refined final images. And when they learn how and when to use it, then they can go back to taking good photographs focusing on the subject and the story they want to tell. And if the HDR technique could help to tell that story, then let it be!

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Yellow-blue colour discrimination in red-green colour deficiency

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Abstract

We measured the colour discrimination thresholds on the equal-luminance colour plane of CIE1976u'v' UCS diagram for trichromats and red-green colour-deficient trichromats. We compared between their thresholds in the yellow-blue direction. The results showed that the thresholds in yellow-blue colour changes for the red-green colour-deficient trichromats were not always larger than those for the normal trichromats. Further, our data suggest that the poor ability of the yellow- blue colour discrimination for the trichromats was caused by the interaction between the L-M mechanism and the S mechanism, although the S mechanism acts in the same way for both the red-green colour-deficient observers and the normal trichromatic observers.

1. Introduction

The protanopes and deuteranopes are well known as red-green colour-deficient person because they hardly discriminate between red colours and green colours due to lack of L cones or M cones. The colours which protanopes or deuteranopes perceives are restricted in yellow-blue colours, according to the colour appearance of a unilateral deuteranope (Graham and Hsia 1958). The dichromatic simulation proposed by Brettel et al. (1997) is based on her colour appearance. In their simulation, the property of yellow-blue mechanism of protanoupes and deuteranopes has been assumed to be the same as that of trichromats. However, a few studies report the yellow-blue color discrimination of red-green color-deficient person is poorer than that of trichromats as well as the red-green color discrimination (Chapanis 1944, Regan et al. 1994). If this is the case, the chromatic contrast of yellow-blue in the dichromatic simulation should be reduced in order to demonstrate the colour appearance of protanopes or deuteranopes more accurately. Here, we measured colour discrimination thresholds on the equal-luminance plane of the CIE1976u'v' UCS for red-green colour-deficient persons.

2. Method

2.1 Observers

Two normal trichromatic observers (SS and GM) and three red-green colour-deficient observers; one protanomalous (KI) and two deuteranomalous (MA and TI) trichromats participated in the experiment. Their colour visions were assessed by a Farnsworth-Munsell 100-hue test. They had normal or corrected-to-normal acuity.

2.2 Apparatus

The stimulus was generated by a high colour resolution graphic board (Cambridge Research Systems VSG 2/4) in a host personal computer (Dell Dimension XPS R350), and displayed on a 17-inch colour CRT monitor (SONY HMD-H200). The monitor was placed at the observer's viewing distance of 60 cm in a darkened room.

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2.3 Stimulus

The stimulus consisted of four rectangles with a large background (Figure 1). The four rectangles were arranged in 2 × 2. The sizes of each rectangle and the background were 1.4 deg and 20.6 deg, respectively. There were black gaps of 0.2 deg in between the rectangles and the background. The u'v' chromaticity of the four rectangles and the background was (0.1978, 0.4683), which was the D65 chromaticity. The luminance of them was 8.0 cd/m².

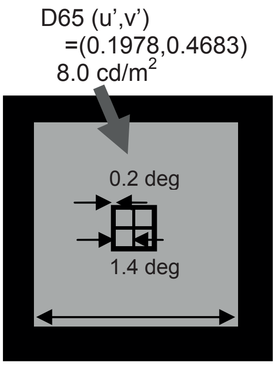

Figure 1. The stimulus used in the colour discrimination experiment.

2.4 Procedure

Following 3 minutes of dark adaptation, the experimental session was conducted. The stimulus was presented to an observer in a time course as shown in Figure 2. The four rectangles disappeared for 75 msec. And then, the four rectangles appeared for 150 msec. In this period, the colour of one rectangle was shifted to one of 16 directions in the u'v' chromaticity diagram, maintaining the constant luminance for individual observer. The colours of rest rectangles did not change. The four rectangles disappeared again for 75 msec, and then they appeared with the D65 chromaticity. The observer's task was to respond the position of the rectangle whose colour changed. The colour discrimination thresholds were measured by the staircase method, which followed a 1-up/3-down rule and that terminated after eight reversals. The threshold was determined by the average of the last four reversals.

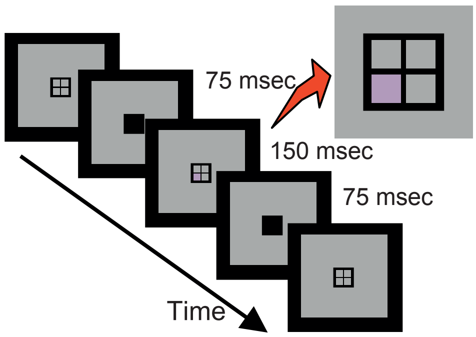

Figure 2. Time course of the stimulus presentation.

3. Results and discussion

Figure 3 shows the colour discrimination thresholds on the u'v' chromaticity diagram. The trichromatic observers' colour discrimination thresholds showed the shape of ellipse, whose major axis was along the v' direction. On the other hand, the major axis of the anomalous observers' ellipse accorded with the protanopic (observer KI) or deuteranopic (observers MA and TI) confusion line through the D65 chromaticity.

Comparing thresholds for the anomalous observers with those for the normal trichromatic observers, the thresholds along the S-cone axis of the anomalous observers were nearly equal to those for the normal trichromatic observers. The S mechanism seems to act in the same way for both the red-green colour-deficient observers and the normal trichromatic observers.

The colours used in the dichromatic simulation (Brettel et al. 1997) are yellows of the dominant wavelength of 575 nm, blues of the dominant wavelength of 475 nm, and achromatic colours. Thus, in the dichromatic simulation, the colour discrimination ability in those directions for protanoupes and deuteranopes has been assumed to be the same as that of trichromats. Here,

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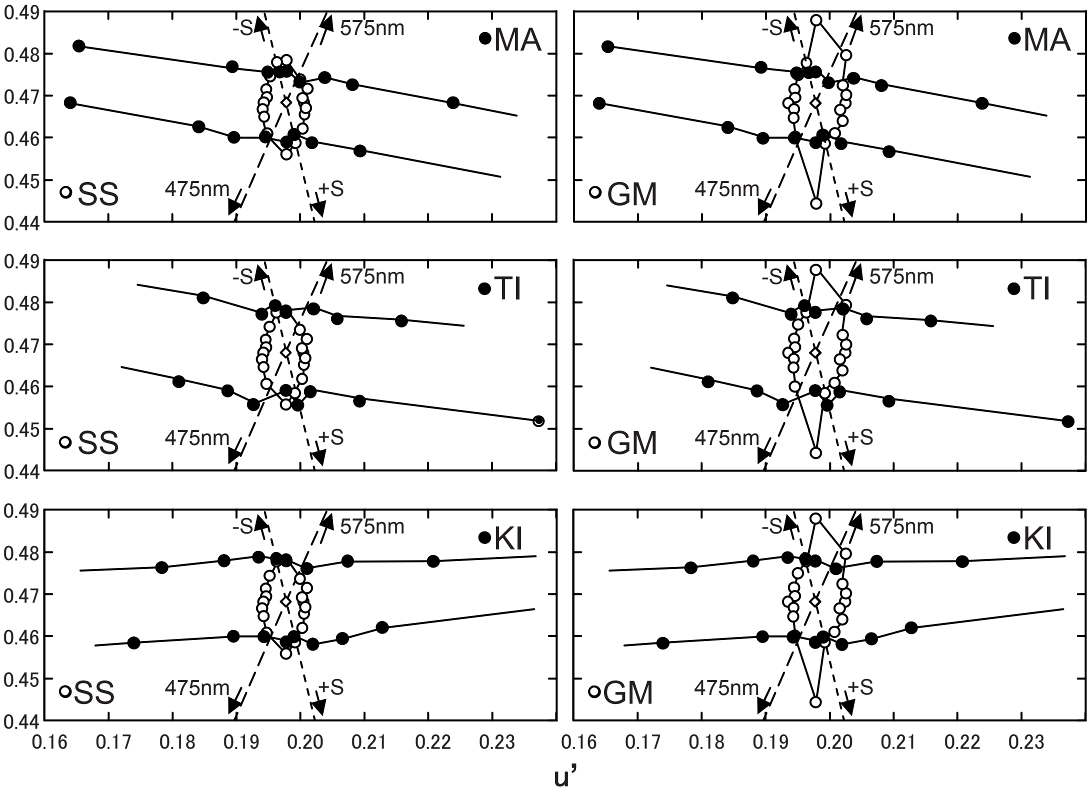

we compared the thresholds in the directions of 475 nm and 575 nm between the normal trichromatic observers and the red-green colour-deficient observers. The comparisons of the thresholds between the red-green colour-deficient observers and the normal trichromatic observers in those directions are shown in Table 1. The thresholds did not always agree between them, although individual differences were observed. Because the L-M mechanism can detect the chromatic changes toward 475 nm and 575nm for the normal trichromatic observers, the contribution of L-M mechanism would result in the differences between their thresholds. Although the thresholds in the direction of 475 nm were nearly equal between them, the thresholds for the colour deficient observers in the direction of 575 nm were larger than those for observers SS, and smaller than those for observer GM. Therefore, these results suggest that the contrast of yellow in the dichromatic simulation should be re-examined to demonstrate colour appearances of dichromats more accurately.

Table 1. The comparisons of the thresholds between the types of colour visions

475 nm			
	MA	**TI**	**KI**
SS	SS ≅ MA	SS < MA	SS ≅ KI
GM	GM ≅ MA	GM ≅ TI	GM ≅ KI
575 nm			
	MA	**TI**	**KI**
SS	SS ≅ MA	SS < MA	SS < KI
GM	GM > MA	GM ≅ TI	GM > KI

In addition, the thresholds in the v' direction for the normal observers were larger than those for the anomalous trichromatic observers, this is, the anomalous trichromatic observers could detect the colour change in the v' direction more easily than the normal trichromatic observers. The major axis of the colour discrimination ellipse for the trichromats was often apart from the S-cone axis (Sankeralli and Mullen 1996). Thus the interaction between the L-M mechanism and the S mechanism would bring the poor colour discrimination in yellow-blue for the trichromats. This idea is partially supported by Sharpe et al. (2006).

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4. Conclusion

We measured the colour discrimination thresholds for the normal trichromatic observers and the red-green colour-deficient observers in order to compare the detection of the yellow-blue colour changes between them. We found that the thresholds in the yellow-blue directions for the anomalous observers are not always higher than those of the normal trichromats observers. The thresholds of the colour changes in the v' direction tended to be smaller for the red-green colour-deficient observers than for the normal trichromats.

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Development of simple color bipartite apparatus using single light source with LEDs and measurement of individual color matching functions

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Abstract

To make individual color matching functions measuring easier, we developed a simple and compact bipartite apparatus with time-controlled monochromatic LEDs. The light from an integral sphere, in which twelve different LEDs were inserted, was split into two optical paths; a test stimulus path and a reference stimulus path. Each optical path was alternately blocked off by a rotating optical chopper. Moreover, the lighting timing of the arbitrary LEDs was switched to synchronize with that of the optical paths. Lights passing through the test and reference stimulus path make color stimuli in a test and reference area of a bipartite field, respectively. As for the switching frequency, we adopted 100Hz in the experiment so that the observer could perceive the stimulus to be continuous emission. In order to match a color of the test field and that of the reference field, the observer adjusted the intensity of three primary LEDs whose peaks were 626nm, 524nm, and 472 nm as red, green and blue primaries, respectively. In the experiment using this apparatus, the individual differences of CMFs were measured from fourteen subjects in the preliminary experiment.

1. Introduction

Color-matching functions (CMFs) of observers with normal color vision vary among individuals [Stiles and Burch (1959), Trezona (1987), Yamauchi et al. (2003)]. The individual variations of CMFs cause observer metamerism and color mismatch for metameric color pairs. This color mismatch is inevitable for real observers with normal color vision. If we could use individual CMFs data, it would allow us to evaluate the degree of color mismatch between a test observer and the reference observer (e.g., CIE standard colorimetric observer) [CIE 080-1989]. In order to realize such observer metamerism evaluation, it is necessary to estimate individual CMFs, but it is not easily attainable. A part of the difficulties comes from the complexities of the optics system which is used to measure CMFs.

A bipartite field is usually used to measure CMFs. Conventional bipartite apparatus consists of plural optical paths; a path to present the test stimulus which consists of three primaries and that for the reference stimulus. Furthermore, it is necessary to present the primary lights to either optical path, as one of the primaries is required to be presented together with the reference stimulus in order to complete color matching, which is expressed as "negative" CMFs. Thus, the conventional apparatus should have respective primary light sources for each optical path and require complicated alignments, and consequently becomes large in size. In the present study, we developed a simple and compact bipartite apparatus with a single light source consisting of time-controlled monochromatic LEDs, and measured individual CMFs.

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2. Methods

The schematic of a new apparatus we designed is shown in Fig. 1. We used a single light source, in which plural LEDs inserted to a small integral sphere (6" diameter). A beam splitter divided the light from the integral sphere into two optical paths; a test stimulus path and a reference stimulus path. Each optical path was alternately interrupted by a rotating optical chopper. Depending on the position of the chopper blade, only one of the test or the reference stimulus was presented to the observer. Moreover, the switching timing of the LEDs was controlled to synchronize with that of the optical paths. These timings are shown in Fig. 2. It was possible to arbitrarily choose any combinations of the LEDs to be presented both to the test and to the reference stimulus area. As for the switching frequency, we adopted 100Hz in the experiment. This was high enough for the observer to perceive the stimulus to be continuous. The intensity of the each LED was controlled by changing the width of the pulse signal what was used to drive a LED [Suzuki et al. (2008)]. Temporal presentation and the appearance of the bipartite matching field are shown in Fig. 3. The apparatus was compact and simple. All the optical parts were placed on a small breadboard (450mm (17.5") x 300mm (11.7")).

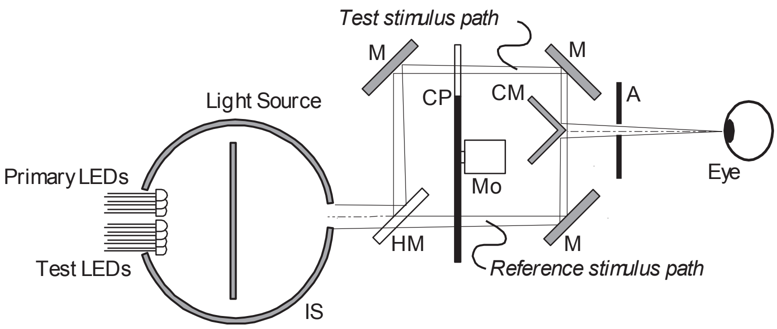

Fig. 1 Experimental apparatus (IS: Integrating Sphere, M: Mirror, HM; Half Mirror, CP: Chopper, CM: Corner Mirror, Mo: Motor, A: Aperture)

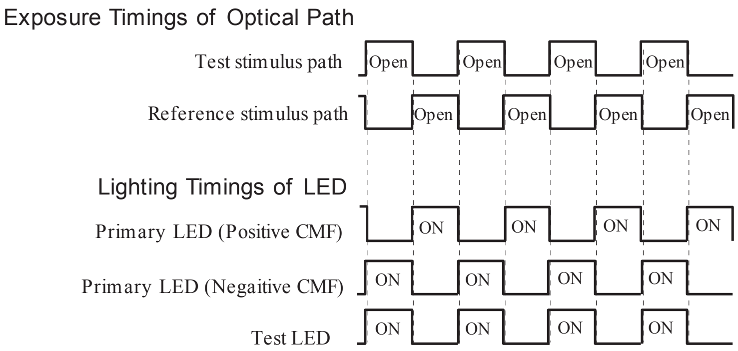

Fig. 2 Timings of exposure and lighting of LEDs

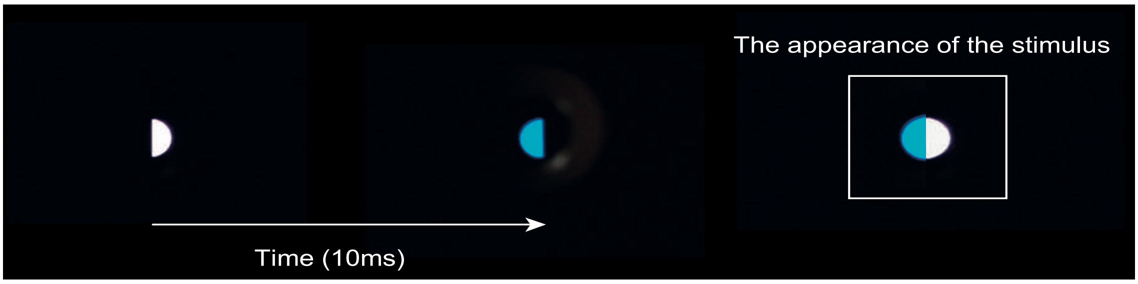

Fig. 3 Temporal presentations of the bipartite matching field and its appearance

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3. Experiment and results

In order to match a color of the reference field in the bipartite and that of the test field, subjects adjusted the intensity of three primary LEDs by operating a controller with six buttons connected to a computer. The head of the subject was fixed with a chin-rest. Twelve different LEDs including three primaries were installed to an integral sphere. Their spectral peaks and distributions are shown in Fig. 4. LEDs whose peaks are 626nm, 524nm, and 472 nm were chosen as red, green and blue primaries, respectively. In the preliminary experiment, the luminance of the stimulus was set to 2 cd/m^2, which corresponds to approximately 80 td. The CMFs obtained from fourteen subjects in the preliminary experiment are shown in Fig.5. Each symbol indicates mean value of results for three trials. Lines in Fig.5 represent CMFs of the CIE1931 standard observer for primaries of 626nm, 524nm, and 472 nm. We can see individual differences of CMFs.

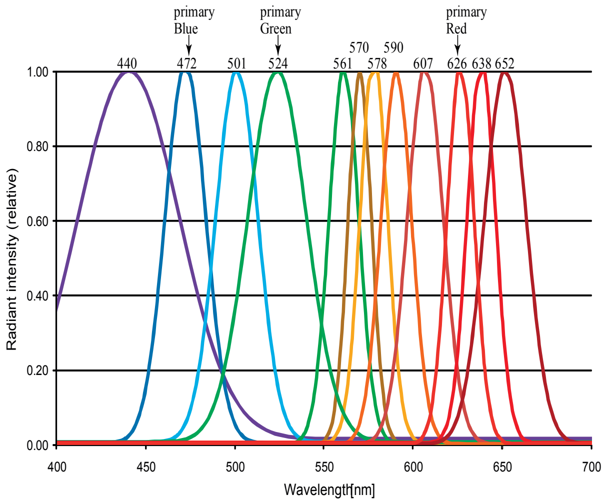

Fig. 4 Spectral radiant intensity of the LEDs used in the experiments

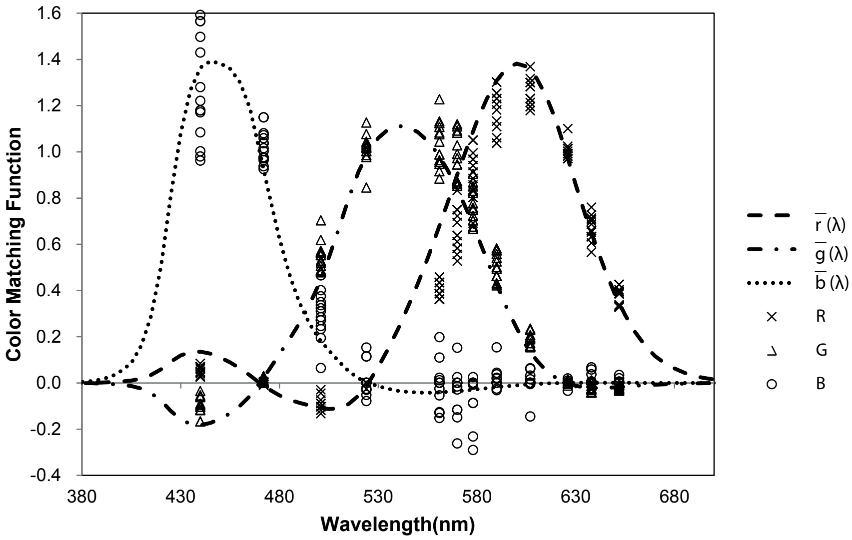

Fig. 5 Measeuerd individual CMFs. Each symbols represent measured results of fourteen subjects for primary(R, G, B) LEDs whose peaks are 626nm, 524nm, and 472 nm. Each lines represent CMFs of the CIE1931 standard observer for primaries of 626nm, 524nm, and 472 nm.

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4. Conclusions

We developed a simple and compact bipartite apparatus with a single light source, and confirmed that it can easily measure the CMFs and their individual differences. Further measurements are also scheduled to collect data from many subjects in order to build the database for the individual variation of the CMFs. We are also interested in collecting CMF data from elderly observers to evaluate the individual differences among them, comparing the results with those of the younger observers

Acknowledgments

Supported partially by the Hoso Bunka Foundation in Japan.

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A color analyzing tool "SciColor" for research and education

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Abstract

This paper describes a color analyzing tool "SciColor," which is newly developed and designed as an add-in software for Microsoft Office (Excel and PowerPoint). High-level skills for computer operation are not required. Some examples of color and image analysis using SciColor are shown.

1. Introduction

In research and education of color science, it is essential to handle information of color and image quantitatively, therefore a computer is an indispensable tool to calculate many numerical data accurately.

As tools for our researches, we developed and used two computer software systems SCIRA (Suzuki et al. 1999) and Colorcel (Kobayasi et al. 2002) for analysis of spectral data, color data, and color images. SCIRA is a kind of program library for information processing of color and image. Users can handle an enormous number of color images precisely. However, skills of computer programming are required to use SCIRA. On the other hand, Colorcel is an interactive analyzing tool for spectral data and color data which is very easy to use. It is implemented as an add-in software for Microsoft Excel. Colorcel does not have functions to handle images.

We developed a new color analyzing system SciColor. SciColor is an extension of Colorcel. Color image processing functions are appended to SciColor from SCIRA.

Analysis and visualization are carried out alternately in research and education of color science. Visualized results of analysis give us new hints for succeeding analysis. In this paper, we describe how SciColor assists quick and smooth continuation of our operation.

2. Design of SciColor

SciColor is designed as an add-in software for Microsoft Office (Excel and PowerPoint) to relieve a requirement of high-level skills for computer operation. Spectral data and color data are listed in Excel sheets directly. On the other hand, color images are stored in external files, and links to these image files are stored in Excel sheets.

SciColor has five major components. ColorDat, ColorCalc and ColorView are inherited from Colorcel. ImageCalc and ImageView are new developments based on the product of SCIRA.

ColorDat: Fundamental constants, for example, color matching functions (CIE 1931 (2 degree) and CIE 1964 (10 degree)), spectral locus, spectral data and chromaticity values of major illuminants (D65, D50, D55, D75, A, B, C, E, F1-F12) are supplied by Excel worksheets.

ColorCalc: It provides a number of user defined functions and interactive tools for analysis of spectral data and color data. SciColor can handle major color spaces: CIEXYZ, CIELAB, CIELUV, Munsell, NCS, OCA-UCS, PCCS (Natori 1997), sRGB and AdobeRGB.

ColorView: It makes graphs of colors which are mutually related on several kinds of color spaces. An add-in viewer ColorViewer is provided to visualize color compositions. Furthermore,

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Excel graph sheets and PowerPoint slides can be chosen as canvases of output graphs to make a presentation of results of analysis easily.

ImageCalc: A set of external programs for analyzing color images is supplied. It includes mosaic image maker, quantization of color values on pixels, color value conversion on pixels, several kinds of filters, and calculation of fundamental statistical characteristics of images. Users can describe a combination of these programs as a catalog in an Excel sheet.

ImageView: A function to visualize color images is prepared. A function to pick up color values of specified points is also supported. Same as ColorView, Excel graph sheets or PowerPoint slides can be chosen as canvases of output images.

3. Examples of color and image analysis with SciColor

3.1 Analysis of measured color

A color analysis using functions of ColorCalc and ColorView is demonstrated.

Figure 1 is a user interface of Interactive ColorCalc tool. A user decides a function, source data, destination range, and required parameters (white point, etc.) and executes a calculation.

Figure 2 is a result of the calculation. Five CIEXYZ color values in A2:C6 cells are measured data of five oil paints: Ocean Blue, Chrome Green Medium, Japanese Yellow Light, French Red Vermilion Hue, and Titanium White. Calculated CIELAB values are stored in D2:F6 cells.

Figure 3 shows another calculation method. A user defined function “XYZtoLAB” is called as a multi-cell array formula to calculate color values. Each factor of 3-dimentional color values is stored in a separate cell.

In Figure 2, calculated cell values are static. If you modify X value in A2 cell, CIELAB value in D2:F2 cells doesn’t change. But in Figure 3, calculated values are dynamic. If you modify X value in A2 cell, recalculation occurs automatically and CIELAB value in D2:F2 cells changes. Auto recalculation is confortable for repeating numerical experimentation, but the portability of data is detracted. If a worksheet is opened in an environment without introducing ColorCalc, errors occur and calculated values aren’t displayed. These two ways for calculation should be chosen for an aim of analysis suitably.

Figure 4 is 3-dimensional and 2-dimensional graphs of calculated CIELAB values produced by ColorViewer. ColorViewer supports many graph-drawing formats.

One merit of using Excel as a platform of SciColor is that analyzing data and working log can be stored at once. Excel with SciColor plays a roll of “dynamic research notebook” for color analysis.

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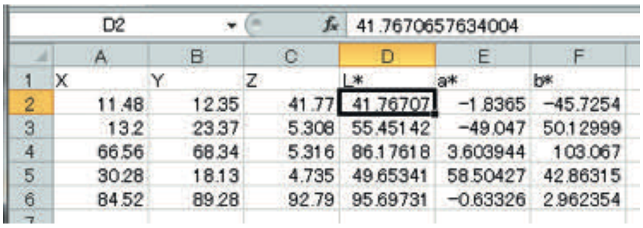
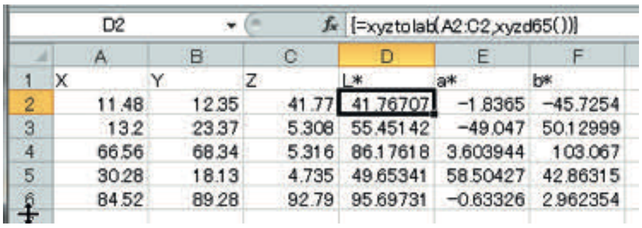
Figure 1.User interface of Interactive ColorCalc.



D2 f_x 41.7670657634004

	A	B	C	D	E	F
1	X	Y	Z	L*	a*	b*
2	11.48	12.35	41.77	41.76707	-1.8365	-45.7254
3	13.2	23.37	5.308	55.45142	-49.047	50.12999
4	66.56	68.34	5.316	86.17618	3.603944	103.067
5	30.28	18.13	4.735	49.65341	58.50427	42.86315
6	84.52	89.28	92.79	95.69731	-0.63326	2.962354

Figure 2. Result of the calculation using Interactive ColorCalc.



D2 f_x {=xyztolab(A2:C2,xyzd65())}

	A	B	C	D	E	F
1	X	Y	Z	L*	a*	b*
2	11.48	12.35	41.77	41.76707	-1.8365	-45.7254
3	13.2	23.37	5.308	55.45142	-49.047	50.12999
4	66.56	68.34	5.316	86.17618	3.603944	103.067
5	30.28	18.13	4.735	49.65341	58.50427	42.86315
6	84.52	89.28	92.79	95.69731	-0.63326	2.962354

Figure 3. Result of the calculation using a user defined function "XYZtoLAB."

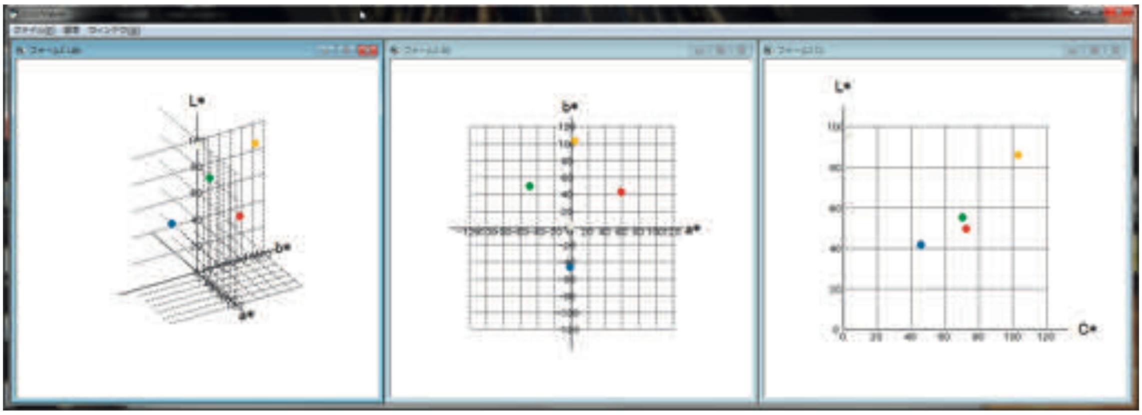


Figure 4.Visualization of calculated CIELAB values.

3.2 Analysis of color in image

Color in image can also be analyzed easily using SciColor. Figure 5 is an image of a self-portrait (van Gogh 1889), and Figure 6 is a graph of colors included in the image illustrated in Munsell color space. Simple usage of colors is observed. To investigate color composition of the image, disjoint images by a color category (Table 1) are made (Figure 7). Each image is clearly separated. Centroid of each image is plotted in Figure 8. Vertical and horizontal dotted lines are center of the image. Every centroid without B is near to the vertical center line. Y centroid is near to the center of the image, and RO, WtGyBk and G centroids are balanced each other. B centroid is functioned as an accent.

To do this analysis, following steps are necessary. First, color value of every pixel of the image is converted from sRGB to Munsell. Second, index of each pixel is calculated by given conditions that are defined as Table 1. Third, extraction of disjoint images by the indices is executed. Finally, centroid and relative area of each disjoint image are calculated.

In SciColor, these steps are described on an Excel worksheet, which enable us to do the step-by-step operation quite easily.

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Figure 5. Source image of analysis.

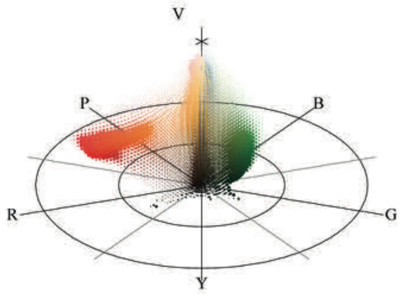

Figure 6. Colors inclued in the image illustrated in Munsell color space.

Table 1. Color category.

Category	Range
R	C≥3, 10RP≤H<10R
O	C≥3, 10R<H≤10YR
Y	C≥3, 10YR<H<10Y
G	C≥3, 10Y≤H<10BG
B	C≥3, 10BG≤H≤10PB
P	C≥3, 10PB<H<10RP
Wt	C<3, V≥8
Gy	C<3, 3≤V<8
Bk	C<3, V<3

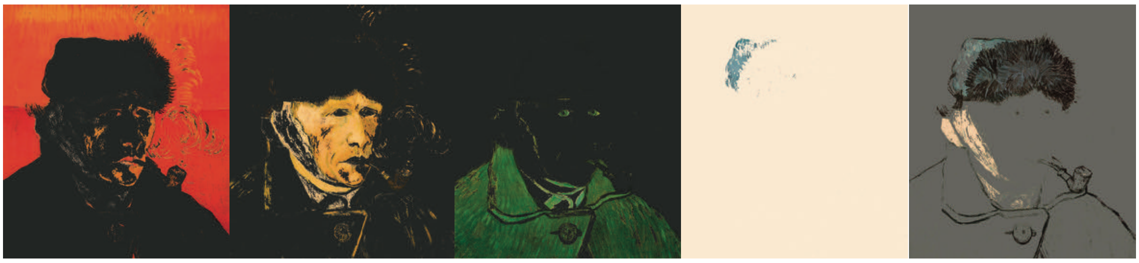

Figure 7. Disjoint images by given color category.

4. Conclusion

Design and aim of SciColor are introduced. SciColor is designed as a platform for step-by-step analysis of color and image. Our object is successfully achieved. We will continue to improve functions and handling of SciColor.

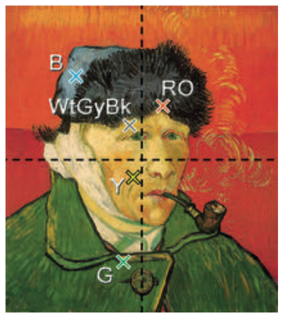

Figure 8.Centroids of disjoint images.

Acknowledgments

We greatly thank Ms. Verena M. Schindler, the AIC 2011 Conference Chair and members of the AIC 2011 Scientific Committee for their kind consideration towards authors of conference papers in Japan.

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A color preference model for different color appearance modes

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Abstract

In our previous study, we found that the color appearance mode affects color preference and color preference relates to perceived color attributes. This study, hence, was carried out to derive a color preference model on the basic of the perceived color attributes for different color appearance modes. The results of color preference score, color appearance mode, and perceived color attributes were obtained from twenty-four color chips presented under six conditions. The color preference model based on the perceived color attributes was proposed. In this model color preference could be predicted by the perceived blackness, perceived whiteness, perceived chromaticness, and perceived hue. The prediction performance for color preference in this model is to extent 73.3%. This model is a new possible method for quantitatively predicting color preferences in three color appearance modes without using colorimetric measuring instruments and provides a reliable platform for the future study of color preference.

1. Introduction

Color preference, although, has been investigated since the early times, it remains a source of debate among the public in many fields such as sciences, designs, advertisings, marketing, fashions and so on. Many researchers have attempted to deal with color preferences and their variations as a function of age, gender, geographical region, culture, and circumstances. Along with the aforesaid variations, color preference also depends on the color appearance mode. In our daily life, colors are perceived not only as an object color mode (OB mode), but also as other modes such as an unnatural object color mode (UN mode) and a light source color mode (LS mode).

In our previous study, we found that the color preference varies according to the mode of color appearance. Although the color preference models are released, the existing models are suitable for colors appearing in the object color mode only. The models based on the CIELAB system, for instance, may be ineffective for predicting the preferences if the color appearance mode of a color changes to other modes but the colorimetric values of that color under different color appearance modes do not change. This study, therefore, was aimed at deriving a possible color preference model for different color appearance modes. A psychophysical experiment was conducted to collect data for color preferences, color appearance modes, and perceived color attributes. The relationships between color preference and perceived color attributes (perceived chromaticness, whiteness, blackness, and hue) were investigated. A color preference model for different color appearance modes was developed on the basic of the perceived color attributes obtained from an elementary color naming. Based on the perceived color attributes, a method for quantitatively predicting color preference was exhibited as a practical application tool for designers. According to our model, the color preference could be predicted without the use of colorimetric measuring devices.

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2. Experiment

As shown in Figure 1, the apparatus was composed of 2 rooms separated by a wall with a 1° square aperture (T). The subject's room was illuminated by adjustable daylight type fluorescent lamps (FL_S). The room illuminance was measured by an illuminometer (I_S) placed below the aperture at distance of 44 cm. Many objects such as artificial flowers, dolls, books, and a clock were put into this room. Color chips were attached to a rotating wheel placed in the test chart's room. They were also illuminated by adjustable daylight type fluorescent lamps (FL_T).

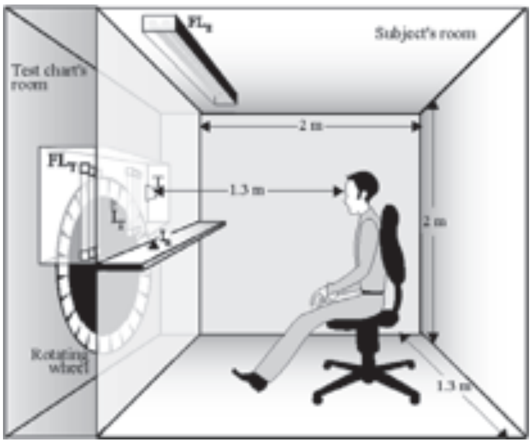

Figure 1. Schematic diagram of the apparatus.

25 color chips selected from the Munsell Color System were used as the test stimuli. The color chips included N5 and 8 hues (5R, 5YR, 5Y, 5GY, 5G, 10BG, 10B, and 5P) varied in different chromas (2, 5, and 8). The Munsell value of all color chips was 5. The experimental conditions were composed of the combination of 2 subject's room illuminance levels (50 and 500 lx) and 3 test chart's room illuminance levels (300, 500, and 700 lx). 13 subjects, including 9 males and 4 females, took part in the experiment. Their ages ranged from 21 to 33 years. There were three tasks for each subject. First, the color preference score was assigned from -3 to 3 according to observer's like-dislike feeling. Second, subjects judged the color appearance mode. The last one, subjects did the elementary color naming by giving percentage for perceived chromaticness, whiteness, and blackness.

3. Results

The color preference scores from all subjects were averaged for each color chip. The color appearance mode was expressed using the color appearance mode index, i_{CAM}. This index was determined using the following equation:

$$\text{Color appearance mode index } (i_{CAM}) = \frac{-1(N_{OB}) + 0(N_{UN}) + 1(N_{LS})}{N_{OB} + N_{UN} + N_{LS}}$$

where N_{OB}, N_{UN}, and N_{LS} are the numbers of responses in OB mode, UN mode, and LS mode, respectively. If $i_{CAM} \geq 0.5$, the color was classified as LS mode; if $i_{CAM} \leq -0.5$, the color was classified as OB mode; an i_{CAM} between -0.5 and 0.5 was classified as UN mode.

Figure 2 shows the effect of the chroma on a subject's preference. The results show that a higher chroma for a color chip results in a higher color preference score, regardless of the hue. It can be concluded that the high-chroma colors were preferred over the low-chroma. The same tendency was observed for all the color appearance modes. Our results agree well with previous studies; brighter and more saturated colors were preferred. Moreover, regardless of the Munsell chroma, the mean score for the color chips that appeared in the OB mode was lower than those in the LS and UN modes.

Next, possible correlations between the color preference and perceived color attributes were determined. The elementary color naming method was used to assess the perceived color

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Table 1. Pearson correlation coefficients between the mean color preference score and the perceived color attributes.

	OB mode	UN mode	LS mode
Perceived chromaticness (C_p)	0.567 [a)]	0.701 [a)]	0.714 [a)]
Perceived whiteness (W_p)	-0.054	-0.667 [a)]	-0.711 [a)]
Perceived blackness (B_p)	-0.72 [a)]	-0.446	-0.441

Note: n = 4,030, 2,795, and 2,535 for OB, UN, and LS modes, respectively.

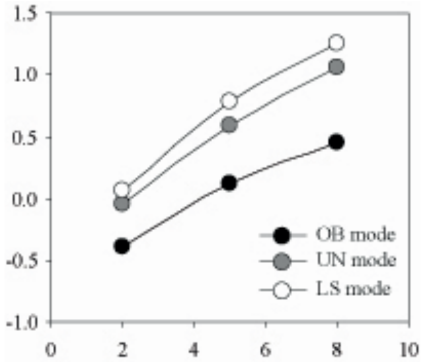

Figure 2. Mean color preference scores plotted aginst chromas for diferenmt color appearance modes.

attributes of the color chips in the three color appearance modes. The amounts of the perceived color attributes were expressed as average values across the thirteen subjects for each color chip under each condition. Table 1 shows the statistical correlation results in the three color appearance modes. These results showed that the color preference score is related to the three perceived color attributes. In the OB mode, the mean preference score was related to the perceived blackness (r = -0.724), but in the UN and LS modes, the mean preference scores were related to the perceived chromaticness (r = 0.701 and 0.714) and perceived whiteness (r = -0.667 and -0.711). This indicates that the color preference may be described as the perceived chromaticness, whiteness, and blackness.

4. Discussions

Figure 3 shows a polar diagram of the perceived hue, with distributed circles. These circles represent the perceived hues for colors in the (a) OB mode, (b) UN mode, and (c) LS mode. Gray circles represent negative color preference scores and white circles, positive ones. The size of the circle indicates the value of the color preference score, with a larger gray circle indicating a greater dislike for the the color and a larger white circle, a greater preference for it. The coordinates of the center of each circle were x_{GR} and y_{BY}. As shown in figure 3, colors located around gray and yellow areas were more disliked, whereas those located further away from those areas received better responses. This feature can be added into the equation by multiple regression, as shown in the following equation:

$$P = 1.22 - 0.037B_P - 0.012W_P + 0.02\left(\frac{C_P \times E_H}{100}\right) + 0.151 i_{CAM} \qquad R^2 = .733,$$

in which

$$E_H = \begin{cases} |h - h_0| \times \dfrac{100}{180};\ 0^\circ \le h \le 270^\circ \\ |h - (h_0 + 360)| \times \dfrac{100}{180};\ h > 270^\circ \end{cases} \quad \text{for} \begin{array}{l} \text{OB-mode } h_0 = 93^\circ \\ \text{UN-mode } h_0 = 89^\circ \\ \text{LS-mode } h_0 = 89^\circ \end{array}$$

$$h = \tan^{-1}\left(\frac{y_{BY}}{x_{GR}}\right),\quad x_{GR} = \begin{Bmatrix} R \times C_P \\ (-1)G \times C_P \end{Bmatrix} \times \frac{1}{100},\quad y_{BY} = \begin{Bmatrix} Y \times C_P \\ (-1)B \times C_P \end{Bmatrix} \times \frac{1}{100}$$

where P is a color preference score; B_P, W_P, and C_P are the amounts of perceived blackness, perceived whiteness, and perceived chromaticness; E_H is the absolute difference in the perceived

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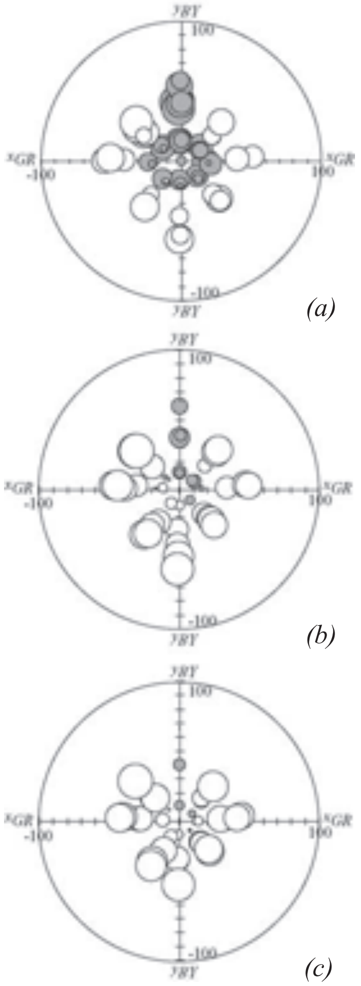

Figure 3. *Results for perceived hue in the polar diagram for (a) OB mode, (b) UN mode, and (c) LS mode.*

hue angle between a test color and the least preferred color; *h*, the perceived hue angle; h_0, the perceived hue angle of the least preferred color; x_{GR} and y_{BY} are the perceived hue coordinates of a test color; and *R, G, B,* and *Y* are the amounts of the perceived red, green, blue, and yellow, respectively, obtained from the elementary color naming task.

5. Conclusions

Our findings show that colors with high chroma and high brightness yielded higher preference scores. In a comparison between the three color appearance modes, the color preferences in the unnatural object color mode and in the light source color mode were significantly higher than those in the object color mode. Furthermore, the color preference was significantly related to the perceived color attributes. Although many researchers have developed preference models, these models have been generated only from a data set of colors appearing in the object color mode. In contrast, this study revealed that the color preference varied according to the color appearance mode. Therefore, a color preference model was designed for the three color appearance modes, based on four perceived color attributes. In this model, the color preference could be predicted on the basic of the perceived blackness, perceived whiteness, and the combination of the perceived chromaticness and perceived hue.

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Colour-shape interaction analysis of the post-Byzantine nave decoration in the Church of the Nativity of Christ, Arbanassi, Bulgaria

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Abstract

In this paper we develop further the work recently carried out so far by the first author on the analysis of the design of the interior decoration of the post-Byzantine Church of the Nativity of Christ in Arbanassi, Bulgaria. The aim was to investigate the degree to which there is a synergy between architecture and decoration. Our research employed the method of *Colour-Shape Interaction Analysis*. This analysis reveals how colour design interacts with the visual appearance of architectural shape under specific lighting, using three concepts developed from camouflage theory for application in an architectural context. By conducting this enquiry we were able to ascertained that in the nave decoration of the church the colour design helps to dematerialise the architectural structure in order to introduce the beholder to the virtual reality of Heaven.

1. Introduction

The aim of the paper is to assess how the compositional patterns of the decoration in the nave of the church interact visually with the architectural structure. This analysis provides a new and deeper understanding of the way in which space works under a particular type of lighting. The interior chosen for examination dates from 1648 and has been proven to be preserved in its original state Prashkov (1979); Haritonov at el. (2003). The lighting at present is provided by 20W candle-shape incandescent lighting, intended to be reminiscent of the original candlelight. Both sources emit light in the yellow region of the spectrum and can be considered to have a comparable effect on the visual appearance of the colours and the architectonics of the space. Berns (2000); Wyszecki and Stiles (2000); Tantcheva et al. (2009).

Previous research on the nave decoration had been limited to meticulous recording of the compositional arrangement of the biblical scenes and their positions in relation to the architectural structure of the space Prashkov (1979). Moreover, the appearance of the individual colours in the artistic palette employed had been identified and recorded using spectral and colorimetric data Tantcheva et al. (2007: 363-366); Tantcheva et al. (2008); Tantcheva et al. (2009). Although the earlier research had developed some understanding of the use of colour in this particular post-Byzantine monument, nevertheless it took colour out of its compositional and spatial context. The present examination bridges this gap by employing the conceptual frame of *Colour-Shape Interaction Analysis.* This analysis reveals how colour design interacts with the visual appearance of architectural shape under specific lighting conditions, using three concepts developed from camouflage theory for application in an architectural context: counter-shading, co-shading, disruption and constructive shading. Häggström (2010: 160-167).

The interior has a plain vaulted ceiling, springing without any demarcation from the vertical walls, defining the nave space. The entire surface of both walls and ceiling is covered with frescoed smooth plaster. Vertical and horizontal lines divide the surface into different sized compositional spaces. The choice and position of the biblical scenes in those spaces follows the spatial theological

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hierarchy observed in Byzantine nave decoration. The vaulted structure is supported by beams which are covered in geometric patterns, creating an ambiguity concerning the purpose of those beams – are they decorative or structural?

2. Analysis

To conduct the *Colour-Shape Interaction Analysis* different sections of the interior were examined. The visual interaction of the geometric patterns painted on the actual three-dimensional shape of the arched beams with the painted plane surfaces of the vault between the beams (see Figure 1 for an example) was analysed.

Figure 1: Fragment of the decorated arch nearest to the entrance into the nave.

The series of light arches carrying the roof appear more illusory than real – they do have volume but their painted decoration produces a visual ambiguity. On the one hand the light, mostly painted white, vertical sides of the beams and the painted in darker colour lower surfaces facing the floor produce *co-shading* which should enhance the visibility of the volume. On the other hand the strongly contrasting geometric pattern in black, white and red, consisting of lines painted on the beams and next to them, produces a *disruptive* function. Because of the strong contrasts the lines dominate visually both the finer variations of real shadows defining the shape as well as the painted *co-shading*. There are several strong contrasting bands, painted parallel to the beams, that could be taken to demarcate the architectural forms, but instead the bands hide the positions of the actual edges, by performing a disruptive function. This particular visual illusion appears not only at the beams, but also on the plain ceilings next to the beams. Such visual re-shaping not only obliterates the real form but also exemplifies *constructive shading*. This type of contradictory painting, combining a shape-enhancing *co-shading* with both a shape-obliterating *disruption* and a non-convincing *constructive shading,* makes the arches appear more as symbolic images of beams than as parts of an actual functional construction. Figures 2 a and b, below, show these techniques being used.

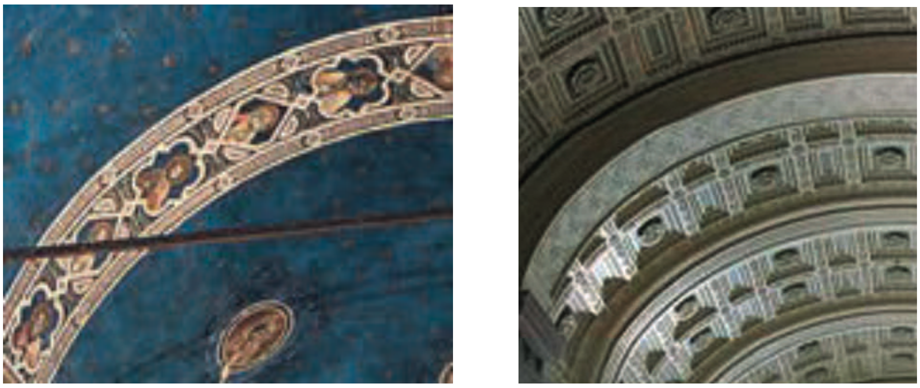

Figure 2(a): Symbolically painted arch on a plain barrel vault ceiling (b) Barrel vault ceiling with beams both plain and articulated by moulding .

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Analysis was also carried out on the plain wall sections of the frescoes. Example of those sections are shown in Figures 3–5. The red grid between the scenes painted on the vaults is visually raised by the constructive shading of dark and light contour lines. The grid divides the smooth plane into rectangular units where the motifs in general harmonise with the constructive shading of painted coffering; in most of the rectangles a wall of human figures is painted in light and bright colours, standing close together at the base against a very dark blue sky which is seen only above their shoulders.

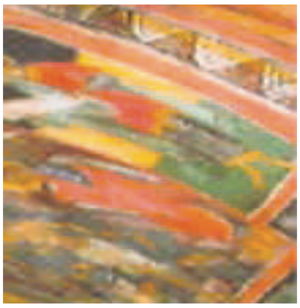

Figure 3: Fragment of the decorated arch nearest to the nave altar.

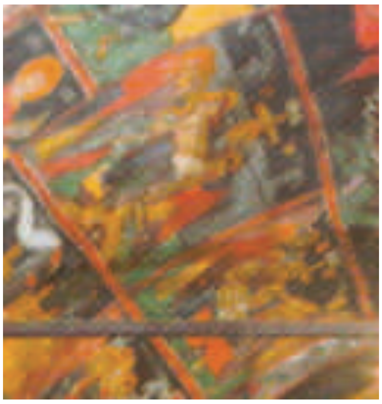

Figure 4: Fragment of the vaulted ceiling of the nave.

The central larger rectangle, however, has no lower wall of standing people in light colours; it suggests no raised shutters or coffering, but rather a large square "oculus" where the figures are not standing on any solid base but hovering in the open air; the very dark blue simulates either a dark sky or a very deep visually limitless opening above, and so motif and constructive shading again work together.

Figure 5: Fragment of the central part of the vaulted ceiling of the nave.

Each rectangle with a composition of strongly contrasting fields (white, yellow, bright red and green, and dark blue), works on its own as a disruptive pattern, breaking up the continuity of the smooth surface. The general composition however also makes the upper part of the rectangle very dark, which conveys the effect either of a shadow created by deep coffering giving the impression of light coming from above (as illustrated by the Pantheon's coffering shown below, Figure 6), or of an opening to the dark sky above, as if each rectangle was a shutter opened to a vertical

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position. Thus motif and constructive shading work together here to create an ambivalent vision that effectively breaks up the smooth ceiling.

Figure 6: Shadows in the coffering of the Pantheon.

The analysis reveals that the decoration of the vaulted ceiling can be likened to a non-perfect trompe l'oeil, creating a feeling of depth and an ambivalent impression of shape. This visually modifies the architectural shape, breaking the solidity of the form and creating an illusory loftiness in the interior space.

3. Conclusion

Our investigation ascertained that the artists who decorated this church employed colour highly intuitively that resulted in the visually intricate design patterns. They produced decorative motifs and figurative compositions that worked together to dematerialise structural elements of the architectural design. This approach transformed the supporting beams into symbols, while the plane of the ceiling gained indeterminate depth. The result is an exuberant interior space, in which the heightened visual experience would have been intended to bring the beholder to a transcendent understanding of the metaphysical reality. In the tradition of the Eastern Christian Church, the interior of a church building, and especially the interior of the nave, is supposed to represent an illustration of Heaven Archimandrite Aleksii (2003: 35-37). Our analysis determines that the artists of the church went further, placing the congregation in the midst of the Heavenly realm through the metamorphosis of the architecture achieved by series of visual illusions.

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Blue colour and light in architecture

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Abstract
In the paper author presents use of blue colour in architectural space – in history as well as in contemporary design, considering its symbolic, functional and decorative aspects.

1. Introduction
Blue has a special place in architecture. As the colour of the sky, it is almost always present in the landscape and gives background to facilities built by human. Blue is also the most frequently chosen tone in the tests of general colour preferences in Europe and the United States. Nevertheless, there is a lot of research showing that blue is the least often chosen as the colour of elevations and it is not popular for roof coverings (e.g. S. Hesselgreen's research on Swedish preferences for elevation colours or research conducted by J. Janssens and R. Kuller at the Lund University since 1960s (Janssens J., Kuller R. 2009)). In history, blue appeared so rarely in architecture and in arts that some culture researchers even suggested that the ancient people were unable to distinguish this colour and this ability only evolved in later times.

In this paper, the author attempts to explain the discrepancy between general preferences and "architectural" preferences for the blue colour. This paper is aimed at presenting varied uses of the blue colour in architecture, taking into account its symbolism as well as usable and decorative functions.

2. Symbolism and meaning of blue colour
The blue colour has a very specific symbolism behind it. From the time of the ancient Egyptians, the blue depths of water personified the female - while sky blue was associated with the male principle. Associations of this colour with eternity and spiritual life common to so many cultures are also a very characteristic feature. No wonder then this colour has become an attribute of many deities, such as Egyptian Amun, Greek Zeus (Roman Jupiter), Hindu Vishnu or Krishna as the blue-skinned incarnation. In the Catholic religion, blue belongs to the Holy Mother who has often been presented in the clothes of this colour in Christian art. (Birren F. 1956; Shakinko L. 1999.)

The fact that this colour is so strongly connected with divinity and Heaven as the place where gods live could not have remained without influence on architecture. On the Greek island of Santorini blue cupolas topping up the white buildings symbolise homage to Virgin Mary. In ancient Egypt, turquoise and blue symbolised the Heaven, so in decorations this colours were reserved to ceilings and vaults. In China, the symbolic value of the blue colour is also clearly visible in the colours of temples, e.g. in the oval temple of Heaven crowned with the vault with blue tiles. In Korea, the symbol of the "temple of power" can also be seen in the blue roof covering on the presidential residence in Seoul, referred to as Cheongwadae, which means the "pavilion of blue tiles".

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In the Islam culture, turquoise and blue, as the symbols of religion and society protecting us from evil, can still be found on the walls and vaults of many mosques. "Blue Mosques" can be found e.g. in Iran, Afghanistan, Malesia, Egypt, Armenia and one of the most famous in Turkey (Sultan Ahmed Mosque, Istanbul).

It is also worth pointing out that historically blue colour was connected with water as an unstable basis and was rarely used for floors or as an element of columns or pillars.

Blue appeared not only in temples. In many regions worldwide blue colour was common on the walls of houses with stripes around windows and doors. According to folk beliefs, a "blue eye" or a "blue bead" was to protect from failure and misfortune. Thus, it cannot be excluded that this colour, just like similar tokens and magic symbols, was to protect the house from evil and diseases. (Cetinturk N., Onur Z., Habib S. 1999)

Perhaps the only historical example of using blue colour for the purpose other than symbolic can be found in ancient Greece where this colour was also used to enhance the form. A characteristic feature was to emphasise the shade on the heads of Ionic columns with the blue colour and to use two shades of blue on triglyphs: brighter one on convex surfaces and darker on concave ones. (Birren F. 1956)

The symbolic value of the blue colour connected with Heaven, divinity and eternal life has found a direct reflection in architecture, mainly sacred architecture. Blue colour has been used in special places closely related to its meaning. This has contributed to creating a strong relation between the symbolic value of the blue colour and its use in architecture which has survived until contemporary times to a certain extent.

3. Blue dyeing pigments – blue is most expensive

The availability and the costs of dyeing pigments are other factors that have definitely had an influence on the use of the blue colour in architecture. Blue does not belong to the "colours of the Earth" and it does not appear naturally in many compounds or minerals, so in history it was both difficult and costly to obtain.

Two ancient blue dyes: Maya Blue (Azul Maya) and Egyptian Blue that were distinguished by incredible durability and a beautiful hue are worth mentioning.

Maya blue is the pigment with light blue to bluish and greenish colour produced on the basis of indigo, extract from the leaves of true indigo (*Indigofera suffruticos*), and the mineral called palygorskite (attapulgite). This pigment was common on the walls of temples (combined with red), in murals, ceramics and body painting during religious ceremonies.

Egyptian blue (calcium copper silicate) is probably one of the oldest synthetic pigments used in ancient Egypt and the Roman Empire (under the name caeruleum). In the Middle Ages, the formula of this dye was lost. Therefore, azurite and costly ultramarine became the only sources of the blue colour. Natural ultramarine obtained from precious stone lapis lazuli and imported from Afghanistan is considered to be the most expensive dyeing pigment in history. In the Renaissance era it was even more expensive than gold (synthetic ultramarine was obtained as late as in 1828!).

Prussian blue (ferric ferrocyanide), the first modern synthetically produced blue dye, appeared in 1704 as a by-product of the reaction of producing the immortality potion by the German alchemist Johann Konrad Dippel.

The costs and difficulties with producing blue pigments made this colour equal to gold and so it became the "royal" colour reserved only for the chosen ones.

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4. Unique blue colour architectural traditions

Despite the rare use of the blue colour in architecture, there are a few places in the world where the blue colour has become more popular and where its application is unique.

One of these places is Jodhpur in India, also known as the "Blue City" with reference to the local tradition of painting houses blue. This custom was connected with the caste of the Brahmins, who were regarded as the purest Indian caste and used to paint their houses blue in order to stand out from the society. Despite the considerable weakening of the caste system, this custom has survived until today but it is no longer reserved for the Brahmins, so the entire city is covered with the network of blue buildings, creating the unique "blue" atmosphere.

Another tradition of using blue is connected with the Navajo Indians from New Mexico who dye the ends of joists, window and door frames with the hue called blue of Taos.

Also in Poland blue colour was commonly used for wooden houses colorization in the second half of the 19th century. All tones of blue – from cyan to navy blue – were common for painting wall surfaces, clay filled gaps between beams as well as stripes around windows and doors. This colour was obtained from widely available natural mineral vivianite (called also blue iron earth or blue ochre), from copper compounds or rarely from ultramarine added to lime used for priming. (Tarajko-Kowalska J. 2005)

Apart from decorative functions, blue colour had also usable functions (insect repelling) and symbolic functions involving the protection of inhabitants from evil. Together with the change of construction material from wood to masonry structures, this tradition was abandoned and is now only an interesting relict of the past, preserved in few existing facilities.

5. Blue colour and light in contemporary built environment

Currently, the symbolic function of the blue colour gives place to functionality and decorative value. Blue has become more frequent in architecture thanks to glass curtain walls which often reflect the blue colour of the sky and water. In the case of tall buildings and large spatial constructions visible on the background of the sky, bright blue can be used as camouflage (e.g. building of the Fukushima power plant in Japan).

Blue light from LEDs is used in the night illumination of buildings and in media facades, as one of the basic light colours in the structure of RGB LEDs (e.g. Herzog & de Meuron, Allianz Arena, Munich, Germany 2005). As the identification colour, it is a spatial representation for the buildings of such companies as Ikea or the chain of Makro Cash& Carry stores. However, buildings painted all in blue have not become very popular and rich blue plasters and paints belong to the best-selling hues in all sales ranking lists. Their use in architecture, especially in the form of monochrome constructions in the city structure usually causes a considerable visual contrast to the surroundings (e.g. Bernard Tschumi, the Blue Tower, New York 2007).

From among the modern "blue" buildings, three realisations are particularly worth mention. One of them is the design of superstructure on the brick tenement house in Rotterdam in which an independent apartment with a terrace similar to a house on the roof has been located (Didden Village, MVRDV, 2002-2007). The colour of this project is its distinguishing feature. All elements of the building together with the surrounding terrace have been covered with a sky-blue polyutherane layer. The building looks like a blue crown on top of dark brick elevations of the neighbouring tenement houses and constitutes an excellent spatial accent.

Another example is the recently demolished Beukelsdijk building (Schildersbedrijf N & F

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Hijnen, 2004). This structure has been placed on the area of the degraded district of Rotterdam, intended for revitalisation and total reconstruction. Before the demolition, the building was painted blue and formed a huge graphic symbol integrated into the space. The blue building quickly became a tourist attraction, inspiring interest not only of the tourists but also of the residents of the city, which gave the designer of the district the possibility to promote the idea of its future development more widely.

The third example is the house in Klagenfurt, Austria (2009), painted ultramarine blue both inside and outside. It was a controversial experiment of an eccentric architect Peter Kaschnig aimed at examining the impact of the blue colour at such a broad scale. As he stated, the result far surpassed his boldest expectations.

From among the modern symbolic meanings of the blue colour, those connected with the sky and water are the clearest. One example can be the building of the Pacific Design Centre designed by Cesar Pelli in which the blue wall covering reflects the company's connection with the sea. The same is the case with the concrete structure Edificio Forum in Barcelona (Herzog & de Meuron, 2004) where the walls have been conceived as a sponge saturated with water blend with the sky and the Mediterranean Sea.

Summary

As the colour of the sky and water, blue is considered in architecture as the least "tangible" and "material" hue. For ages, it has been an attribute of divinity, connected with Heaven as the domicile of deities and gods, so it has received a considerable spiritual load which has emphasised its uniqueness even more. The universality of this symbolism combined with the costs of pigments have given the blue colour its unique and exclusive value.

Even nowadays, despite the weaker symbolic meaning and greater availability of dying pigments, blue has not become a very common colour in architecture. Its visual impact, both in glass curtain walls and in media facades, seems only to emphasise its immateriality and reference to spiritual symbolism.

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Chromatic study of the architectural work "La Muralla Roja" by Ricardo Bofill

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Abstract

La Muralla Roja is located in the resort of La Manzanera (Calpe-Alicante). This building is the modern architectural reference work concerning the application of color in Spain. It is one of the first to consider the color in the global project. The project began in 1968 and finished the construction in 1972. We are confident that its location is a reference for the application of color in modern architecture.

The aim of this study is to assess the perception of color in La Muralla Roja (one time at 12 h sun hours), depending on their orientation (North, South, East and West) and faced landscape (sea-blue, forest-green and red editions and blue).

1. Introduction

In La Muralla Roja, however, space and character are treated in a more general way, without losing the necessary reference to the locality. The name already suggests this relationship; being conceived as a "muralla", the building serves as a "wall" in the landscape, which visualizes its structure and character through simultaneous adaptation and contrast (Cruells, 1992). Adaptation is here achieved by means of subdivision and articulation of the mass, whereby a relevant spatial rhythm is created, whereas contrast is mainly due to the use of color. The red exterior thus contrasts with the surrounding rocks and vegetation, at the same time as it constitutes a focus which gives presence to the heat of the sun. The blue courtyard offers a refreshing complement (Figure 1).

Figure 1. La Muralla Roja seen as a wall from the Mediterranean shore.

The applicability of color is determined by the structural function of the different architectural elements.

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The exterior surfaces were painted various shades of red to highlight the contrast with the landscape. For yards and stairs was chosen the sky color: blue, indigo, violet, etc., which is more or less intense the contrast with the sky and optical effects between the interior walls and sky intermingle (Bofill, 1985). Natural lighting was taken into account when setting the intensity of colors, giving the occasion to show the combination of these that can bring a greater illusion of space (Figure 2).

Figure 2. La Muralla Roja, view with different chromaticities.

The proposed spatial planning of "La Muralla Roja" presents an architecture characterized by the need to define an urban form, which looks back at the rich tradition and vitality of the Islamic city dense inherited the ancient Mediterranean cultures: cellular urban population, labyrinthine structure and organization of the habitat.

Its composition corresponds to a geometric plan based on a Greek cross type where are collected in various ways, leaving the service towers at the intersection of the crosses. Itself is a clear reference to the popular Mediterranean and Arabic architecture, particularly adobe towers and North African casbah (Bofill, 1988). The criteria applied to building a diverse color range starts from the purpose of giving relief given to the various architectural elements according to their structural function.

2. Experimental technique

The experimental technique we used in this work involves the allocation of 6 areas to analyze the color. In each zone there were two points marked with a permanent marker so that with the weather conditions could not be deleted. The points should have easy access to take measurements at the same time must be in inconspicuous locations to avoid complaints from the homeowners.

To get the job done consulted the Mayor of Calpe and gave his consent to the measurements. So did the administrator of the building and the president of the homeowners.

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The points are placed at the eye level meter (approximately 170 cm).

The points are placed on the front (red) except an area that is inside (blue). Points 1 and 2 correspond to the side facing the sea with east. Points 3 and 4 in the same orientation up to a height of 3 meters. Points 5 and 6 on the upper terrace of the building with the same orientation. Points 7 and 8 facing west (opposite to the direction used) and the maximum building height. Points 9 and 10 are inside and due to its location are blue (Figure 3. This is ideological architect Ricardo Bofill of the building). Points 11 and 12 are 1.70 m above the ground on the west side of the building facing the forest.

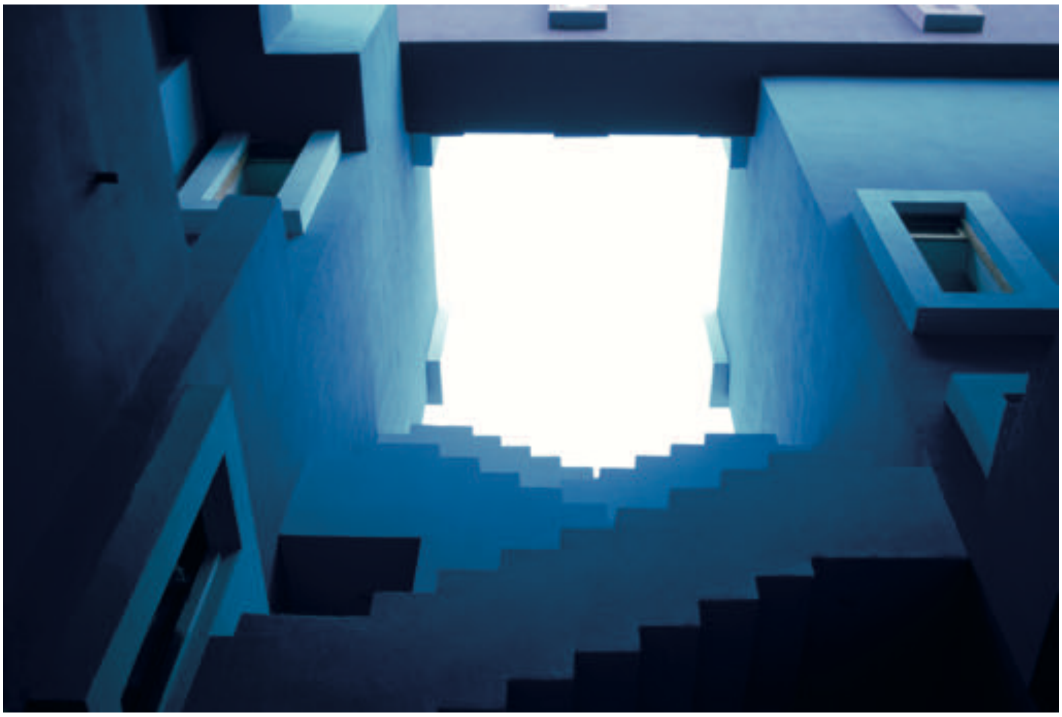

Figure 3. Interior of "La Muralla Roja", where you can appreciate the intense blue that blends with the blue sky.

The measurement of chromaticity points were made with a portable spectrophotometer with the characteristic that makes the average of five measurements. The spectrophotometer emits its own light which does not vary in all measurements, and we facilitate the analysis of results. The interest remains in the red color of the facade because of its contrast with the context where is located the architectural work.

At first we project the possibility of measuring the perception of color with a portable colorimeter distance. We reject this option for the practical impossibility of setting a single point of measurement and distance remain constant.

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3. Results and discussion

The results (Table 1) shows two measurements with a time difference of 30 days.

Table 1. Results of two measurements taken from each of twelve different points at the site La Muralla Roja.

Measuring points	Y	x	y
1	16.02|16.34	0.40|0.40	0.34|0.34
2	15.74|15.44	0.41|0.41	0.34|0.34
3	16.92|17.18	0.41|0.40	0.34|0.34
4	15.69|15.45	0.41|0.41	0.34|0.34
5	14.83|14.37	0.41|0.41	0.34|0.34
6	13.51|13.34	0.42|0.41	0.34|0.34
7	11.76|12.10	0.43|0.43	0.34|0.34
8	9.50|9.59	0.43|0.43	0.34|0.34
9	19.80|19.99	0.23|0.23	0.27|0.27
10	20.07|22.08	0.23|0.23	0.27|0.27
11	11.15|12.19	0.43|0.43	0.34|0.34
12	13.04|12.79	0.43|0.43	0.39|0.39

Conclusions we can draw from these results are not definitive and that this work belongs to a project that has not yet come to an end.

The manager assures us that the building was painted with the same paint and the measurements with two points near (1 & 2, 3 & 4, etc..) lead us to believe that the measurements are correct. No significant variability between two nearby points.

We can guess that the red height tends to remain more saturated than in the lowlands.

The orientation also appears to influence the area, overlooking the sea seems to be more affected (sea, sun, etc.) to the west (forest).

We will continue working on this line to determine the deterioration of the paint due to the orientation of the facade.

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Learning and teaching color as a multidisciplinary topic based on scientific knowledges and artistic concepts

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Abstract

Art and science are actually largely different from each other, although there are many interesting things to learn from either side. Color as a science seems to have been relegated for many years in art, design, architecture, and media education. The objective of this paper is to bridge the gap faced by scientists and designers when teaching color and to enhance the interest of color for learning, teaching and research in the Art and Design education but also in Computer Vision and Computer Graphics education.

1. Introduction

The lack of common understanding and a common language that can facilitate communication across disciplines is missing. An understanding of the fundamentals of color cannot advance without the underpinning of basic principles and methods. On the one hand, many science master programs based color courses are offered to a student audience with a scientific background, who may have difficulties in grasping very subjective concepts such as color emotion, color harmony and color appearance. On the other hand, many art, design, architecture or media oriented master color courses are presented to a student audience with an art and design background that have very little scientific knowledge, thus encountering difficulties assimilating theoretical concepts such as color management, color reproduction or color science. Several associations, consortia or networks, such as the International Association of Color (AIC), see http://www.aic-colour.org/, the Inter-Society Color Council (ISCC), see http://www.iscc.org/, the International Association of Universities and Colleges in Art, Design and Media (Cumulus Association), see http://www.cumulusassociation.org/, the Society of Dyers and Colourists (SDC), see http://www.sdc.org.uk/, and within the Framework 6 Marie Curie the project CREATE (see http://www.create.uwe.ac.uk/index.htm) have tried to bridge this gap.

The main objective of this paper is to show how the Erasmus Mundus master program CIMET (Color in Informatics and Media Technology, see http://www.master-erasmusmundus-color.eu) proposed by the Universities of Saint-Etienne (France, coordinator), Granada (Spain), Joensuu (Finland), and Gjøvik (Norway) contributes to bridge this gap and to show how the foundation skills, the learning outcomes, the topics taught, the teaching methods, the assessment criteria, etc. used in this scientific master program could be extended to other scientific and non-scientific master programs. The study programme of CIMET master is broadly interdisciplinary, encompassing photonics, computer vision and imaging science, computer science and multimedia technology as a mix of relevant theoretical and practical knowledge. The objective is to educate students in advanced methodologies and models in computationnal color science with two goals of research orientation and further studies at the doctoral level on one hand, and practical applications on the other hand (see Tremeau et al. (2011)). CIMET offers three areas of

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specialization: Color Imaging Science, Spectral Color Science and Multimedia Technology Science. These areas are being emergent, rapidly evolving, and of growing impact on the Information Society Technologies which require specialized competencies. Courses targeted by the master CIMET cover:

- Color in art (media art, painting, textile, printing and 3D art), design (objects, 3D environment, computer graphic, games, web applications, videos) and architecture (use of color for healing, color highlight of buildings, color harmony of interiors),
- Color and lighting (optics and photonics) interactions, lighting and objects interactions (human environment in a 3D scene), color invariants, color constancy,
- Color reproduction (scanning, printing, display technologies), color management (characterization, calibration, modeling, gamut mapping, and virtual proofing),
- Color measurement (surfaces, 3D objects, 3D room, etc.), new color imaging technologies (stereo systems, 3D displays),
- Color in visual perception (seeing, naming, understanding, color memory, color cognition, emotional interaction, color and communication), visual appearance (color, texture, cesia), visual perception and computer vision (3D modeling and reconstruction, object tracking, motion flow, virtual reality and augmented reality and presence),
- Color science, color coding (color spaces),
- Computational color imaging (color content aware processing, pattern recognition, image retrieval, video processing, etc.),
- Spectral color imaging, multispectral sensing and reproduction, forthcoming technologies,

We will show, in the following section, through the example of the *Color in Art and Design* course how some artistic concepts (e.g. color symbolism, color harmony, color emotion, etc.) can be taught to scientific students and how subjective concepts can be formalize as objective concepts. We will show also through the example of the *Lighting and Image capture* course how some fundamental skills (e.g. interaction between light and matters, interaction between light and visual appearance, etc.) can be taught to non-scientific students thanks to practical laboratory sessions and a systematic use of concrete and illustrative examples. Lastly, we will show through the example of the CIMET course catalog how color is multidisciplinary, for example to compute illuminant-invariant descriptors in the *Computer Vision* course students must first follow the *Human Vision* course, the *Color Science* course, the *Lighting and Image capture* course, etc. We have indeed observed that students, not having a scientific background, can intuitively understand the main concepts of such a problem but cannot assimilate all theoretical concepts underlying the problem.

2. Color as a multidisciplinary topic

In order to reduce difficulties in assimilating theoretical concepts, whatever the background of the student, we consider that is very important:

- To split such a multidisciplinary topic in several sub-topic (i.e. courses),
- To multiply the number of practice-oriented projects and laboratory sessions,
- To facilitate access to specific laboratories/equipment/libraries available/accessible,
- To develop technologically advanced teaching and learning methods (e.g. courses on-line, interactive learning modules, virtual classroom, multimedia tutorials),
- To multiply the number of oriented-examples to illustrate lecture sessions.

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The specificities of the CIMET Master also lie in the innovative pedagogical methods of teaching and learning and the Cross-European mobility scheme offered to students and teaching staff. Those two aspects are indeed enhancing the excellence and value of the Master program.

To stimulate student interest in learning and to encourage effective student training initiative several courses are based on a “project approach”. The idea is to emphasis on independent learning and exploration of students, emphasize the development of self-learning abilities of students. The main objective is to exceed the traditional passive concept of learning by “learn” to “learn”.

Each course of this master program is based on about 20 hours of lectures, 20 hours of exercises and 20 hours of practical laboratory sessions supervised by a teacher. Not counting the homework done by students. This is sufficient to introduce the main fundamentals of a subject but it is not enough to cover all aspects of a given item. To face this problem and to encourage active “self learning” teachers encourage students to read reference books, states of the art, scientific articles, etc. and guide students to find relevant information, algorithms and codes, on Internet. Teachers monitor student’s self-construction of knowledge. To foster the open-mindness and the adaptability of students, several scientific seminars are proposed each semester on challenging issues.

That is, teaching theoretical courses that require the understanding of many mathematical models and equations to students who do not have a strong background in mathematics is always challenging. We had to face this problem especially with the color science course. We have observed in this master program that the first half of a lecture on a theoretical subject is the most crucial part in terms of students’ learning and feeling about the topic. We have observed that if a majority of students do not grasp the basics of a course during the first half of the lectures, a general lack of interest in the topic might be created. This lack of interest in one topic may even last for the entire semester and for any related topic during the following semester. It is even harder to find a solution to this problem when dealing with a heterogeneous student population with very different backgrounds and from very different academic systems. Identifying the students’ learning style preferences and considering them in the design of learning and teaching packages can be a right solution. We have observed that a majority of students prefers:

1. seeing many graphs, graphics, images and relevant animations during the lecture;
2. testing concepts with interfaces, demos, practical test during the exercises/laboratory sessions;
3. that the teacher provides a great deal of verbal explanations during the lectures.

We have also observed that a minority of students prefers having the opportunity to read a topic from a book or handbook, before a lecture or instead a lecture, and then ask the teacher any questions that they may have. The main question we tried to answer is “what is the optimum way to learn?“ bearing in mind that studying in a master program is not the same thing as being in a magic show! Sometimes learning is not funny, so that does not make sense to try to answer to “how do they like to learn?” The questionnaires that we ask students to fill have shown that using other media, in addition to Powerpoint presentation and providing clear direction have the preference of students who do not seem to enjoy theoretical courses.

In the CIMET master, we tried to minimize the time taken in conveying the main message of each topic and to maximize their desire to learn and to some extent their enjoyment to learn. Thus, first we encouraged teachers to use multimedia systems in complement (not as a substitute) of traditional teaching/learning methods. That is, in some courses videos, animations and menu items do not necessarily add value. In other course, such as *Color and Art and Design,* interactive materials stimulate further interest in the relationship between *Color Science* and Art. As exemple,

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online exhibits such as http://www.webexhibits.org/colorart, are very useful to develop intellectual curiosity through several illustrative visual examples. Other websites, such as http://www.handprint.com/HP/WCL/ or http://www.colorsystem.com/, are very rich sources of data and of explanations to talk about color, to understand color theories, to apprehend visual color relationships, etc. Mediums such as optical illusions are also essential to convince students of what they are told because they see by themselves. Lastly, 3D Virtual Reality is a powerful tool to illustrate how the concepts of color space and color order systems are essential to analyze, to model, to understand a work of art (see http://www.couleur.org/colorspace.html) but also to characterize the spectral response of a piece of art or to interactively test in real-time different hypothesis on spectral reflectance data (see Colantoni et al. (2006, 2008)).

We also encouraged teachers from consortium universities to use the same eWorking platform. Claroline is an Open Source eLearning and eWorking platform allowing teachers to build effective online courses and to manage learning and collaborative activities on the web. Each course dedicated space provides a list of tools enabling the teacher to:

– publish documents in any format (text, PDF, HTML, video...),
– develop learning paths,
– create groups of students,
– prepare online exercises,
– propose assignments to be handed in online,
– use the wiki to write collaborative documents.

We consider that eLearning courses are complementary to regular face-to-face courses. The aim is for students to be able to complete, add to and build on learning on specific subject, such as color science course which is based on a range of models and equations developed over the years, anywhere and anytime, i.e. outside the classroom whenever and for as long as they want. The idea is also to encourage students to do homework to deepen lectures content.

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A digital visualization tool for the evaluation of colour vision deficiency

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Abstract

The Digital Visualization Tool (DVT) for checking colour vision deficiency (CVD) was developed in this study. The proposed colour vision test plate (CVTP) based on DVT has three parts of process. Firstly, we must decide the content (symbol or number) in the DVT system. Secondly, we have to set the appropriate parameters (shape, density, and colour) for designing a new test target. Finally, we decide the text colour and the background colour based on the principle of confusion lines. The results evaluated by CVD observers showed that CVD checking accuracy of using the proposed DVT with proper parameter settings is approximately equivalent to the conventional methods (i.e. Ishihara pseudoisochromatic plate and Farnsworth-Munsell Dichotomous D-15 Test).

1. Introduction

There are around 8% male and 0.2% female who suffer from colour vision deficiency (CVD) in the world [1]. The people with abnormal colour vision are unable to discriminate some specific colours and hence suffering in their lives. Moreover, with the advance and widely spread of new display and illumination technologies, such as wide colour gamut displays and colour-varied LEDs, we expect that more problems of colour discrimination would occur often than the past. However, if the CVD could be efficiently diagnosed by a digital tool, it would help us to build a friendly open environment of living and working for considering both normal colour vision and CVD observers.

There are various colour vision tests including anomaloscope, dichotomous hue test and pseudoisochromatic plates. The Ishihara pseudoisochromatic plate is the most widely used method [2]. The Digital Visualization Tool (DVT) is developed based on theories of confusion line, colour discrimination and opponent-colours, which is derived from the improved Ishihara pseudo-isochromatic plates [3]. All colours on the designed target were accurately reproduced on a well colour-calibrated monitor.

2. Methods

2.1 Colour vision test plate based on digital visualization tool

The developed DVT could be set several parameters to create a digital colour vision test plate (DCVTP). The setting parameters of a DCVTP were arranged in **Tab.1**. The symbols of L / M / S in table mean large / middle / small dot sizes.

Tab 1. Parametersof the DCVIP

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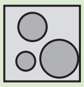
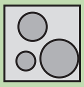
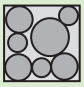
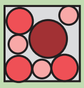
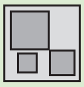
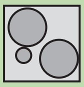
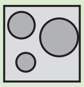
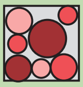
Type	Size	Density	Colour
Circular dot 	(L, M, S) 	High 	Dot-size dependency 
Square dot 	(L, S) 	Low 	Random 

In order to achieve effective colour vision test, the pseudoisochromatic plate with the optimal arrangement could be produced by varying colours and sizes of dots. In this study, we focus that the colour combinations between text colour and background colour on a DCVTP for checking CVD, which is determined based on the principle of confusion lines in CIE xy chromaticity diagram. It showed a normal colour vision (NCV) observer can correctly discriminate two colours if the colour differences between the text colour and the background colour are large than a general colour difference unit, e.g. $\Delta E^*_{ab}>3$. However, a CVD observer would be confused by any of two colours along the corresponding confusion line [4]. Based on the above principle, we can design pair of text colour and background colour in CIE xy chromaticity diagram for checking CVD. Firstly, we could draw a straight line passing the chromaticity point of a selected background colour to each of three co-punctal points. Then we defined three types of confusion lines passing through the chromaticity point of the selected background colour to any points on spectrum locus in CIE xy chromaticity diagram individually.

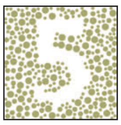
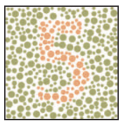
The text colours on a DCVTP were freely chosen for confusing CVD in reading a character or symbol. Therefore, the NCV and CVD observers would perceive a different number or symbol, although they were asked to read the same content.

2.2 Experiments

We used a 24-inch sRGB calibrated LCD monitor (EIZO CG241W) as a test display platform. The illuminance level in experimental environment was set to 64 lux. All DCVTPs in our experiment can be described by **Eq.1**. Here, *i* and *j* mean selecting colour number in text (i.e. “Text”) and background (i.e. “Back”), respectively. An example of DCVTP with one text colour and one background colour was shown in **Tab.2.**

$$\mathrm{DCVTP}(i, j)=\mathrm{Text}(i)+\mathrm{Back}(j) \quad i=1\sim3, j=1\sim3 \tag{1}$$

Tab.2 An example of DCVTP

Text(1)	Back(1)	DCVTP (1,1)
		

The observers participating in psychophysical experiment would include 8 young people with 4 NCVs and 4 CVDs. Firstly, all observers’ color visions were confirmedied according to the pilot

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testing of colour vision tests, including Ishihara pseudoisochromatic plate and Farnsworth-Munsell Dichotomous D-15 Test. Then our experiment was performed. The setups of the experiment for colour vision test are shown in **Fig.1**. Each DCVTP would be checked on a sRGB-calibrated monitor embedded with CVD simulating software.

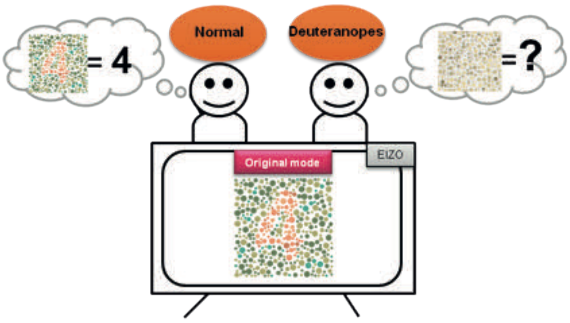


Fig.1 The setups of evaluated experiments.

3. Results

Because four CVD subjects of deuteranopes were chosen in our experiments, we decided to only select co-punctal chromaticity conditions to design the checking colour vision of deuteranopes. The designed chromaticities of the DCVTP's text colour and background colour for checking deuteranopes were shown in **Fig.3**. The CIE u'v' chromaticity points of (T1, T2, T3) and (B1, B2, B3) represent 3 sets of text colours and background colours on a DCVTP, respectively. The DVT examples of *DCVTP(1, 1)*, *DCVTP(2, 2)* and *DCVTP(3, 3)* were shown in **Tab.3**.

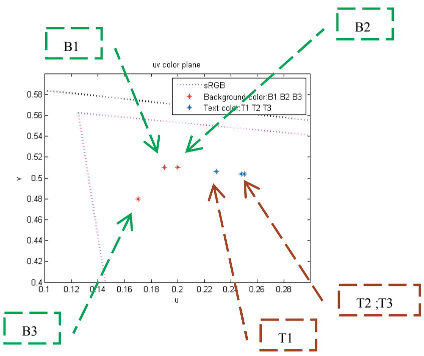
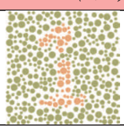
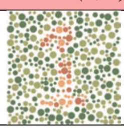
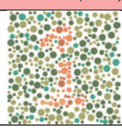


Fig.2 Confusing test plates for Deuteranopes

Tab.3 The examples varying colour numbers of text colour and background colour

	DCVTP(1, 1)	***DCVTP(2, 2)***	***DCVTP(3, 3)***
DVT			

The results of checking CVD accuracy was shown in **Tab.4**. The results were compared with the other two conventional methods (i.e. Ishihara pseudoisochromatic plate and Farnsworth-Munsell Dichotomous D-15 Test). In addition, we also assessed the performances in different colour number combinations of test colour and background colour on DCVTPs. The evaluated results showed that *DCVTP(2, 2)* and *DCVTP(3, 3)* were better than *DCVTP(1, 1)*. It also showed that the CVD checking accuracy of using the proposed DVT with proper parameter settings is approximately equivalent to the conventional methods.

Tab.4 CVD checking accuracy

Observers \ Test	D-15 test	Ishihara test	Proposed method		
			DCVTP(1, 1)	*DCVTP(2, 2)*	*DCVTP(3, 3)*
Deuteranopes	100%	100%	60%	95%	95%

4. Conclusion

In this study, Digital Visualization Tool (DVT) for checking colour vision deficiency (CVD) was proposed. The proposed DVT can be adaptability adjusted in designing text content and colours on a digital colour vision test plates (DCVTP). In addition, it can easily reproduce the exact colours on a well colour-calibrated monitor. Future works include examining colour discrimination in terms of the brightness difference or color difference threshold between text colour and background colour on a DCVTP.

Acknowledgments

We gratefully acknowledge all of the observers and the various members of the CIIC in the National Taiwan University of Science and Technology.

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A study on perceived colours of façades under different light sources

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Abstract

The colour quality of the sources used in the façade lighting has an important role in the appearance of the façade colours. The colours and the arrangements have differences for each building accordingly every building need different lighting designs. Therefore light sources should be chosen in the context of light and surface colour interaction and the changes in the façade colours should be known at the design process. In this study the differences between inherent and perceived colours of the colour composition of facades illuminated by the artificial light sources have been determined.

1. Introduction

The meaning and effect of coloured surfaces used side by side, change depending on the differences (contrast) among the hue, value and chroma components of surface colours. Colour contrast arrangements which depends on the changes between the components of surface colours can be classified in three groups; triple contrast arrangements, binary contrast arrangements (same hue, same value, same chroma) and simple contrast arrangements (hue contrast, value contrast, chroma contrast); Unver (1998), Yavuz (2009). These arrangements (compositions) can be used in the design of facade colours.

The colour quality of the light sources that are used in the facade lighting design, have an important role in having the required effect and impact with the lighting. Nowadays the improvements in technology and the increase in the number of artificial light sources make possible to select and use any source in any colour. Especially with the invention of gas-discharge lamps and LEDs (light emitting diode) designers have began to use coloured sources in facade lighting.

It is obvious that, the usage of coloured light sources can cause different appearances from the daytime, the original architecture and colour composition of the building. In this context, prediction of the changes in colour appearances caused by the light will help to create appropriate lighting designs and to prevent unexpected colour appearances or effects in terms of the facade colour design.

This paper aims to determine the perceived colours of different facade paints under different light sources, to reveal the changes in facade colours and to present the beneficial data for facade lighting designers.

2. The methodology and assumptions

Methodology of the study is;

- Identifying the colour properties of different light sources that are widely used in facade lighting.
- Determining facade paint colours for the hue contrast and same hues arrangements.
- Measuring the spectral reflectance distributions and the inherent colours of the chosen paints.

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– Calculating the perceived colours of the chosen paints under different sources of light considering human visual system.
– Determining the difference between the inherent and perceived colours of the paint colours from the context of hue contrast and same hues arrangements.
– In accordance with the method given above,
– 8 light sources (2 gas discharge lamps; high pressure mercury (K1), metal halide lamp (K2)), and 6 LEDs (Light Emitting Diodes; blue (L1), red (L2), green (L3), and 3 different white LEDs (L4, L5, L6)) having different colour temperatures and colour renderings have been determined,
– 4 paint colours (R1, R2, R3, R4) that had been stated to be the frequently used façade paints by manufacturers have been chosen. Same hues (S.H.; hues are same, values and chromas change) and hue contrast (H.C.; hues change, values and chromas are same) arrangements have been composed by matching these paints as binary groups.

The number and degree of contrasts in a colour arrangements, the area of the coloured surfaces, distribution of the areas in the visual field and adaptation of the eyes, causes different effects and results on the composition. In the definite scope of this study, arrangements have been evaluated in terms of the number and degree of contrasts.

The luminous flux and colour properties of the light sources have been given in Table 1 and 2; Philips (2008), Türkoğlu (2010). The power of LEDs change 1 to 3 mW; Türkoğlu (2010).

Table 1. The features of the gas discharge lamps used in the study.

Source	Lamp codes	Luminous flux (lm)	Colour temperature *Tc* (K)	Colour rendering (Ra)	Trichromatic Coordinates	
					x10	y10
K1	High pressure mercury / HPLR	12000	3900	37	0,39	0,37
K2	Metal halide /MHN-TD	12100	4200	80	0,38	0,37

Table 2. The features of the LEDs used in the study.

Source	LED	Colour *Tc* (K)	Colour (Ra)	Trichromatic Coordinates		Source	LED	Colour *Tc* (K)	Colour (Ra)	Trichromatic Coordinates	
				x10	y10					x10	y10
L1	Blue	34367	39	0,1278	0,0818	**L4**	White	10134	70	0,2807	0,2860
L2	Red	1000	19	0,6957	0,3024	**L5**	White	9287	71	0,2895	0,2896
L3	Green	7612	12	0,1921	0,6914	**L6**	White	9465	83	0,2873	0,2962

3. Determination of the inherent and perceived colours

The inherent colours of surfaces measured under standard illuminant D65 by using "Minolta Spectrophotometer-CM-2600D". The measurements were converted to the Munsell, Lab and Lch Colour Systems by using the Spectra Magic (Ver.3.6) Program. The samples of façade paints chosen are matte and evaluations had been made for SCI values. The perceived colours of the

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surfaces were calculated according to the chromatic coordinates (x10, y10, z10) of CIE 1964 X10, Y10, Z10 system for the 1964 Supplementary Standard Colorimetric Observer; CIE (2004), Yavuz (2009), Yavuz, M., Ünver, R. (2009) Judd, D., Wyszecki, G. (1975).

The groups, manufacturer codes and Munsell Colour System symbols of the inherent and perceived colours of surfaces illuminated by K1, K2 sources are given in Table 3 for the same hues arrangement and hue contrast arrangement as an example.

Table 3. The groups, manufacturer codes and Munsell Colour System symbols of the inherent colours and perceived colours of the surfaces under K1 and K2 sources for same hues arrangement (S.H.) and hue contrast arrangement (H.C.)

Group number	Colour		Inherent colour (hue-val./chr.)	Perceived colour (hue-val./chr.)	
	Number	Code		K1/mercury	K2/metal halide
S.H.	**R1**	Copper	8,4R-4,1/5,6	2,47YR-4,57/12,88	1,42YR-4,31/8,44
	R2	Cameo 180	8,4R-8,4/5	2,5R-9,24/2	1,54YR-8,73/10,62
H.C.	**R3**	Tundra 80	9,5Y-6/3,2	5,1YR-6,18/13,85	8,79YR-6,1/7,17
	R4	Bodrum blue	8,9B-6,5/3,5	3,48YR-6,25/10,52	6,43YR-6,49/2,33

4. Evaluation and conclusion

The differences between the inherent colours and the perceived colours of the same hues (S.H) and hue contrast (H.C.) arrangements can be evaluated by using Munsell Colour System as follows:

– **Same hues arrangement (S.H.; hues of the group colours are the same, values and chromas change; R1 and R2)**

Under gas discharge lamps (K1, K2): The perceived hues changed nearly 7 steps under K1. However there were not considerable changes in the value of the colours. The chroma of the R1 colour increased 7 steps under K1 and increased 3 steps under K2. The chroma of the R2 decreased 3 steps under K1, increased twice as much under K2.

Under coloured LEDs (L1, L2,L3): When the hue of the R1 colour had major deviations under blue (L1) and green (L3) LEDs, the hue changed on average 2 steps under red LED (L2). The value of the R1 colour changed approximately 1 steps under all coloured LEDs. The chroma of the colour had a considerable increase also under all LEDs. However the hue and value of the R2 colour had similar changes with R1 under all three LEDs. But the chroma of R2 increased approximately 4,5 times under green LED (L3). The same hues arrangement turned to similar to same hues arrangement.

Under white LEDs (L4, L5,L6): The hue of the R1 colour had the maximum change (4 hue steps) under L4 source and the minimum change (1 hue change) under L6 source. The value did not have an important change under all three white LEDs. However the chroma of the R1 decreased 2 chroma steps under three LEDs. The red R2 colour turned into purplish red under L4 and L5 source and changed 7 hue steps under L6 LED. The value and chroma of the R2 colour did not have an important change under all three LEDs.

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– **Hue contrast arrangement (H.C.; hues of the group colours change, values and chromas are the same; R3 and R4)**

Under gas discharge lamps (K1, K2): The greenish yellow R3 and purple blue R4 turned to reddish yellow under K1 and K2. The values had little changes (0,2 steps). The chroma of the R3 colour increased approximately 5 steps, when the chroma of the R4 colour increased nearly 3 times under K1 and decreased a little under K2. Consequently the hue contrast arrangement turned into the same hues arrangement under two gas discharge lamps.

Under coloured LEDs (L1, L2, L3): The hue of R3 and R4 colours shifted to the light sources' colours. There is no considerable change in the value of the colours under all coloured LEDs. However the chroma increased on average 14 steps. This hue contrast arrangement turned into similar to same hues arrangement.

Under white LEDs (L4, L5, L6): The hue and value of the R3 colour did not have a considerable change under the three white LEDs. The chroma decreased a little. The purplish blue R4 turned into bluish purple under the three LEDs. When the value did not have an important change, the chroma changed 2,5 chroma steps.

The evaluation reveals that the value (lightness darkness) of the inherent colours does not change according to the light sources, nevermore hue and chroma has important deviations. In this context, it has been determined that the studied colour arrangements have been changed.

The methodology and evaluations presented in the study will conduct the lighting designers in terms of the prediction of the perceived colours under artificial light sources in façade colour design with in the context of colour arrangements and also contribute the night appearances of buildings and cities.

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Colour Edu.System: A creative and systematic approach to colour education in design

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Abstract

This paper aims to present the process and the first results of my PhD research on colour education at design schools and faculties. The basic idea is that to ensure the successful development of a real *colour culture*, it is essential to educate the importance of colour at a young age. A didactic model which can support both colour learning and teaching in the design field through a creative and systematic approach has been designed and tested through *action research* methodology at the École Nationale Supérieure des Arts Visuels "La Cambre" in Brussels. The achieved results are useful to improve the model to be tested again.

1. Introduction

Both colour and design have complex and interdisciplinary nature, more and more accentuated by increasingly contaminations among different research and market fields. But design can be considered as a tool to manage the colour complexity, because of its capacity to systematize the articulation of numerous information and disciplines.

Design can be represented by the intersection between art, science, technology spheres, according to the "archetype of design curriculum" scheme by Alain Findeli (2001). In my opinion also colour could be represented through the same intersection, as also it is demonstrated by a European research that some members of the AIC's Study Group of Colour Education (SGCE) are conducting.

Thanks to a brief investigation of colour education offered within European design schools, and a survey conducted at the Design Faculty in Politecnico di Milano that revealed the BA degree level students' colour knowledge, I've identified some lacks in the actual colour education methodologies and several needs about colour knowledge application during the design process. So I thought about a didactic model which aim is to support the creation and development of students' *culture of vision*, and to integrate their *design culture*, already acquired during the BA study career. Consequently I designed and realized a didactic tool using the so called *issue cards*[1], to support the design process in the complex and often undervalued project of the colour component. This system of cards, that I called *Colour Edu.System*, should help students be independent in developing their own colour sensibility and their objective approach when choosing and using it.

I had the opportunity to test *Colour Edu.System* at the École Nationale Supérieure des Arts Visuels "La Cambre" in Brussels during the open doors week with students of 2nd BA year that are attending the *general course of colour* taught by Prof. Felix D'Haeseleer.

The workshop conducted by me involved 40 students in the exploration of colour interdisciplinary nature through a creative and systematic process able to make them aware about

1 The *issue cards* are a tool to induce and feed interactive dynamics inside a team; they are generally used for co-design processes.

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the matter and its importance as design component. In fact through the use of these *meta-design cards*, leading in *brainstorming* and *learning by doing* activities, the students worked in team group on a design project idea in which their approach to the colour component design had to come out on a meta-design level. These cards are designed to systematize the chromatic component complexity, trying to take under control the colour choice, coding and representation. They should also implement the students' capability to observe and facilitate their changing point of view during the design process too.

2. Testing Colour Edu.System cards

The use of *issue cards,* then *card sorting* activity was chosen among the different methods and tools for *problem solving*, *brain storming* and *learning by doing* contexts, where the complexity and interdisciplinarity levels of design process and acquisition of knowledge are high.

Two card decks were designed: the former for the *analysis* phase, the latter for *synthesis* one in which the collected information and observations must be selected and mapped to support and develop the chromatic component design. Analysis/synthesis refer to Swann's iterative process of design (problem/analysis/synthesis/execution/production/ evaluation). *It can only be effective if it is a constant process of revisiting the problem, reanalyzing it and synthesizing revised solutions*[2] (Swann C., 2002).

Because of the nature of card sorting, that *is one of a family of user research techniques designed to give you insight into how people think*[3], my aim was also to test how students of design think and describe categories and concepts about colour and design process, identifying also the key steps in the colour meta-design process.

Colour Edu.System testing at "La Cambre" was conducted through *action research* methodology. Action research is *an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning*.[4] It is a qualitative research methodology that comes from the social field and actually becomes important in the field of education.

2.1 Workshop at La Cambre

The workshop at "La Cambre" was conducted for three times with three different classes of 2nd BA students coming from different design background (interior design, textile design, industrial design), but also with some from painting and ceramics courses. Each class worked for three hours following this schedule: the presentation and explanation of card decks, the analysis and synthesis development, and finally a collective discussion.

Each group of students (4/5 people, mixed background) had to chose one of the selected items (selected considering the students' design background, and also to accelerate the timing of activities): a space at 4th floor like the elevator hall, or the male/female toilet; an object like doors and their handles, toilet tiles, and bins. Then students used the *card deck 1* for analysis phase, and *card deck 2*, the *meta-design cards*, for synthesis one.

Card deck 1 consists in a series of questions that allow students to observe, and to become

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2 Swann, C. 2002. Action Research and the Practice of Design, *Design Issues* 18: 53.
3 Spencer, D. 2009. *Card Sorting. Designing Usable Categories*, New York: Rosenfeld Media, p.14.
4 Avison, D.E., Lau F., Myers M.D., Nielsen P.A. 1999. Action Research. *Communications of the ACM* 42: 94.

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aware of some design aspects including the colour role and its interaction with other aspects and design variables. Each card had to be filled writing and sketching the observations, answering the following questions: What is this? (name and definition); What is its function? (main and secondary ones); How is it? (analyzing its shape, dimension, material, texture and colour); The user; The spatial context (reporting where the object/space is located, how can be perceived changing the point of view); The cultural context (reporting the values and meanings of the item for the cultural context of reference). At last a series of questions about colour role: How does colour interact with the other variables? What are the colour functions? What are its main meanings? Do you think the colour component is significant in the spatial and cultural context you have analyzed? Do you think colour component design could be improved? If yes, how will be your next design approach? If no, can you work on different semantic or functional levels? These last questions should be useful to get to the next synthesis phase.

To manage the synthesis phase, students used the *meta-design cards*, which aim is to organize and direct the collected information in a *mind map*[5], to support the following choices for the design of colour component. Each group of students had to sort some cards from each sub-deck (*design fields*; *research fields*; *design components*; *production*; *topic*; *colour systems and charts*; *questions*) according to their own meta-design colour choices. Aims of using *meta-design cards* are: to encourage a systematic approach to colour design complexity; to help students to assume an objective approach when choosing and using colour; to encourage strategic designing choices; to encourage students to think about colour in relationship with other design components; to encourage students to assume an interdisciplinary approach in designing colour; finally to give teachers the opportunity to choose which design aspects be central and check students' design process.

Figure 1. In order from the left: card deck 1; students using cards; mind map using meta-design cards.

3. Results

The current results, achieved at "La Cambre" through card sorting activity and teamwork discussions with students and professors, allowed me to have positive and negative feedbacks about both the didactic activity management, and the contents of *Colour Edu.System* cards (especially for meta-design card deck).

The timing (only three hours for each class) and the type of involved students in part bound the performance of planned activities, especially during the synthesis phase. Students responded differently according to card decks 1 and 2: if using the former they hadn't many difficulties, on

5 The *mind map* is a tool for the visual explicit of our thoughts and their connections. The visualization begins with a problem or an idea put in the centre of the representation. The hand and the mind work simultaneously. (http://www.servicedesigntools.org/tools/15)

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the contrary, the latter revealed different critical points. The meta-design cards were rich of technical contents and this confused students that had just one hour of time to choose and create their mind map; they hadn't the time to digest and really understand the utility of this tool, so educational, but most for research in the colour field.

The fact that students could compare their own knowledge on colour and design was interesting, but only industrial designers responded in a right way to the using of card deck during the meta-design phase. More difficulties for painting and ceramics students that have another kind of design culture.

Even if the cards aren't designed for this short timing, but for longer and deeper design processes, this workshop experience suggested me to simplify the contents of some cards, especially for *research field* sub-deck, and make more intuitive the understanding of some keywords. It is also important to clarify functions and opportunities of the didactic tool because both students and teachers can use it in the best and strategic way.

Moreover this workshop experience confirmed that students have some difficulties in applying their theoretical colour knowledge during the design process. Their difficulty is in managing colour complexity in a systematic way, finding connections across different disciplinary fields. Then it confirmed my research idea to support the design education of students that have already acquired some colour basics and can understand design complexity (then I suggest the use of this didactic tool at least from the 2nd BA year).

Colour Edu.System should help future designers, not only to improve their consciousness on colour aspects and relationships with the project field, but at first to manage the colour complexity within the design process complexity by a systematic approach. It should also help them to build all the requirements to create a real shared colour culture that put together art, science and technology.

Acknowledgments

I wish to thank Prof. Felix A. D'Haeseleer and Christophe Lepot for their support during the workshop activity conducted at the École Nationale Supérieure des Arts Visuels "La Cambre" in Bruxelles. There I had the possibility to test my didactic model, the cards and the way of using them for the first time, and achieve the first results to correct them and test them again in other design school, as at Design Faculty of Politecnico di Milano.

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Vectors of development of folk dwellings coloristic formations of Europe (time and geographical aspects)

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Abstract

Coloristics of folk architecture in Europe at the end of the XVIIIth century falls under the influence of urban industrial culture expansion, thus launching the process of its urbanization. Traditional pigment and construction materials are replaced with more affordable materials of mass production (Лемешев 1989.) Starting with that moment two basic vectors of coloristic decoration of folk dwelling come to be pointed out: urbanistic and local ones.

Polychromy of architectural and spatial environment in modern folk architecture is changing towards the growth in the number of colour carriers engaged in the formation of the architectural surroundings palette. Coloristic combinations start being applied in folk dwellings architecture, and chaotic variety of colours in them totally endangers the specific features of traditional coloristic environment, regional peculiarities that had been formed through centuries, putting them on the verge of total disappearing.

1. Peculiarities of folk architecture coloristics formation

In old buildings representing folk architecture colour was applied moderately, there dominated mainly natural colours of construction materials: wood, clay, rock, straw and pigments of natural origin.

Colours in folk architecture were mainly used for purely practical purposes. The activities of residents, climate, landscapes, availability of this or that easily available construction material determined the conditions of some coloristic solution the dwelling would acquire. Thus, for instance, as far wooden walls in some regions of Scandinavia close to the sea are concerned, for disinfection purposes the wood of the front was covered with fish oil (that of whales) which made the wood take on a kind of red shade. On the territory of northern Poland for such purposes blood of oxen was used, as the result of application of which wood became of a rusty shade and was protected from moisture (Trocka–Leszczyńska 2000). In the Carpathian region in residential buildings it was popular to make joints of wooden bars be covered in clay and further on be painted in lime mortar, it improving heat and noise insulation, and at the same time imparting an interesting artistic and decorative appearances to the building (Самойлович 1989). On the territory of France, Italy, Germany and, in particular, the Netherlands it became popular to cover wooden elements of the building (window frames, window shutters, door leaf) with copper oxide which protected wood from outer climatic factors.[1]

On the territory of Western and Southern Europe there prevailed stone building, and in this case depending on the region and availability of local rock the coloristics of the very façade varied, but the more to the south the more the colours of facades became lighter, and in case of absence of light construction material white lime mortar was used, often with addition of colour

1 That is one of a few examples of coloristic solution of folk architecture which became popular in the urbanistic surroundings.

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clays and pigments. Here also colour and construction material were used for purely practical purposes. In the summer period light colours better reflected the sunrays, and stone provided coolness, while in winter it, on the contrary, preserved heat (Ігнатьєва 2002).

It is worth mentioning combined solutions for wall facades where the coloristics of wood, stone, or bricks and their various combinations created the uniqueness of the simplest folk architecture.

Peculiarities of painting outer walls and architectural details depend on a number of practical and economic factors: housing planning, climate conditions as well as folk decorative and artistic traditions and aesthetic tastes of the residents of different regions of Europe.

The use of local construction materials, uniqueness and originality of devices in the constructive settlement, planning and in the means of polychromous and decorative ornamentation of folk dwelling, to a certain extent, contributed to the formation of a harmonious architectural surroundings, which, in their turn, merged with the surrounding landscape in terms of coloristics, harmoniously fitting into the natural environment.

The colour diversity of the palette of the traditional environment was enriched with aesthetic understandings of epochs, mythological, symbolic colour images, transferred on to the architectural form as well as cultural import of coloristic tastes. Under the influence of those factors coloristic solutions in the architectural surroundings in folk architecture got formed as a harmonious polychromous system.

2. Vectors of folk dwelling architecture development

Polychromy of architectural and spatial environment in folk architecture of Europe at the beginning of the XVIIIth c. and during urbanization processes[2] in folk architecture gets under the influence of urban industrial culturel expansion. Traditional pigments and construction materials are replaced by readily available mass production ones.

In parallel there get developed two basic directions of coloristic solution of folk life: urbanistic and local ones

Urbanistic vector presupposed direct borrowing and introduction of new coloristic solutions applied in professional architecture, mass production decorative elements, artistic and decorative materials, which appeared in urban culture, into folk architecture. Not only decorative and relief facing of the facades of the Renaissance, baroque or modern were interpreted, but their coloristic solutions as well (Figure 1).

Local vector of coloristics in the folk architecture of Europe presupposed interpretation of the polychromy of ethnoses, their decorative and artistic as well as coloristic solutions using mass production artistic decorative materials which appeared in urban professional culture (Figure 2).

Similar directions of coloristics development in rural architecture were caused by social and political as well as economic factors and agricultural policy of states which included these or those territories.

If we take into account folk dwelling development in the west of Europe, dwelling coloristics here was developing towards a totalitarian direction, it being intensified by an urbanistic vector.

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2 The process of coloristic urbanization of folk dwelling started not simultaneously throughout the whole territory of Europe, it was launched in the more economically developed countries located to the west of Europe at the beginning of the XVIII c., and it gradually started moving to the east by the end of the XIX c.

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Starting with mid-XIX – early XX c. in folk architecture and in everyday life in Europe there were already some rooted stable coloristic and compositional devices, the variants of combination of which became traditional, having acquired the features of a subject matter-spatial compositional system (Лемешев 1989.) .

Architectural styles and their coloristics assimilated by folk architecture up till the end of the XIXth c. are perceived as a traditional solution for folk dwellings. The region of Moravia the west of Hungary) can serve as an example here – the facades with clearly marked baroque elements and characteristic coloristics are considered to constitute traditional architecture of the region. In the western territories of Russia, Ukraine and Belarus there can be traced some characteristics secession decorative architectural elements and coloristics.

On the territory of Eastern Europe up till the end of the XIX – the beginning of the XX c. no significant moves were made towards urbanistics of coloristic decisions of folk architecture, on the contrary there rather continued to be applied interpretation of traditional coloristics of people's decorations of polychromy on the fronts of buildings. On those territories the symbolics of colour got seriously developed, and each colour on the front in combination with its graphic contents can signalize or inform, and most frequently possess the protective functions for the house residents (Zoldi 2000). As a sample here almost a cult attitude to blue colour, or ultramarine, can be taken, it symbolizing welfare and along with white colour protecting the building and residents from different troubles and misfortunes. Quite often on the modern facades of folk dwellings there occur full-fledged picturesque graphic pictures with the images of noble animals, birds, flowers or young people in the background of rich and luxurious landscapes. Such images were transformed and appeared out of simple symbolic graphic images and depictions on old buildings.

Till the beginning of the XX c. symbolic meaning of polychromy on the facades could quite frequently be traced on the territories of Eastern Hungary, Slovakia, Poland, but till the middle of the XX c. such symbols gradually disappeared giving place to the urbanistic vector of dwelling development. In the present-day times in the western territories of Russia, Ukraine and Belarus there take place similar processes of shifts in development vectors, however, further on to the east, in particular, the east of Romania, the south and east of Ukraine, the major part of Belarus and the European part of Russia so far still keep the traditions of colour solution of folk dwellings and local development vector.

In the areas of development of urbanized and local vectors of coloristic formation there are also formed local peculiarities of solutions for folk dwellings.

Such tendencies are in effect up till now, and there are some friction processes taking place at the junction of those directions, and sometimes there takes place the merger of vectors of coloristic decoration of folk dwellings.

Colour in folk architecture as well as its cultural and aesthetic development are constantly undergoing the process of layering and tracing own vision of the new tendencies.

Unfortunately, globalization processes gradually destroy coloristic identity of folk architectural and spatial environment, leaving uniformity and monotony in its place, them being deprived of a deep spiritual content hidden in the coloristics of the folk art of dwelling decoration.

Drawing conclusions, one can point out several basic differences in the coloristic solutions for folk dwellings, these are – attitude to colours which participate in their formation. In the coloristic solution of dwelling in the west of Europe there dominates a purely pragmatic utilitarian attitude to the colour in folk architecture. In the east of Europe there remains some symbolic coloristics in effect, it having certain content. The movement of the urbanistic vector of folk

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dwellings development from the west to the east, intensified with globalization processes, and gradual deviation from and disappearance of local development direction remain unchanged.

1 2 3 4

Figure 1. Urbanistic vector (1 France, 2 Germany, 3 Hungary, 4 Poland)

1 2 3 4

Figure 2. Local vector (1 Ukraine, 2 Belarus, 3 Romania, 4 Russia)

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Colour contrast revisit

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Abstract

The work presented here gives a detailed account of the investigation of simultaneous colour contrast using 2-field paradigm as opposed to traditional 3-field patterns. The effect of colour contrast is studied via the conduction of a series of psychophysical experiments, by which the same colour is placed under different coloured backgrounds and is estimated by a group of subjects using the approach of magnitude estimation. The experimental setting is similar in style to a typical colour picture where a region of interest is surrounded by many other non-uniform colourful objects, the viewing pattern that has not been experimented before. The results are in many ways consistent with the findings in the literature but not entirely in an agreement with them. Modification of CIECAM02 is attempted to predict the effect, which shows potentials.

1. Introduction

Simultaneous colour contrast is a phenomenon that a colour appearance changes with the change of its surrounding colours and has played an important role in traditional art and design practices. Due to the advances of computer internet technology, large amount of colour images (both still and in motion) are available digitally, especially for the purpose of online shopping, which brings the effect of simultaneous colour contrast into a new spot light as a background colour can alter the colour of an object of interest. At present, retrieval of images via their appearance features, e.g., colour, texture, and shape, coined as content-based image retrieval (CBIR), has proven to be a more efficient approach than text-based method, in particular over the internet with huge amount of images being available but not labelled yet apart from their titles. In CBIR, colour is the most popular feature to be applied to index images and is represented by employing colour spaces of mainly RGB, HSV, CIELAB and CIELUB (Qian, 2003). Those spaces however do not take colour contrast into consideration. Thereby, although a query image and retrieved images have similar physical measures of colour attributes in terms of, for example, lightness, chroma, or hue, perceptually, they do not match, leading to lots of elaborative efforts in further improvement to these models. In this study, colour contrast is investigated fundamentally aiming at the arrival of a colour appearance model for CBIR in the long term.

To model a colour appearance, CIE (Commission internationale de l'éclairage) has recommended two versions of models, named as CIECAM97s (Luo, 1998) and CIECAM02 (Moroney, 1998) that can offer the prediction of colour appearance as accurate as an average observer under a number of given viewing conditions. The way that the models describe a colour is similar to that in subjective psychophysical terms, i.e., hue, colourfulness, chroma, brightness and lightness. Although the viewing conditions can vary from dark to light backgrounds, these models are mainly applied for colours with monochromatic backgrounds/surroundings. On the other hand, colour contrast has been considered being too complex to predict by simply modifying the response to reference white (Luo, 1995) in an earlier study. Nevertheless, with the modification of reference white, this effect has been predicted with a very good match to observers' estimations

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by drawing on CIECAM02 in a centre-surrounding paradigm (Wu, 2007), the viewing pattern with three fields, including a test colour field that is surrounded by an induction, with both of fields being against a background.

Since the main goal of this research is to account for retrieving correct coloured objects regardless of the colour of the background the object is against to, two-field pattern of a central test colour coupling with a background is investigated extensively in this research, i.e., the induction field in a 3-field pattern being merged with the background. The existing models will then be evaluated using the data obtained from the psychophysical experiments that are carried out as the first part of the study.

2. Methodology

As illustrated in Figure 1 (left), the experimental pattern utilised in this study comprises two fields, which are a test colour and a background. The right figure is the conventional 3-field paradigm.

Experiments are conducted on a 19” LCD monitor that is calibrated daily using Pantone ColorVision OptiCAL Spyder software (http://spyder.datacolor.com) . The illuminant in these experiments is set to D65 to be consistent with the other existing studies. Thirty test colours are selected to cover a wider range of colours, together with sixteen chromatic backgrounds including 3 grey backgrounds, which are chosen with varying luminance levels. Throughout all the experiments, the reference white, reference colourfulness and surrounding colours remain the same. The test field in the centre in Figure 4 subtends a visual angle of 2^o at a viewing distance of ~60cm.

Figure 1. Experimental setup of colour contrast (left). The colours close to the border of the pattern are surrounding colours. The right figure shows the conventional 3-field paradigm employed for the same study.

Ten subjects with normal colour vision according to the Ishihara colour vision test are recruited to conduct these psychophysical experiments, aged between 20 to 40 years old mixed with both males and females. They are chosen from undergraduates, postgraduates and post-doc researchers. Magnitude estimation method is employed to measure each colour in terms of lightness, colourfulness, and hue. Among sixteen backgrounds that are investigated in the experiments, there are three levels of luminance with CIELAB L* = 30%, 50% and 70% respectively.

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3. Results

In general, the effect of a 2-field paradigm is different from that of a 3-field pattern. For lightness, darker background does make colours appearing lighter, which is in line with the findings with the literature in (Luo, 1995; Wu, 2007). However, the amount of the shift in this study appears not significant with CV (correlation coefficient) values ranging from 11 to 17 when comparing with the variations within subjects that CV values amounting from 17 to 22. The reason could be due to the fact that the reference white being at the same background with a test colour. In this way, a coloured background opts to contribute equally in terms of lightness to both reference white and test colours.

By contrast, changed backgrounds tend to vary perceived colourfulness considerably. Similar to reference white, the reference colourfulness is displayed on the same background with a test colour. However, the estimation of colourfulness appears to be effected largely by the changes of lightness levels of a background. In other words, a darker background makes colours appearing more colourful, especially for red background where colours appear more colourful when the difference of luminance levels between two backgrounds increases. For green and blue backgrounds, on the other hand, the perceived colourfulness tends to be more colourful than under grey background regardless luminance levels.

Another interesting phenomenon is that a very colourful background (CIELAB C*=90) out-shines those test colours, making them less colourful, even though the same reference colourfulness sample is applied to all the experiments. This effect is more profound under red and green backgrounds with about 25% (CV) discrepancies than with blue background. The data under Red-Yellow (orange) background also demonstrates that the responses of colourfulness are consistently getting smaller, which is because that the C* value (=90) of the background doubles the C* values of the other colour backgrounds, effecting the test colours less colourful significantly with ~25% variations.

Similar to the simultaneous contrast where there is an induction field, a colour shifts towards the opponent hue of a background. For example, the hues of test colours seen under a Green background shift towards Red, i.e., most colours appear reddish under green background, the phenomenon that is evidenced in many literatures.

In terms of modelling, CIECAM02 serves mainly for reflective (surface) colours under grey background. To apply this model to the data obtained under LCD monitors, the parameters of a surrounding is set as f=0.9, c=0.41, nc=0.8, which are similar to those applied for transparency samples (Luo, 1995) and produces a good match. However, this model does not provide the facility to predict colour contrast.

To predict the effect of simultaneous contrast, Hunt (Hunt, 1991) has proposed a solution to modify the responses of ρ_w, γ_w, β_w for reference white by the inclusion of same responses for both induction field and background using Eq. (1) where subscription *p* and *b* indicating ρ, γ, β signals for induction and background respectively. This equation has been successfully employed to modify CIECAM02 in (Wu, 2007). The values of p depend on the size and shape of an induction field and should be between 0 and -1 for simultaneous contrast. However, in our work, the induction field and a background are merged into one, i.e., p=0, leading to 1 value in Eq.(2), which in turn producing the signals of $\rho_{w'}$, $\gamma_{w'}$, $\beta_{w'}$ being the same as ρ_w, γ_w, β_w, i.e., it is unlikely to predict colour contrast by the modification of reference white in this way when an induction field is merged with background.

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$$\rho_{w'} = \rho_w \frac{\left[(1-p)P_\rho + \frac{1+p}{P_\rho}\right]^{\frac{1}{2}}}{\left[(1+p)P_\rho + \frac{1-p}{P_\rho}\right]^{\frac{1}{2}}}, \gamma_{w'} = \gamma_w \frac{\left[(1-p)P_\gamma + \frac{1+p}{P_\gamma}\right]^{\frac{1}{2}}}{\left[(1+p)P_\gamma + \frac{1-p}{P_\gamma}\right]^{\frac{1}{2}}}, \beta_{w'} = \beta_w \frac{\left[(1-p)P_\beta + \frac{1+p}{P_\beta}\right]^{\frac{1}{2}}}{\left[(1+p)P_\beta + \frac{1-p}{P_\beta}\right]^{\frac{1}{2}}} \quad (2)$$

Where

$$P_\rho = \frac{\rho_p}{\rho_b}, P_\gamma = \frac{\gamma_p}{\gamma_b}, P_\beta = \frac{\beta_p}{\beta_b} \quad (2)$$

To a certain extent, changing a background is similar to chromatic adaptation where a lighting source is changed from one to another [Hunt, 1991; Li, 2002]. Therefore attempt has been made in this investigation to modify chromatic adaptation response in CIECAM02 for a test colour by adding $\lambda R_{wr}/Y_{wr}$ to CIECAM02 when it comes to calculate colourfulness and hue (since lightness has little changes with the change of a background as described in Section 3). In Eq. (3), a background is considered as an adopted white and reference white is applied to calculate R_{wr}/Y_{wr}. According to the data we have collected so far, λ=1, which leads to a good match between observers' estimation and the predictions by the model, demonstrating that CIECAM02 has substantial potentials in predicting the effect of colour contrast by the modification of response to the chromatic adaptation of a test colour.

$$R_c = R[D \frac{Y_w}{R_w} \lambda \frac{R_{wr}}{Y_{wr}} + 1 - D] \quad (3)$$

4. Conclusion

In summary, the effect of colour contrast has lent itself well to the colour research. This investigation focuses on 2-field patterns with the aim to provide a service for content-based image retrieval. CIECAM02 has been evaluated to predict the effect and has shown potentials in doing so. So far, much of our success owes to our limited data, further investigation is worth doing to further the modification and evaluation, especially in the need of defining the constant factor value of λ in Eq. (3).

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Teaching color to architecture students

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Abstract

Teaching principles of color to architecture students is a challenge different from teaching color to artists. In the education of architects, the aspect of color plays rather a marginal role and in the architectural planning process it is often considered a component that is secondary to the design of the plans or the shape and structure of the building.

In the actual experience of architecture however, color is experienced via the materials that make up the surfaces of buildings and spaces, and therefore, an integral part of the perceptual process. How can this dichotomy between reception and production of architecture be resolved? How can students of architecture be taught to imagine the first ideas about architectural shape and space as material ideas right from the start, instead of merely draping a finished design with color, texture and lighting at the end and thus disregarding their role as intrinsic components of the design process.

How can this integrative approach be realized in teaching? What can we learn from other disciplines about the integration of color, light and material into architectural design and possibly generate new innovative ideas for design.

Didactic Concept

In recent years, the curriculum at the Institute of Spatial Design at the Department of Architecture at the University of Dresden has been considerably revamped in order to better integrate color. Rather than teaching the systematics of color theory, which then become more or less successfully applied to design, we chose to investigate the components of light, color and shape as part of an integrated whole.

During introductory courses the students are first familiarized with color as a material, here they learn to understand the systematics of color as a result of experimentation and reflective thinking. Beginning with the manufacturing of their own colors from various natural materials and the production of a multitude of large color swatches they learn to value color as a sensual medium. By analyzing colors in nature and in architectural surfaces, the students begin to understand the many facets of color and their importance in architecture.

At the graduate level students investigate the various connections between the components of Spatial Geometry, Surface, Color/Texture and Light in terms of their spatial appearance and the atmosphere they create. The underlying idea is that these characteristics of architecture can be systematically analyzed and subsequently taught as principles. One of the teaching exercises used is the transposition of a specific ambience shown in one particular medium, e.g. drawing, photograph, model, text, etc. into another medium.

In our presentation we will also discuss the role of collections in our curriculum, such as the so-called “Sammlung Farbenlehre” at our institute, or the collection of pigments - the so-called „Historische Farbstoffsammlung“ established 150 years ago at the Faculty of Chemistry at the University of Dresden. Both are still actively used in teaching and research. We will also

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discuss collaboration with other institutions in Germany and Switzerland that teach color and how we can find common ground.

Introductory Level

Since students have little knowledge about color when they come to us, we begin with very focused, basic exercises that only concentrate on the aspect of color and generally ignore other aspects of design.

The starting point for all further exercises is the production of a multitude of paper swatches with different shades and hues of color. This way the students get hands-on experience with the medium of color. This is the point of departure for all further exercises.

After this labor intensive but instructive process students now begin with quick exercises in collage techniques where they share each others color swatches in group projects. The advantage of this process is direct experiential feedback. Students immediately see changes in the overall effect of the compositions due to qualitative and quantitative variations in detail and can react immediately without having to produce new swatches and are not delayed by having to wait while the paint dries.

This very extensive collection of color swatches forms the basis for all further exercises to investigate color. Steps in this process can be described by terms such as: universes, systems, collections, interactions and associations of color.

Even with a finite number of swatches, the combination possibilities are nearly infinite. Moritz Zwimpfer makes use of this effect in „Colorondo - a game with 64 colors". When the students produce these cards themselves, they learn much about the intricacies of mixing colors and value the final results accordingly.

During this process the students realized that the effect of color is relative. A color in itself is not ugly or beautiful; only in a composition as a whole can such a judgement be made. Students had no trouble mixing variations of their favorite colors, but in the beginning colors they disliked were harder for them to mix. However, in the end they also started appreciating some of the variations of less favored colors.

Figure1: Collection of student color swatches using four tones in two different magnitudes: a large variety.

Three Weeks of Color. The University implemented an entirely restructured curriculum in 2011 which allows us to offer for the first time three intensive weeks of color instruction. Therefore, we were able to add the aspect of light and its effect on color. In addition, we could also introduce aspects such as perception and meaning of color. We offered excursions to the University's color collections and to several museums in Dresden. Guest lectures offered by scientists and artists rounded out the program.

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Graduate level

In the seminar "*Space, Color, Light*" students focus primarily on the triad of spatial geometry, colors/surfaces and light and its role in creating atmosphere as an immanent part of the architectural concept, as shown in Figure 2. All three criteria are examined with varying emphasis in different exercises. The students learn to design with rapid exposure to 2D/3D media such as model making, sketching, photography and computer design using the process of multiple transpositions between these various media.

Figure 2: Student Works: Paint & Detergent by Daniel Fritz, Traces of Tools by Kathrin Hoffmann; Triad of Space, Color and Light, with the idea somewhere in between. Burghardt, Matthias 2008

Because we assume that in the graduate level students come into the program with a basic understanding of color and light, we are able to focus upon the creative potential expressed in the triad model.

The exercises spreading over the semester can be categorized into three areas of experience: material color, immaterial color and contextual color. While each exercise concentrates on one of the aspects, the others figure in as well. The advantage of working with smaller groups of ca. 25 at the graduate level compared to 150 in the introductory level allows for more experimentation at an individual level.

Under the heading *Material Color* exercises that deal with coloring materials and the inherent colors of materials are subsumed. We produce colors from a range of materials such as spices, minerals, plants, etc. and apply them directly. During this process students learn from unexpected results where reds, because of oxidation of organic materials, become blues. Students also learn about pigments, solvents and binding agents. Such experiments make a long lasting impression. In addition, a variety of media and techniques applied in the arts are practiced: oil, tempra, gouache, acrylic, ink, wax, etc. as well as other more unusual media such as powders, detergents, glues, and household items. This allows for new unexpected combinations which give the impetus for extensive experimentation. Only in the next step does a systematic exploration of the materials and tools begin.

Exercises that deal with the interplay between color and light in space are subsumed under the heading *Immaterial Color*. In addition to color hues and shades, surface qualities such as luminosity, texture and transparency are explored directly in 3D space. We use photography twofold: to record the steps of the individual experiments and to critically explore its function as a medium in architectural presentation.

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In the exercise „Speed Dating" 2D photographs of famous architectural spaces are used as a starting point to produce a 3D model whose purpose is to represent the geometry, color and light of the original photograph. Then another photograph is taken of the model. By transposing the original architectural design through different media, its qualities become more distilled and furthers the students own conceptual understanding.

Finally, the category of *Contextual Color* broadens the spectrum of exercises to the level of symbolism and the role of color in the arts and other areas of everyday life. We investigate the importance between the development of new colors and the evolution of new stylistic periods in art but also the creation of scientific color systems themselves.

Dresden's world famous collection of Old Masters and the museums of contemporary art offer an unique and inspiring environment for this study. More than just a typical museum tour the students conduct an in depth investigation into how color, light and space impact a particular work of art spanning from Lukas Cranach, Titian and Gerhard Richter. Students work on a semester long project exploring how to alter actual architectural spaces in Dresden through artistic intervention.

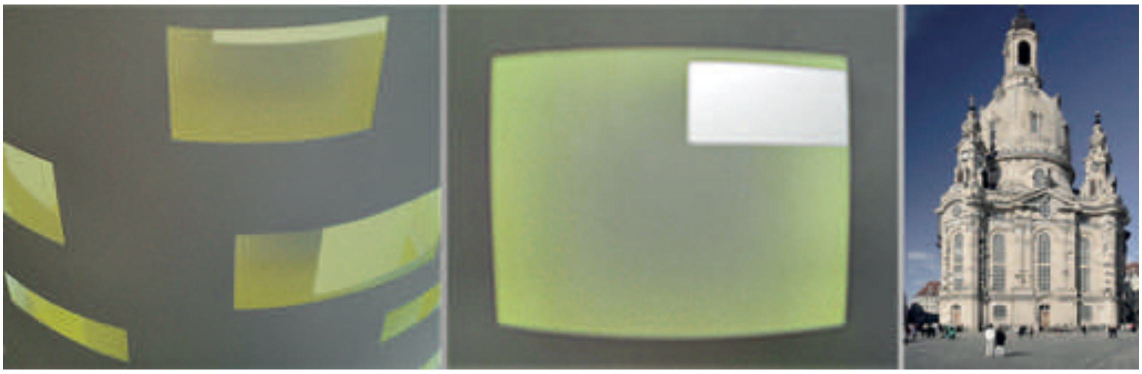

Figure 3: "Sandstone" a project by Lars Jacob in the course "Space Colour Light – Ambassadors to Dresden"

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The influence of backgrounds on mura detection in TFT-LCDs

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Abstract

Mura is a type of defect on liquid crystal displays (LCD) that affects image quality. In this paper, the influence of colour and background patterns on Mura detection is investigated. The method of adjustment was used to obtain the required psychophysical visual assessment data. The variables used in this experiment were the type (uniform, isotropic noisy and grating), spatial frequency (0, 0.2, 0.4, 1, 2, 4 and 10 cpd), orientation (0˚, 45˚ and 90˚), background pattern colour (red, green, blue, yellow and grey), and size of the simulated Mura. Our analysis shows that the orientation of the Mura patterns has no effect for uniform and noisy background types. The masking[1] effect for spatial frequency tunings is significant for noisy and grating backgrounds in which the spatial frequencies of Mura are close to that of the patterned backgrounds. This phenomenon also applies to grating backgrounds when Mura orientation is close to that of the background. The influence of colour is not as strong as the masking effect, but there is a consistent trend for both noisy and grating backgrounds. Mura size has a mild influence on detection when viewed against different backgrounds. The trend, however, is opposite to that found in previous studies conducted with uniform grey backgrounds.

1. Introduction

Mura is an LCD defect that impacts on image quality. Forming in various shapes, they cause slight changes in transmission for local areas of the display (Sawkar et al. 1994). This subtle nature, consisting of gradual and non-uniform changes in lightness within a specific region, results in them being hard to detect by normal optical instruments, although our highly-sensitive visual system can see them with relative ease. For years, researchers have endeavoured to establish a reliable automatic inspection system (Gibour and Leroux 2003, Mori et al. 2003) as well as a widely-accepted inspection standard (VESA 2001, SEMI 2002). This, however, is only half the problem. Few have extended their investigations into the conditions in which Mura defects are viewed against complex backgrounds. Research fails to account for the reality that humans, who are capable of processing complex image content, would barely notice a Mura defect on their displays.

We strongly believe that only when investigations are extended into the conditions in which Mura defects are viewed against complex image backgrounds, then the other half of the problem may be addressed. To follow on from previous research (on uniform grey backgrounds), this research began by viewing Mura patterns against different uniform coloured background, and then extended into patterned backgrounds such as noise and grating. The ultimate goal is to investigate the visibility of Mura against complex images, and to develop a detection model capable of differentiating between all of the conditions mentioned above.

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1 A perceptual phenomenon whereby the visibility of one pattern is reduced by the presence of another.

2. Method

To determine the just notice difference (JND) for different Mura viewed against different types of coloured backgrounds, the method of adjustment (Engeldrum 2000) was used to accumulate psychophysical visual assessment data acquired in a dark room.

A 22-inch EIZO CG220 LCD was used as the experimental platform in this research. A three-dimensional look-up table (3D-LUT) characterisation model of the display was also established in order to generate desired stimuli for the experiment and to calculate JNDs in terms of colour difference (i.e. ΔE^*_{ab}) for each observer at a later stage. The variables used in this experiment were the type (uniform, isotropic noise and sinusoidal grating), spatial frequency (0, 0.2, 0.4, 1, 2, 4 and 10 cpd), orientation (0˚, 45˚ and 90˚), background pattern colour (red, green, blue, yellow, bright grey and dark grey), and size of the simulated Mura (small and large). The patterns of the simulated Mura were defined by the two-dimensional Gaussian function given in Equation (1) (Chen et al. 2006).

$$Mura(x,y)=L_0^*((1+c)*\exp(-(x^2/\sigma^2))*\exp(-(y^2/10\sigma^2))) \quad (1)$$

where L_0 is the local background luminance, c is the contrast and σ is a scaling parameter defining the size of the Mura pattern. In this study, the aspect ratio (height/width) of the Mura patterns was 1.73 whilst the widths (heights) were about 3.3˚ (6˚) and 1.2˚ (2˚), which is equivalent to 0.3 (0.17) cpd and 1 (0.58) cpd, respectively. The grating and noise patterns were luminance-varying and defined in the MacLeod-Boynton domain (MacLeod and Boynton 1979); their contrasts were 0.25 and 0.10. Figure 1 illustrates images with different conditions used in this experiment. It also lists the background colours in CIELAB L^*C^*h. All the measurements involved in the experiment were carried out using a Minolta CS-1000 tele-spectroradiometer (TSR). There were 14 subjects, 8 males and 6 females, with normal vision (according to the Ishihara test), participating in this experiment. During the experiments, they sat 60 cm away from the display to view a 7.5 cm^2 test image surrounded by a neutral background having a brightness of 23.43 cd/m^2.

	BG	DG	R	G	B	Y
L^*C^*h	(68.0,4.0,-35.4)	(23.8,0.7,-16.9)	(39.6,72.6,43.3)	(48.6,78.1,144.4)	(21.6,52.7,-59.5)	(89.0,94.1,98.7)

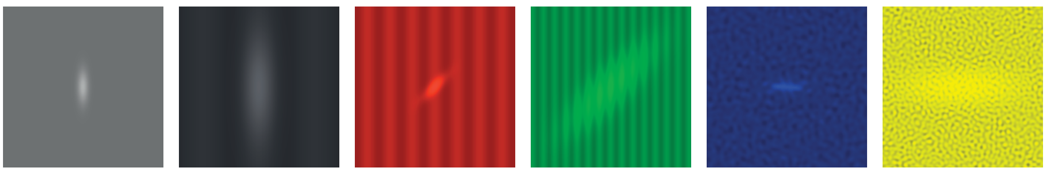

Fig 1. Illustration of Mura on different types of backgrounds with various spatial frequencies. The CIELAB L^*C^*h values of these coloured backgrounds are provided above.

3. Results

Figure 2 shows the JNDs in terms of ΔE^*_{ab} for all experimental conditions and includes one standard deviation error bars. As can be seen, there is a consistent trend for all background types that the JNDs of all colours follow this order: yellow ≈ green ≈ red > blue ≈ bright grey > dark grey. Therefore an averaging operation was further used to remove colour influence, i.e. the JNDs for different colour conditions were combined. The result is shown in Figure 3 and provides a clearer view of the size and masking effect.

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Apparently the orientation of the Mura patterns has no effect for uniform and noisy background types, but it does have considerable influence on grating types when the orientation of the Mura is close to that of background. The masking effect for spatial frequency tunings is significant for noisy and grating backgrounds in which the spatial frequencies of Mura are close to that of the patterned backgrounds, i.e. 0.3 cpd for the large Mura and 1 cpd for the small Mura. This phenomenon also applies to grating backgrounds. When the masking effect occurred, JNDs were elevated by around 0.3-1.0 ΔE^*_{ab} for spatial frequency tuning and by 1.0-1.5 ΔE^*_{ab} for orientation tuning. Mura size has a mild influence on detection against different backgrounds; the difference is about 0.2-0.5 ΔE^*_{ab} greater for large Mura. In summary, JND values obtained here range from 0.3-3.5 ΔE^*_{ab}.

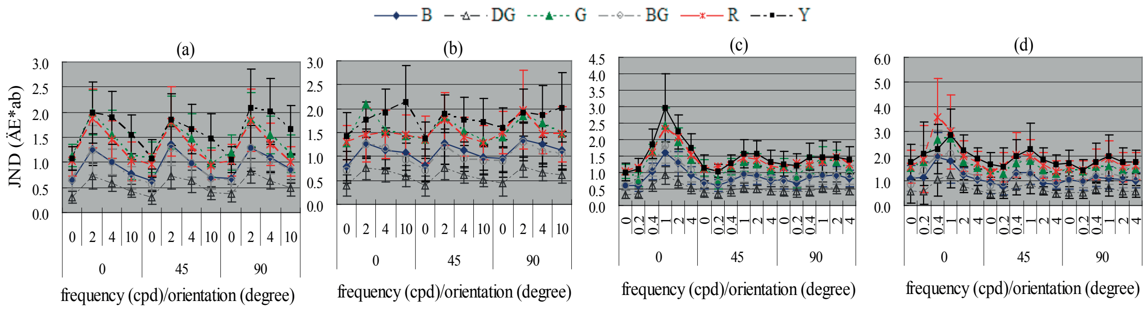

Fig 2. JNDs of (a) small and (b) large Mura on noisy background; (c) small and (d) large Mura on grating background.

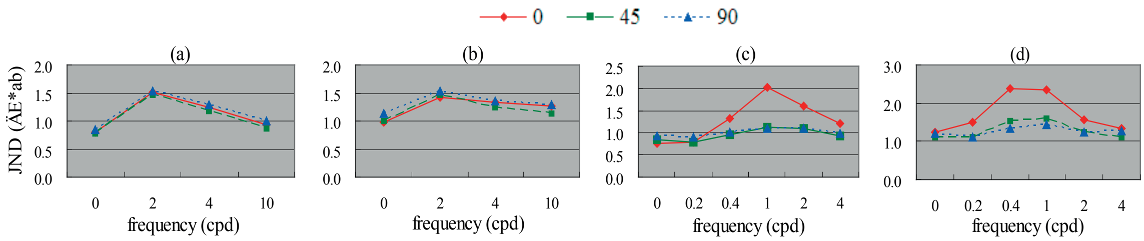

Fig 3. Mean JNDs of (a) small and (b) large Mura on noise background; (c) small and (d) large Mura on grating background.

Discussions

This study aimed to investigate the influence of colour and masking effect on Mura detection against different types of backgrounds. As expected, the masking effect shows the greatest influence when the spatial frequency and orientation of the target (Mura) and mask (background pattern) are similar. This, however, is not the case for the large Mura horizontally (90˚) and vertically (0˚) viewed against a yellow noisy background (Fig. 2b). By comparison with the results from an observer who repeated the experiment for the same (yellow noisy) conditions 11 times, this exception was clarified as being due to the greater standard deviations of 4 cpd and 10 cpd noisy backgrounds when a few observers struggled to identify the shape of the large Mura. This phenomenon has been previously reported (Wei, Luo and Rhodes 2010) and implies that bright yellow backgrounds could make it difficult for observers to detect subtle Mura patterns. On the other hand, the influence of colour was consistent with the findings of Chen et al. (2008) in which a red background was reported to have the greatest visual contrast threshold, followed by green and blue.

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Some earlier studies, including two industrial inspection standards, show that larger Mura are easier to detect (VESA 2001, SEMI 2002 and Lee et al. 2003). The trend obtained in this study, however, is opposite to that found elsewhere using 'uniform' grey backgrounds. We believe that the area ratio of Mura to background, which is about 30% for the large Mura, played a key role. This ratio was not used in those studies previously mentioned. It is likely that when the area ratio exceeds a specific threshold, those models would no longer be applicable. This inference may gain support from the more recent study by Masakura et al. (2007) in which their model was not applicable to large Mura.

Conclusions

Mura size was found to have a mild influence on Mura detection. The trend, however, is opposite to that found in previous studies conducted with uniform grey backgrounds. Compared to previous research, our analysis shows that the masking effect dominates Mura visibility and is the key to reliable prediction during detection against different types of backgrounds. In other words, using Mura size as a unique index to predict visibility is no longer appropriate, particularly when the Mura is viewed against complex images rather than simple uniform backgrounds.

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Analysis on color perception characteristics of senior people by the method of decreasing color differences

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Abstract

The purpose of this study is to analyze the color perception characteristics in senior housing through the quantitative analysis of interaction between color and lighting. We made Mock-up model of real senior housing, and made a interior color evaluation test with lens filters according to the color of lighting, and analyze the color difference of senior people through the color difference decreasing method. We focused to find the appropriate indoor illuminance for senior people to decrease color perception error. As a result, 500lux of indoor illuminance with bulb color lamp is desirable for 40-50 ages. And, daylight color lamp over a 850lux indoor illuminance can be expected to reduce the color difference level of interior space for 60-70 ages.

1. Introduction

According to "The Sex and Age Distribution of World Population" published by UN, Korea is expected to carry into Aging Society(more than 9.0% of elderly population) in 2005, Aged Society in 2010(14%), and Super-Aged Society in 2026(20%). This is the most rapid aging progress in the world. Several studies have been performed to prepare such rapid aging society. In this study, we would like to discuss about the color, and the interaction between color and light, which is very important in visual information transfer for elderly people.

2. Overview of the experiment

The full-scale mock-up was designed in 3500×3500×2500mm, as horizontal, vertical and height, respectively, considering real size of a room in a house. Moreover, to get accurate data without daylight effects in visual comparison test of interior colors according to the artificial lighting variation, it was built as windowless space. (Figure 1)

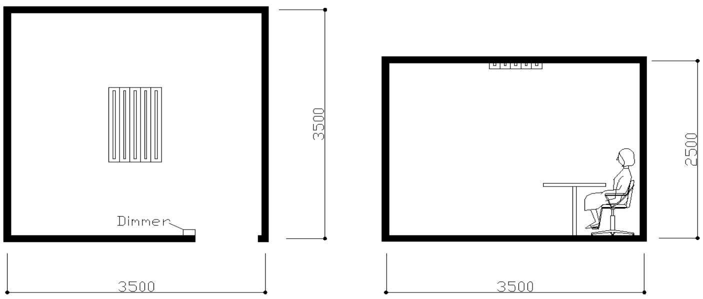

Figure 1. A Ground plan(left) and an Elevation(right)

1200mm long, line types of fluorescent lamps were installed for interior lighting, and a digital dimmer was connected to allow 500-850lux dimming. The color temperatures of the lamps are decided as 3500K with bulb color and 4500K with daylight color, which are the most popular in

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general lighting. In addition, color and reflectance, typically used in residential space, were applied to the ceiling, walls and floors of interior space. (Table 1)

Table 1. Interior Conditions of the Full-scale Mock-up

Lighting type	Interior condition	Color	Reflectance (%)
Daylight color Bulb color	Ceiling	N9	80
	Wall	2.5Y 8.5/2	70
	Floor	10YR 8/6	45

Table 2. Measured Parameters of Full-scale Mock-up on each Location

Lighting type	Interior condition	Luminance (cd/㎡)		Horizontal illuminance (lux)
		500lux	850lux	
Daylight color	Ceiling	43.47	54.56	500
	Wall	73.89	122.8	
	Floor	49.23	87.93	
Bulb color	Ceiling	43.47	54.56	850
	Wall	73.89	122.8	
	Floor	49.23	87.93	

2.1 Measure physical parameters

Interior illumination was measured (by Minolta T-10), in horizontal at the same level of the person's eye when subject is sitting on the chair. Illuminations used in this experiment are 500lux, which is general value in the current housing, and 850lux, to assess visual responses of the elderly who needs high intensity of the illuminance.

Luminance were measured (by Minolta LS-100), in perpendicular to the ceiling, wall and floor from the center of the room where the occupant will be positioned. Measured Illuminance and luminance on each location were represented in Table 2.

2.2 Lens filter

In this study, to analyze the visual characteristics in each ages, three kind of groups were selected, 20~30s without any visual aging, 40~50s from whom presbyopia is started, and 60~70s in which 90% of people experienced the yellow spot symptoms.

Simulated lens were used to reproduce the visual characteristics from infancy to 70s using lens and filters. The 20-30s subjects did not use any lens filters, 40-50s use Y2 filter, and 60-70s use YA3 filters. The two lens filters were made in glasses type to make easy to wear for the subjects, and if the subjects were wearing his/her own glasses, they wore a lens filters after taking a disposal contact lenses.

2.3 Constitution of the subject

Subjects were selected from the 3rd and 4th grade students in Interior design department who were highly-trained at visual colorimetric. First, they got Munsell 100 color test (hue test) and color blindness test to check if they have any Color Vision Deficiencies. Finally, total 32 persons with higher than 1.0 of visual acuity were selected in 17 women and 15 men. (Table 3).

2.4 Method of the experiment

First, The experimental variables were summarized in Table 4. Experiments were made as follows: After varying the brightness and color temperature of the lighting source, one subject went into the full-scale model with changed conditions. As getting into the model, subject wore the lens filter glasses and made a simple start-up for 5 minutes to adjust in the interior atmosphere. After, subject measured the color of the ceiling, wall, and floor through visual colorimetric using Munsell Color Systems and marked with Munsell signal. To make a more accurate evaluation from a subject, each test with different parameters were made in different day.

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Table 3. Constitution of the Subjects

Sex	Women : 17, Men : 15		
Belonging	Professional : 2, Undergraduate : 30		
Age	22 ~ 37 years		
Visual acuity	Left:1.0 ~ 1.5, Right:1.0 ~ 1.5		
Glasses	No	Yes	Contact lenses
	13	9	10
Total	32		

Table 4. Experimental Variables

Lighting Color (Color Temp.)		Illumination (lux)		Age (Lens filters)	
1	Daylight (4500K)	1	500	1	20-30s (No wearing)
2	Bulb lamp (3500K)	2	850	2	40-50s (Y 2)
				3	60-70s (YA 3)

3. Evaluation and analysis

In this study, to identify the amount of color difference in each ages (a lens filter types), the method of decreasing color difference is used.

3.1 The method of decreasing color difference

The method of decreasing color difference can compensate the error of 2D color difference calculation of the color which is represented in Value(V), Chroma(C), and Hue(H). Finally, color difference calculation can be interpreted into 3D Munsell Space for precise calculation by this method. The colors of ceiling, wall and floor were defined as Base color, and the evaluated color by subjects with lens filters(Y2, YA3) are defined as Object colors.

The method of decreasing color difference can be represented as the distance between two points, A(H, V, C) and B(H +ΔH, V +ΔV, C +ΔC), in Munsell Space.

$$E = [(\Delta C)^2 + (\Delta V)^2 + 2C(C+\Delta C)\times(1-\cos(3.6^{\circ}\Delta H))]^{1/2}$$ --- *(Equation. 1)*

Here, *C : Chroma,* *ΔC : Chroma difference*
V : Value *ΔV : Value difference*
H : Hue *ΔH : Hue difference*

Table 5. Color difference of the Wall in each Lighting Type andLlens Filters

Lens filter	Lighting color	Illuminance (lux)	H	V	C	ΔH	ΔV	ΔC	E
Y2	Bulb	500	5.53	7.74	10.21	3.29	0.82	1.50	1.96
YA3	Bulb	500	5.53	5.63	12.21	9.87	2.87	10.21	11.09
Y2	Daylight	500	6.00	7.82	10.72	3.54	0.68	8.72	8.81
YA3	Daylight	500	4.50	5.72	12.48	8.40	2.78	10.48	11.27
Y2	Bulb	850	6.67	7.95	10.29	4.17	0.55	8.29	8.34
YA3	Bulb	850	3.81	6.33	12.48	8.69	2.17	6.69	7.40
Y2	Daylight	850	6.17	8.32	9.20	3.67	0.28	7.20	7.25
YA3	Daylight	850	4.90	6.98	10.40	7.33	1.62	8.40	8.81

3.2 Color difference analysis

In a condition of 500lux interior illumination, color difference(E) of Y2 lens filter(40-50s) is 10 times of YA3 lens filter(60-70s). And, in 850lux illumination, color difference of Y2 lens filter was increased more than 7 times of 500lux.

When the interior illuminance is 500lux, Y2(40-50s) lens filter showed very small amount of color difference in bulb color than daylight color condition, and the shift were increased along the illuminance increase to 850lux. In case of YA3(60-70s) lens filter, color difference was most largest in 500lux with bulb color condition.

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Table 6. Base Color and Color Difference from Object Color of each Location

Illuminance (lux)	Location	Lens filter	Color distance(E)	
			Daylight color	Bulb color
850	Ceiling	Y2	9.079602	10.16363
		YA3	15.1017	12.66095
	Wall	Y2	7.252691	8.344852
		YA3	8.810449	7.400842
	Floor	Y2	4.320783	2.790912
		YA3	5.799656	2.710405
500	Ceiling	Y2	15.53081	11.02251
		YA3	15.71559	13.77272
	Wall	Y2	8.806218	1.964805
		YA3	11.26861	11.08726
	Floor	Y2	3.855009	3.507349
		YA3	6.83829	6.197903

4. Conclusion

The analysis results of color difference of lens filter Y2(40-50s) and YA3(60-70s), which are simulates crystalline lens according to the variation of the lighting conditions(indoor illumination, color of lighting) in interior space of elderly people, are shown as follows.

Firstly, the lower illuminance, the bigger color difference between base colors and the object colors formed by the lens filter. And, with the higher illuminance, color difference was not affected significantly, and the difference of color difference of Y2 and YA3 lens filters were similar.

Secondly, in case of daylight color above 4500K color temperature with the 850lux illuminance level, the color distance showed larger with using YA3 lens filter (60-70 ages) than Y2 (40-50 units). In case of bulb colors under 3500K color temperature, it showed that no significant color distance between Y2 and YA3 lens filters.

Lastly, considering that Y2 lens filter represent the visual characteristics of 40-50 ages, 500lux of indoor illuminance with bulb color lamp is desirable. And YA3 represent for 60-70 ages, daylight color lamp over a 850lux indoor illuminance can be expected to reduce the color difference level of interior space.

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Gender differences in color and shape emotion

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Abstract

Color exists in a various shape. Shape takes a role as a container. The same color can express different emotion when it is applied in different shapes. In this study, effect of shape on total emotion is investigated. 5 garment shapes and 10 single and 20 pair colors shown on the monitor are used in the experiment. Emotion is assessed using 7 bipolar affective adjectives. As a result, the color emotion assessed in rectangle patch is not significantly different between male and female. The male observers respond the shape similarly but the female observers respond diversely between them. In order to identify the effect of shape on total emotion, the color emotion evoked in the rectangle and total emotion evoked by color combined with shape are compared directly. In male's case, total emotion shifted toward shape emotion. While in female's case, total emotion is not effected by the shape emotion implying that the total emotion mostly comes from the color emotion.

1. Introduction

People communicate using language, shape, symbol, and color in daily life. A language is the most powerful, among those communication tools. However, when designer designs a product, non-verbal-language can be more effective to persuade customer. These days, people buy a product which design is mainly determined by "color" and “shape". Therefore, expressing emotional characteristic using color and shape is important in the design field.

Traditionally, color emotion researcher has been focused on color, without shape. Shape takes a role as a container. The same color can express different emotion when it is applied in different shapes, vice versa. In this study, effect of shape on total emotion by color combined with shape is investigated.

2. Experimental setting

shape(a) shape(b) shape(c) shape(d) shape(e)

Figure 1-1 Test shape

Figure 1-2 Test colors

Figure 1-3 Test stimuli

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Test shapes consist of 5 female garments and 1 rectangle. (Figure 1-1) They are shown with black line on the grey background. Test colors consist of 10 single colors and 20 color pairs and 1 grey color which are selected from the book, 'Color image scale' written by Kobayashi (1981) (Figure 1-2). Totally, 186 stimuli are shown to observers. ((5 shape +1 rectangle) x (10 single colors and 20 pair colors + 1 grey background color) =186 stimuli) Test stimuli (Figure 1-3) are reproduced on the LCD monitor in the dark room. The PLCC method (Thomas, 2008) is used to match patch color and monitor color. Then, observers are asked to assess the emotion of test stimuli using 7 bipolar affect adjectives; warm-cool, heavy-light, clean-dirty, active-passive, hard-soft, tense-relaxed, and fresh-stale. First, they are asked to choose one of the adjectives and then answer the intensity of given stimulus. First word converted to positive value and last word converted to negative. 10 male and 10 female observers in their early twenties participated in this experiment. All of them are Korean.

3. Result

3.1 Color emotion differences between male and female

The color emotion is collected from rectangle patch. The color emotion of male and female are compared directly as shown in Figure 2-1. As a result, the overall correlation is high. The overall pearson correlation co-efficient value is 0.85.

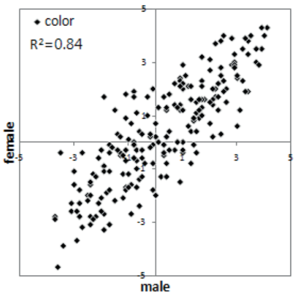

Figure 2 color emotion comparison between male and femal

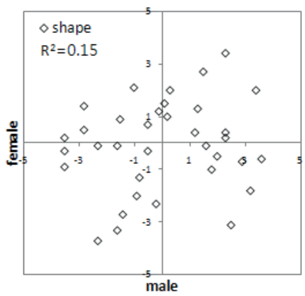

Figure 3 shape emotion comparision between male and female

3.2 Shape emotion differences between male and female

The shape emotions are collected from the emotions of 5 shape patterns with grey color. The shape emotion between male and female are compared as shown in Figure 3.The Pearson correlation co-efficient value is 0.19. It means that the shape emotion between male and female is very different.

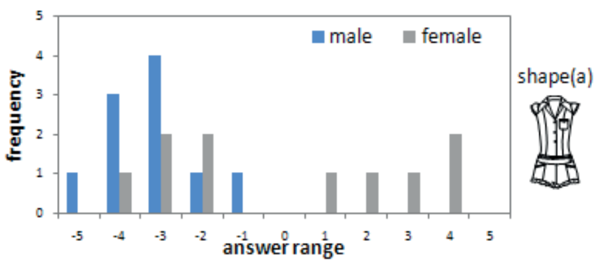

Figure 4 frequencies of shape (a) on warm-cool

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In Figure 4, frequencies of male and female answer of shape (a) on warm-cool are plotted. The male observer's answers are converged, while the female observer's answers are diverse. It means that the male observers recognize shape in a simply way, but the female observers does not. Each female observer accepts shape emotions differently. In this shape (a) case, since shape (a) is short-blouse and short pants, the male observers must have been simply answered 'cool', while some of the female observers must have noticed details like lace and frill. Lace and frill gives 'warm' feeling.

3.3 Relationships between color emotion and shape emotion

The total emotion means the emotion evoked by color combined with shape. The relation between the color emotion and the total emotion is analyzed by comparing the responses from the same color directly. If there is no total emotion change by shape changes, the color emotion and total emotion will be similar to each other. In this case, the graph similarly shows y=x graph. On the other hand, if there is total emotion changes by shape emotion, total emotion data will be shifted upwards or downwards depending on shape emotion.

3.3.1 Relation between color emotion and total emotion of the male observers

Figure 5-1 Comparison between color emotion and total emotion (Male, Shape(b), warm-cool)

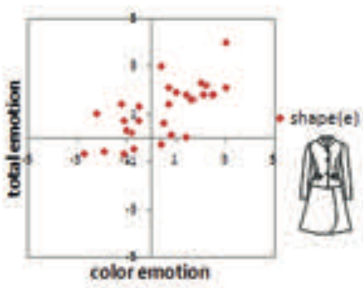

Figure 5-2 Comparision between coloremotion and total emotion (Male, shape(e), warm-cool)

The shape (b) and the shape (e) have the most different warm-cool emotion among test shapes. The average warm-cool emotion for shape (b) assessed by the male observers is -3.5 (cool) and that for shape (e) is 2.9(warm). As you can see Figure 5-1, total emotion of shape(b) is shifted downward along y-axis in negative (cool) direction than rectangle shape while as shown in Figure 5-2, warm-cool emotion of shape(e) is shifted upwards (warm direction) along y- axis. The total emotion must have been shifted toward shape emotion.

The trends of other bipolar affective adjectives and other shapes are similar to warm-cool results in Figure 5-1 and 5-2. It can be interpreted like this; shape emotion affects the total emotion by shifting total emotion toward shape emotion.

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3.3.2 Relation between color emotion and total emotion of the female observers

Figure 6-1 Comparison between color emotion and total emotion (Female, Shape(b), warm-cool)

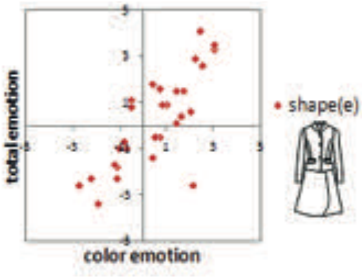

Figure 6-1 Comparison between color emotion and total emotion (Female, Shape(e), warm-cool)

Unlikely the male's case, each female observers assesses the shape emotion differently. The average of warm-cool emotion of shape (b) is -0.9 and the average of warm-cool emotion of shape (a) is -0.5. As you can see in Figure 6-1 or 6-2, there are no significant shifts between color emotion and total emotion.

Even after gruoping into two, i.e. positive emotion group and negative emotion group, according to each observer's answer of the shape(b), there is no significant shifts betweem them. It means that the total emotion does not changed by shape emotion and the female observers consider mainly color emotion.

4. Conclusions

The effect of shape on total emotion is investigated. 5 garment shapes and 10 single and 20 pair colors shown on the monitor are used in this experiment. Emotion is assessed using 7 bipolar affective adjectives.

The results show that the color emotion is not significantly different between male and female (R^2=0.84). However, shape emotion between male and female is considerably different each other (R^2=0.15). The male observers respond the shape emotions similarly, but the female observers respond diversely between them. In order to identify the effect of shape on total emotion, the color emotion evoked in the rectangle and total emotion evoked by color combined with shape is compared directly. In male's case, total emotion shifted toward shape emotion. While in female's case, total emotion is not affected by shape emotion implying that the total emotion mostly comes from the color emotion.

Acknowledgments

We thank the fashion designer, Soyoun Koo, for kindly allowing the authors to use her fashion artworks shape (a), (c), (d), (e) in our study.

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Gender differences in social perception for skin tones

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Abstract

This study used computer-generated face images to study the impact of skin tone on the viewer's perceptions of attractiveness, masculinity and cooperativeness. Twenty-nine British observers, 14 male and 15 female, participated in the experiment. The experimental results show that for attractiveness, female observers were found to be more sensitive than the male in rating the images varying only in chroma; however, for images varying only in hue, male observers tended to be more sensitive than female. For masculinity, male observers tended to rate higher than female for all test images. In terms of cooperativeness, female observers tended to regard face images with higher-chroma values as less cooperative, while the opposite trend was found in the male response.

1. Introduction

Facial skin tone can have a significant impact on the viewer's social perception for certain traits, such as attractiveness and kindness (e.g. Hassin and Trope 2000; Swami et al. 2008). Such an impact is important to study for its potential contribution to image quality enhancement in the imaging industry and in the animation character design area. Despite a large number of related studies (e.g. Borkenau and Liebler 1992; Berry and Landry 1997; Yano and Hashimoto 1997; Hassin and Trope 2000; Arya et al. 2006; Swami et al. 2008; Hsu et al. 2009; Zeng and Luo 2011), these existing studies mainly used real human face images as stimuli, without controlling any factors that might affect the visual results, such as race, age, gender, facial feature or emotional expressions shown on the face images. Without any control of these factors, it is hard to justify whether the results were based solely on skin tone or whether there was any interaction between the factors.

To address the issue, the current study used computer-generated face images to study the impact of skin tone on the viewer's perceptions of attractiveness, masculinity and cooperativeness. Comparisons of the experimental results were made between male and female observer groups, revealing strong gender differences in these scales, as will be discussed in more detail later in this paper.

2. Methods

Twelve computer-generated face images were used as the stimuli. A three-dimensional human face was initially generated using the FaceGen computer software, with average L*, a* and b* values (for the skin part only) of 54.5, 18.1 and 19.0, respectively. The image was then manipulated using MatLab by varying CIELAB a* and b* values for each pixel by equal amount while the L* value remained unchanged. Table 1 shows mean CIELAB values for each image. During the experiment, the images were presented in random order on a cathode ray tube (CRT) monitor (peak white: 64.9 cd/m^2).

Three word pairs, attractive/unattractive, masculine/feminine and cooperative/uncooperative, were used for each observer to assess social perception of each image. The word pairs were

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Table 1 CIELAB values (pixel average) for test images used in this study

	L*	a*	b*	C^*_{ab}	h_{ab}
1	54.5	18.1	19.0	26.2	46
2	54.5	23.1	24.0	33.3	46
3	54.5	23.1	34.0	41.1	56
4	54.5	23.1	14.0	27.0	31
5	54.5	28.1	19.0	33.9	34
6	54.5	28.1	29.0	40.4	46
7	54.5	33.1	24.0	40.9	36
8	54.5	13.1	24.0	27.3	61
9	54.5	13.1	14.0	19.2	47
10	54.5	8.1	19.0	20.6	67
11	54.5	18.1	29.0	34.2	58
12	54.5	18.1	9.0	20.2	26

Figure 1. Screen layout of the experiment

selected on the basis of results of factor analysis for original 12 scales, which were related to social perception of human faces: sociable/unsociable, cooperative/uncooperative, easy-going/irritable, relaxed/nervous, careful/careless, imaginative/ unimaginative, masculine/feminine, mature/ immature, clever/silly, natural/unnatural, attractive/ unattractive and likeable/ dislikeable.

A panel of 29 British observers, 14 male and 15 female, all passing Ishihara's test for colour deficiency, took part in the experiment. They were all current students at the University of Leeds, UK. During the experiment, each observer was seated in front of the CRT monitor, with a viewing distance of 50cm. Each observer rated the 12 face images (each presented twice) on six-point force-choice scale in terms of the three word pairs, using the six numbered buttons shown beneath the face image (see Figure 1), in which the button number 1 means "a little", 2 "moderately", and 3 "a lot".

3. Results

The experimental results were first examined in terms of repeatability, as determined by correlation coefficient of observer responses to images shown for the first and the second times. Attractive/ unattractive shows the highest repeatability value for all observers (R = 0.85), followed by cooperative/uncooperative (0.73) and masculine/feminine (0.53). The repeatability was also tested within each gender group. As a result, the two groups show similar repeatability for attractive/unattractive (R = 0.80 for male and 0.83 for female) and for masculine/feminine (0.41 for male and 0.44 for female). Regarding cooperative/ uncooperative, however, male observers were found to have higher repeatability than female, with correlation coefficients of 0.71 and 0.54 respectively. These results suggest that for both gender groups, the perception for attractiveness of the face images was highly repeatable. For cooperativeness, the male data were more repeatable than the female.

Responses of the two gender groups were compared using scatter graphs. Figures 2 (a) to (c) show the comparison results, with a correlation coefficient of 0.71 for attractive/ unattractive, 0.35 for masculine/feminine and -0.16 for cooperative/ uncooperative. This indicates the two gender groups agreed well on the attractiveness. For masculinity and cooperativeness, however, the correlation coefficients for both scales were low, especially for cooperativeness, suggesting strong gender differences in the two types of social perception.

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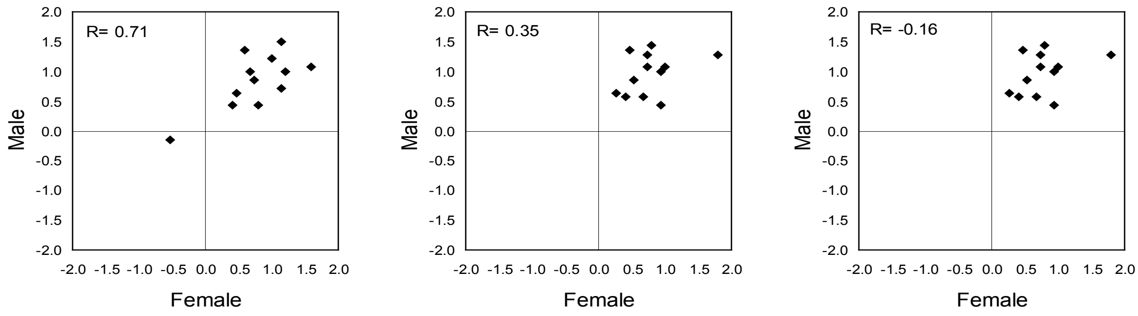
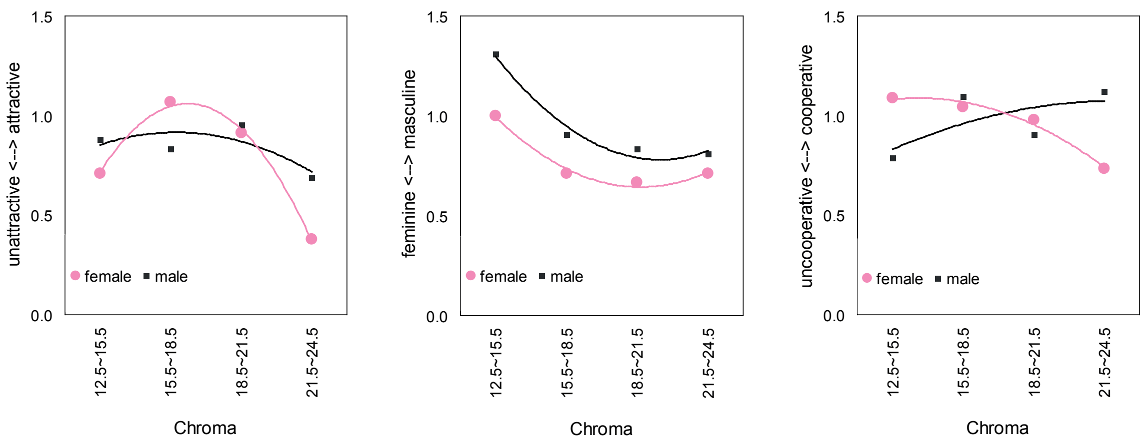


(a) (b) (c)

Figure 2 Male response plotted against female response: (a) attractiveness, (b) masculinity and (c) cooperativeness

To see whether such differences were related to skin tone, the responses of the two gender groups were plotted against mean chroma and mean hue angle for each scale. Figures 3 (a) to (c) show the results for mean chroma. For attractiveness, the data points for female group seem to peak at around 15.5 to 18.5 in chroma, where the scale value tends to fall sharply on either side. For male group, on the other hand, the data points do not show such a strong variation. This seems to suggest that female observers were more sensitive than male observers in rating attractiveness when the image chroma varied. In terms of masculinity, male observers gave higher scale values than did female observers, while both gender groups show similar trends: the image appears less and less masculine as chroma increases until 18.5~21.5. For cooperativeness, the data points of the two gender groups seem to show opposite trends – female observers tended to rate lower (i.e. less cooperative) for high-chroma face images than for low-chroma face images, while male observers tended to regard those with higher chroma as more cooperative.



(a) (b) (c)

Figure 3 Observer response plotted against chroma: (a) attractiveness, (b) masculinity and (c) cooperativeness

Figures 4 (a) to (c) show the comparison results based on image hue. In terms of attractiveness, responses of both female and male observers increase as the skin tone becomes yellowish until the hue angle reached just over 55°. However, the male data points show higher scale value than the female at the peak, suggesting that hue had stronger impact on male observers' response in attractiveness than on female's response. With regard to masculinity, both gender groups show similar trends – the scale value gets higher and higher (i.e. more masculine) as hue angle increases (i.e. becoming more yellowish). Note, however, that male observers gave similar ratings for images with a mean hue angle of lower than 55°, suggesting that male observers were less sensitive than

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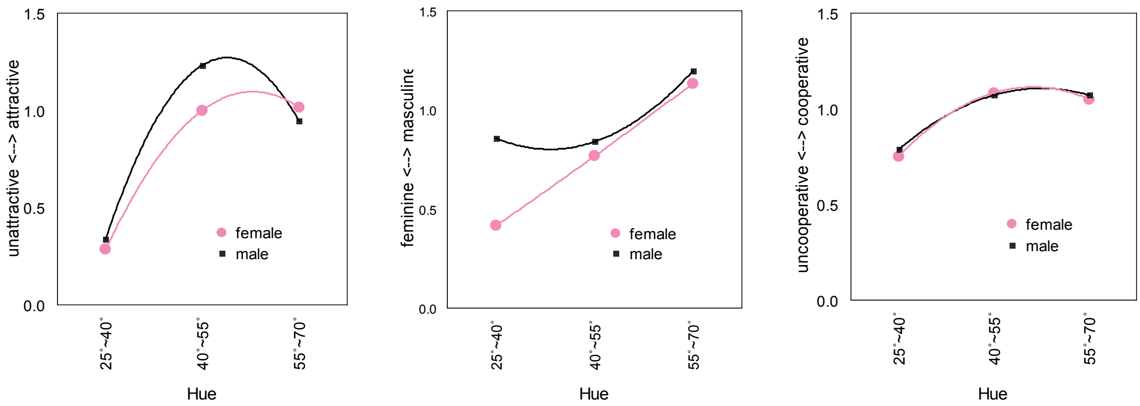
the female in assessing masculinity of images in the orange to red region. For cooperativeness, both gender groups show similar trends – the scale value gets higher and higher (i.e. more cooperative) as hue angle increases (i.e. becoming more yellowish) until around 55°. This suggests that for both gender groups, the more yellowish the skin tone is, the more cooperative the face looks.



(a) *(b)* *(c)*

Figure 4 Observer response plotted against hue angle: (a) attractiveness, (b) masculinity and (c) cooperativeness

4. Conclusion

The experimental results show strong evidence that male and female observers rated differently for computer-generated face images with varied skin tones, in terms of attractiveness, masculinity and cooperativeness. For attractiveness, female observers were found to be more sensitive than the male in rating the images varying only in chroma; however, for images varying only in hue, male observers tended to be more sensitive than female. For masculinity, male observers tended to rate higher than the female for all test images. In terms of cooperativeness, female observers tended to regard higher-chroma face images as less cooperative, while the opposite trend was found in the male response.

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Sublime ugly architecture

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Abstract
Inside the "Colour & Light in Architecture" research Unit of the Iuav University of Venice there is a group involved in the investigation of the colour and light role into the aesthetic evolution of the Italian architecture, specifically that of the northern industrialized area. The research scope is to identify the main phenomena taking place into the contemporary urban environment. The method used to catch the first results is focused on analysis of the most evident urban phenomena. In places with high anthropic impact it seems that the ugly tends to prevail, generously sponsored by the market that is finalized to increase the sales of its products. The dissonant colours, vulgar, ambiguous, are commonplace in every western city, none excluded. It seems that in these places the rules of colour/light composition are to be rewritten, if these have never been. Also the urban building walls are more subject of attention from the street art, graffiti writers, stickers, stencil artists and so on. Their not institutional presence often entails overlapping of several layers run by different hands. The lights and the colours of contemporariness sublimate in chaos, confusion, in self contradiction of our time, where the architecture remains queen in the chromatic exaggeration.

1. Floating art?
Dino Formaggio, philosopher who taught aesthetic mainly in Milan and Padua, in the incipit of his book entitled *Art* provides this definition: "art is what men call it art". If this assertion is verified by the fact of being "the only acceptable definition and verifiable art concept" then it can be argued that between the arts also architecture is an art form, when it is called thereby.

This definition prevents immediately any hidden, mysterious, unclear or tendentious meaning. In addition, it clarifies unequivocally that every age, every community, every single manifestation called different things as art, allowing the relativity and variability of every form of art in every time and everywhere.

Art, as architecture, is that in different times and places on the basis of the appointment. But it is not to be confused by the question of who are these men that call (art): individuals, social groups related to cultural affinities, by economic interests, by particular inclinations and so on. Is question that may not have sense, or as have so much sense to be decisive. Two are the ways out of this impasse: either you reply meticulously, precisely, sufficiently clarified in the book of Formaggio, or leave away, since the passage of time and of interests of individuals and societies change from time to time the answer. In individualistic society, for example, like the one we're we are living, in so-called democracies, a simple answer is wrong anyway.

The error in which we fall appears inherent in the origin of the word, which comes with a precise objective, but that is then changed with the advent of the modernity. In Sanskrit the word art is derived from the word "are", which means giving order, in Greek by "τέχνη" which indicates the ability to accomplish something, which derives from the knowledge of the rules, and so also in the Latin "ars" keeps this relationship with the organizational wisdom aimed to obtain an object, or express a thought. Organize or carry out by applying rules assume that these exist.

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Therefore, someone in antiquity had taken the burden of make the rules, sharing them and thus acceptable. As long as the society was organised on the fulfilment of shared rules also art was showing and consolidating itself, filling the art spaces with those achievements that we all admire today. However, when these rules are contravened, even the ancient art meaning is no longer the same. It becomes changeable in relation to new rules replacing the previous ones from time to time. A rule which varies continuously is no longer a rule. Therefore the meaning of his existence disappears. At present this aspect leads to a serious crisis of identity in art and architecture, both navigating at sight along many courses, but without reaching a safe port. In this floating of artistic matters colour and light play a strategic role.

2. Fluid art?

Each art should be able to represent its contemporaneity. The complexity of today's world, however, can only request a complex art, which we can see clearly in many contemporary arts. Seem permanently declined the times when Mies van der Rohe said "less is more". The complexity and complication has moved inexorably in architectures, especially from a technological point of view. In architecture technologies act figuratively than in other arts, and then in the colors and lights that let perception and interpretation.

Ease of handling big loads, combined with the availability of materials and techniques from various sectors, provides forms the most disparate, especially those who have little or nothing to do with Euclidean geometry, loved and preached by the Modern Movement. This resulted in the advent of architectures hard to classify as such, resembling more as mega sculptures or media buildings, urban screens, and so on. These kinds of buildings, according to the Formaggio definition, should no longer be defined as architectures, or at least put in crisis the definition of art initially defined.

The excessive science fragmentation, beginning with Descartes, was able to inoculate the division also in the artistic world, relegating the knowledge and definitions only to specialists. Therefore the only ones who call art the works of some kind of architecture are only a few specialists, isolated from the rest of the world of users.

So these architectures are so defined not from men but by a few followers. New products of these arts are interpreted by the man in the street as incomprehensible eccentric things, even if original, able to shock. The colours that appear on the surfaces of these achievements constitute an unessential complement, being the unusual shape by itself able to determine almost always the artistry, in the sense of foreignness of the artwork.

While in very long architectural tradition, static, utility and beauty (*firmitas*, *utilitas, venustas,* from Vitruvius) were essential in obtaining an architecture, today buildings are not responding, or may not respond, to any one of the three points just mentioned. If the fundamental rule on which the current architectural production is the originality, diversity, unusual, shocking, this implies that the buildings currently realized belong to a reality from time to time different, falling within parameters defined as artistic, but scarcely architectural. The clarification is inherent in the fact that the current society has a particular propensity for diversity, "liquid" as defined by Zygmunt Bauman. The continuous vary, change, modify, adapt, translate, combine or reject, simultaneously establish the advent of new rules, if so we can say. These are propensities that may be more noticeable in urban places, in the cities, where proximity of diversity allows an easier reading of these aspects.

The coming and consolidation of globalization has, in a certain way, condensed the

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fragmentation that existed before its mass acceptance. What was not considered artistic in a place now became accepted hypothetically for the entire globe, opening more uncertainty and confusion channels never seen before. The local continue its daily scroll alongside some global aspects, variously amalgamated locally by changing not only the lifestyles and thinking, but also the interpretations. Colour and light, focal points of each speech concerning Visual Arts, including architecture, are emblematic of change.

3. Dust and urban blight

In urban realities, the predominant colour is grey, or more precisely the color of the dust. It is known that the dust, in human history, has always had an important role, even if so common and to which not giving serious attention. In catholicism is even behind the appearance of man, which takes the form from dust in the hands of the god.

The real turning point in art than in the past is with Duchamp, or more precisely from the collaboration of Duchamp with Man Ray, during the project execution: *Elevage de poussière*. "It is with Marcel Duchamp that dust plays a key role and takes a shape and a new and unexpected development. The reason is that dust now enters into the work no longer in the figured form, represented, but directly as a material. "(Elio Grazioli, p. 55).

The subject that most affects the appearance of the city is the grey colour of dirt, deposited on the walls of buildings. At least this is the urban image that the minds of many contemporary men have settled. The smog, particulate substances of a more or less large filling the air of each city, settling everywhere fade the colours of the materials. They perform a visual filter function, and at the same time is the support for every additional deposit or cleaning action. So when you apply a layer of paint or clean a surface you got the same effect: to give colour. In the first case adding further substance and in the second one removing substance.

If the base, the primer on which the architecture appears is not accepted as contemporary, in the sense that aging is not tolerated in today's society, and if at the same time the environment is stressed by the pollution that can not be win, then all that remains is to play the same game: degrade, rape, act blatantly upsetting the idea of beauty that accompanied the history of the arts.

It's clear that the rebellion, swallowed up by the world of production and consumption, also based on some of the assumptions mentioned above, involves and push down any attempt to bring order, to organize, to initiate a new process of confusion regulation. The research has highlighted the weakness of any attempt to control the urban colour. It may seem counterintuitive, but even where the plans have been activated colour (at least in the Italian cities examined), most of them have acted causing an increase in tone and saturation, required the application of rules purely subjective, free of any historical basis, acting anti historically, introducing different colours than the local tradition. At least for the moment it seems to be out of date all efforts against anti-aestheticism and vulgarity of contemporary society.

In places with high anthropic impact the ugly tends to prevail, generously sponsored by the market that it takes to raise, and then sell, its products. The chromatic dissonant, vulgar, ambiguous, are commonplace in every western city. It seems that in these places are to be rewritten the rules, if these have never been, of color composition. Also the urban building walls are more subject of attention from the street art, graffiti writers, stickers, stencil artists and so on. Their not institutional presence often entails overlapping of several layers made by different hands. It follows a mixture of colors, and messages, messy and contradictory, the same found in clothing for young generations, but also furniture and furnishings in the matching of many homes of ordinary people. The lights

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and the colours of contemporaneity sublimate in chaos, confusion, in contradiction of our time. The architecture in all this remains queen, also in the chromatic exaggeration.

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