AIC2013
Bringing Colour to Life

AIC Colour 2013

12th Congress of the International Colour Association
8-12 July, 2013
Newcastle upon Tyne, UK

Proceedings
Volume 1

Editors:
Lindsay MacDonald,
Stephen Westland,
Sophie Wuerger

The Colour Group (Great Britain)

AIC

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

programme overview

Sunday 7th July

- 10:00–18:45 — ***Lit & Phil*** — AIC Executive Committee Meeting
- 15:00–22:00 — ***BALTIC Terrace*** — Welcome Drinks + Registration Open

Monday 8th July

- 07:00–17:30 — Registration and Exhibition Open
- 07:00–08:15 — Registration and Exhibition Open
- 08:15–08:45 — ***Hall One*** — Opening Ceremony
- 08:45–09:45 — ***Hall One*** — Keynote - Andrew Parker
- 09:45–10:30 — COFFEE
- 10:30–13:00 — ***Hall One*** — Special Symposium: LED Lighting
- 10:30–12:00 — ***Hall Two*** — Colour and Food
- 12:00–13:00 — ***Hall Two*** — Colour and Wellbeing
- 10:30–13:00 — ***Northern Rock Room*** — Colour in Art
- 13:00–14:00 — LUNCH
- 14:00–15:30 — ***Foyer*** — Posters and Exhibition
- 15:30–17:30 — ***Hall One*** Special Symposium: Museum Lighting
- 15:30–17:30 — ***Hall Two*** — Colour Ergonomics
- 15:30–17:30 — ***Northern Rock Room*** — Colour Aesthetics
- 19:00–21:45 — ***The Hatton Gallery*** — Official Congress Opening

Tuesday 9th July

- 07:00–18:00 — Registration and Exhibition Open
- 07:00–08:30 — Registration and Exhibition Open
- 08:30–09:30 — ***Hall One*** — Keynote - Fiona Jenvey
- 09:30–10:30 — COFFEE
- 10:00–13:00 — ***Hall One*** — Special Symposium: Fashion
- 10:30–13:00 — ***Hall Two*** — Architectural Colour
- 10:30–13:00 — ***Northern Rock Room*** — Colour Technology
- 13:00–14:00 — LUNCH*
- 14:00–15:30 — ***Foyer*** — Posters and Exhibition
- 15:30–18:00 — ***Barbour Room*** — Special Symposium: Sustainable Coloration
- 15:30–18:00 — ***AIC Study Groups***
- 15:30–18:00 — ***Northern Rock Room*** — Colour Imaging
- 18:30–20:00 — ***The Sage Gateshead*** — Concert

* 13:00-14:15 - SDC Networking Lunch (invitees only)

Wednesday 10th July

- 07:00–14:30 — Registration and Exhibition Open
- 07:00–08:30 — Registration and Exhibition Open
- 08:30–09:30 — ***Hall One*** — JUDD Award
- 09:30–10:30 — COFFEE
- 10:30–13:00 — ***Hall One*** — Special Symposium: MCS2013
- 10:30–11:45 — ***Hall Two*** — Fashion
- 11:45–13:00 — ***Hall Two*** — Product Design and Branding
- 10:30–13:00 — ***Northern Rock Room*** — The Colour of Culture
- 13:30–14:30 — ***Hall One*** — AIC General Assembly
- 14:30–15:00 — Coaches depart for city excursion
- 15:00–19:00 — ***Durham City*** — City Excursion

Thursday 11th July

- 07:00–18:00 — Registration and Exhibition Open
- 07:00–08:30 — Registration and Exhibition Open
- 08:30–09:30 — ***Hall One*** — Keynote - Hilary Dalke
- 09:30–10:30 — COFFEE
- 10:00–13:00 — ***Hall One*** — Special Symposium: Aesthetics
- 10:30–11:45 — ***Hall Two*** — Colorimetry
- 11:45–13:00 — ***Hall Two*** — Colour Difference
- 10:30–13:00 — ***Northern Rock Room*** — Interdisciplinary Colour
- 13:00–14:00 — LUNCH
- 14:00–15:45 — ***Foyer*** — Posters and Exhibition
- 15:45–18:00 — ***Hall One*** — Special Symposium: Environmental Colour
- 15:45–18:00 — ***Hall Two*** — Colour Printing
- 15:45–18:00 — ***Northern Rock Room*** — Colour Vision
- 18:00–19:00 — Coaches depart for Alnwick
- 19:00–23:00 — ***The Alnwick Gardens*** — Official Congress Banquet

Friday 12th July

- 07:00–17:00 — Registration and Exhibition Open
- 07:00–08:30 — Registration and Exhibition Open
- 08:30–09:30 — ***Hall One*** — Keynote - Stephen Palmer
- 09:30–10:30 — COFFEE
- 10:30–12:45 — ***Hall One*** — Special Symposium: Human Colour Vision: From the Retina to the Cortex
- 10:30–12:45 — ***Hall Two*** — Colour Education
- 10:30–12:45 — ***Northern Rock Room*** — Interior Design and Lighting
- 12:45–14:00 — ***Foyer*** — LUNCH, Posters and Exhibition
- 14:00–15:45 — ***Hall One*** — Special Symposium: Colour Harmony
- 14:00–15:30 — ***Hall Two*** — Colour and Music
- 14:00–15:30 — ***Hall Two*** — Colour Naming
- 16:00–16:30 — ***Hall One:*** Capstone Presentation
- 16:30–17:00 — ***Hall One*** — Closing Ceremony

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Contents

AIC President's Foreword

It is with great pleasure that AIC is coming here to Newcastle. It is the second time that the Colour Group, Great Britain have organised a congress. Forty years ago, the second AIC Congress was held at the University of York from 2-6 July, 1973. That congress gathered together 431 participants from 26 countries and had 115 papers. This time we have in excess of 500 participants from 37 countries and we will listen to 146 oral presentations and we will study 256 different poster presentations. The AIC congresses are truly international events and gather together participants from all corners of the globe which is clearly evident in this congress.

Today there are 26 regular members and within the AIC executive committee we are continuously working to attract new AIC member's countries. Another important task for AIC is to engage young researchers to contribute to the AIC meetings with paper presentations. We have to ensure that the already established colour society will be able to convince young students about the possibilities in colour science. These are really important activities to strengthen the position of AIC. I also think that our five AIC Study Groups are an important key to attracting new interest for the colour science community as well for AIC as a powerful colour organisation.

Now we are looking forward to the five coming days of this AIC congress, and I would like to thank especially the Co-chairs for this congress Lindsay MacDonald and Stephen Westland, the Colour Group of Great Britain and their team for the great organisation of this congress. I also would like to express my appreciation to the members of the international scientific committee who reviewed so many abstracts whose presentations we will be able to listen to and to study in the poster sessions.

After the very successful and memorable meeting in Taipei, Taiwan last year, we are now working on the forthcoming meetings. Next year's will be the AIC Interim Meeting 2014 "*Colors, Culture and Identity: Past, Present and Future*" and will take place in Oaxaca, Mexico, 21-24 October. The AIC Midterm Meeting 2015 "*Color and Image*" will be held in Tokyo, Japan from 19-22 May. The Interim Meeting 2016 "*Color in Urban Life: Usability in Images, Objects and Space*" will be in Santiago, Chile, 18-22 October. The 13th AIC Congress will be held at Jeju Island, Korea from 16-20 October, 2017.

I know that the members of the organising committee have done their best to ensure that this congress 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 in all aspects of colour. I am sure there will be many memorable moments and fruitful meetings to remember in the coming years and that this congress will bring more colours into our lives.

Berit Bergström, AIC president
Stockholm, June 2013

AIC International Colour Association

AIC EXECUTIVE COMMITTEE

President: Berit Bergström // **Vice President**: Javier Romero // **Secretary/Treasurer**: Nick Harkness // **Committee Members**: Lindsay MacDonald, Shoji Tominaga, Verena M. Schindler, María Luisa Musso.

MEMBER COUNTRIES

Argentina: Grupo Argentino del Color
Australia: Colour Society of Australia
Brazil: Associação Pró-Cor do Brasil
Bulgaria: Colour Group – Bulgaria
Canada: Colour Research Society of Canada
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
Great Britain: The Colour Group (GB)
Hungary: Hungarian National Colour Committee
Italy: Gruppo del Colore
Japan: Color Science Association of Japan
Korea: Korean Society of Color Studies
Mexico: Asociación Mexicana de Investigadores del Color
Netherlands: Nedrlandse Vereniging voor Kleurenstudie
Poland: Glówny Urzad Miar
Portugal: Associação Portuguesa 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

ASSOCIATE MEMBERS

International Association of Color Consultants/Designers, North America

Color Marketing Group, USA

AIC STUDY GROUPS

Color Education (CE): Robert Hirschler // **Environmental Color Design (ECD)**: Verena M. Schindler // **Visual Illusions and Effects (VIE)**: Osvaldo da Pos // **Color Perception of the Elderly (CPE)**: Katsunori Okajima // **The Language of Color (LC)**: Jin-Sook Lee.

www.aic-colour.org

AIC2013 Chairs' Foreword

It is with great pleasure that we welcome you to the 12th Congress of the International Colour Association, AIC2013, at the Sage Gateshead, 8-12 July 2013. The AIC Congress is held every four years, and is the only colour conference in the world that promotes all facets of colour. Since the first Congress in Stockholm, Sweden in 1969, the Congress has been hosted at locations all over the world including the USA, Germany, Japan, Spain and most recently in 2009 in Sydney, Australia. The Colour Group (Great Britain) was host for the second Congress in York in 1973 and now it is again our turn to host this magnificent and important event. The Congress provides a unique forum bringing together colour practitioners, researchers, academics, designers, architects, lighting experts, artists and business leaders from all over the world with the aim of sharing ideas, interacting and learning about recent advances in their fields of expertise.

The objectives of the AIC are to encourage research in all aspects of colour, to disseminate the knowledge gained from this research, and to promote its application in science, art, design and industry. The main theme of the AIC2013 Congress is '*Bringing Colour to Life*'. This theme is developed throughout the week in several complementary directions: first in the practical sense of colour production and reproduction; second in the sense of colour in nature; and third in the sense of how colour can be used sustainably now and in the future. Beyond these worldly aspects the theme also alludes to the inspirational ability of colour to lift the human spirit to new heights.

The Congress received around 600 abstract submissions from 59 countries. A Technical Programme Committee was assembled co-led by Dr Sophie Wuerger (University of Liverpool) and Professor Stephen Westland (University of Leeds), consisting of over 120 colour experts drawn from around the world. A total of 1377 reviews were conducted by members of the Technical Programme Committee to help organise and rank the submissions. We would like especially to thank all of the reviewers who gave their valuable time as volunteers to undertake this critical task. The accepted papers have been organised into oral sessions and poster sessions. The oral sessions include the following topics: colour in art, colour and food, colour and well-being, colour aesthetics, colour ergonomics, colour technology, architectural colour, colour imaging, the colour of culture, fashion, product design and branding, interdisciplinary colour, colorimetry, colour difference, colour printing, colour vision, interior design and lighting, colour education, colour naming, and colour and music.

We are particularly pleased also to offer, embedded within the programme, nine high-quality Special Symposia with internationally renowned speakers. The Symposia topics include: LED lighting (sponsored by VeriVide), museum lighting, fashion, sustainable coloration (sponsored by the Society of Dyers and Colourists), multispectral colour science (MCS2013), aesthetics, colour and environments (sponsored by RAL Colours), human colour vision from the retina to the cortex, and colour harmony.

Each day of the conference begins with a plenary session featuring a speaker of particular significance and we are proud to present Andrew Parker, Fiona Jenvey, Roy Berns, Hilary Dalke and Stephen Palmer as our keynote speakers. Roy Berns is also the recipient of the prestigious AIC Judd Award. Additionally, John McCann will present the important capstone lecture, drawing together the chromatic threads of the week, just before the closing ceremony on Friday afternoon.

In addition to the Technical Programme we hope you will enjoy the AIC Study Group meetings on Tuesday afternoon and the exciting social events that we have planned around the conference, including a reception at the Hatton Gallery, a symphony concert of chromo-synaesthetic music at the Sage, an excursion to Durham Cathedral, and the congress banquet at Alnwick Castle Gardens. We hope too that you will delight in the wonderful architecture of the Sage, visit the gallery at Baltic Mill, walk across the Millennium Bridge, and take in the city of Newcastle which is renowned for its many attractions and facilities.

Lindsay MacDonald and **Stephen Westland**
General Co-Chairs, AIC2013 Organising Committee

Congress Organising Committee

General Co-Chairs:	Lindsay MacDonald	University College London
	Stephen Westland	University of Leeds
Secretary:	Carinna Parraman	University of West of England
Programme Co-Chairs:	Stephen Westland	University of Leeds
	Sophie Wuerger	University of Liverpool
Treasurer:	Mike Pointer	University of Leeds
Publications Chair:	Peter Rhodes	University of Leeds
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Short Course Chair:	Caterina Ripamonti	University College London
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AV Chair:	Dimitris Mylonas	University College London
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	Andrew Stockman	University College London
Other Members:	Janet Best	Consultant
	Hilary Dalke	Kingston University
	Andrew Hanson	National Physical Laboratory

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Seyed Hossein Amirshahi	Philip Henry	Ondrej Panak
Ulrich Bachmann	Javier Hernández-Andrés	Galina Paramei
Berit Bergstrom	Bernard Hill	C. Alejandro Parraga
Roy Berns	Robert Hirschler	Carinna Parraman
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Rob Buckley	Ajit Khare	Marisa Rodriguezcarmona
Jose Caivano	Eric Kirchner	Javier Rodriguezcarmona
Joaquín Campos-Acosta	Youngshin Kwak	Tetsuya Sato
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Tracy Cassidy	Wen-Yuan Lee	Meong Jin Shin
Tom Cassidy	Reiner Lenz	Cecilia Sik Lanyi
Qiao Chen	Joanne Leonard	David Simmons
Vien Cheung	Yazhu Ling	Hannah Smithson
Patrick Chong	Ronnier Ming Luo	Wenwen Song
Asim Choudhury	Wen Luo	Andrew Stockman
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Tracy Cochrane	Forough Mahyar	Peili Sun
Osvaldo Da Pos	Laurence Maloney	Kulthida Teachavorasinskun
Hillary Dalke	Gabriel Marcu	Shoji Tominaga
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Helen Gurura	Katsunori Okajima	Guanrong Ye
Andrew Hanson	Satoko Okubayashi	Joanne Yip
Jon Hardeberg	Li-Chen Ou	Dazun Zhao

The Colour Group (Great Britain)

Originally founded in 1940 as part of the Institute of Physics (IoP), the nascent Colour Group was made up mainly of colour vision scientists. The Colour Group of the IoP soon expanded and broadened its interests. In the 1950's it separated from the IoP and added the suffix (GB) to differentiate itself from other colour groups around the world. The Group is a company limited by guarantee and a registered charity.

Since its origin the purpose of the Colour Group has been to promote the study of colour in all its aspects, to disseminate colour knowledge and to provide opportunities for all those concerned with the various aspects of colour to meet and share ideas and insights.

COLOUR GROUP ACTIVITIES

Meetings

The Colour Group organises monthly meetings from October to July each year either independently or in collaboration with other national or international partner organisations. Meetings cover colour-related topics from science, technology and art in their applied or fundamental aspects with the goal of fostering cross-disciplinary interactions.

Awards

Three awards are available from the Colour Group to assist UK-based individuals in the early stages of their career to attend conferences:-

1. The WD Wright Awards[1] intended for Post Graduate students are made in even calendar years.
2. The Palmer Awards[2] intended for both Post Graduate students and Post Doctoral Fellows (or equivalent) are made in odd calendar years.
3. The CRS Award[3] for scientific presentations is made every year.

Two medals, the Newton Medal and the Turner Medal are awarded in alternate years to distinguished recipients in, respectively, the domains of Science and Art for contributions in the field of colour.

Every year, the Colour Group invites a distinguished vision expert to deliver the annual Palmer Lecture in January at its colour vision meeting.

Teaching Fellowships

For four consecutive years the Colour Group has sponsored two Teaching Fellows (Dr Ben Craven and Prof. Ron Douglas) successfully with an outreach of more than 4700 people.

1 http://www.colour.org.uk/wdwaward.html
2 http://www.colour.org.uk/palmeraward.html
3 http://www.colour.org.uk/CRSaward.html

Newsletters

Colour Group newsletters are published monthly. They are provided to Colour Group members and include meeting reports, information about upcoming events, and national and international colour news.

Occasional Publications

The Colour Group publishes a series of Occasional Publications from invited speakers' talks which are available on the CG website. Two publications are currently available:-

1. *Emulous of Light: Turner's Colour Revisited* by John Gage (PDF[4], 698 kb), a version of the 2009 Turner lecture.
2. *Chevreul's Colour Theory and its Consequences for Artists* by Georges Roque, CNRS, Paris (PDF[5], 828 kb).

Website

The Colour Group website keeps updated information, information about past and upcoming events, awards details, membership information and archives about its activities. Please visit the site: http://www.colour.org.uk.

KEY EVENTS IN 2013

8th - 12th July: AIC 2013 Congress, Gateshead, UK

As a member of the AIC the Colour Group underwriting and helping to organise the 12th AIC International Congress at the Sage, Gateshead. The AIC Congress is held every four years, and is the only colour conference in the world that promotes all facets of colour. The congress provides a unique forum bringing together colour practitioners, researchers, academics, designers, lighting experts, and business leaders from all over the world in the aim of sharing ideas, interacting and learning of recent advances in their field of expertise. Further details can be found at: http://www.aic2013.org.

14th July: Colour Neurophysiology Symposium, University of Winchester, UK

In association with the International Colour Vision Society (ICVS), the Colour Group is co-organising a symposium to celebrate the retirement of Prof. Barry Lee, who will present an historical lecture sponsored by the Cambridge Research Systems. Information about the meeting can be found on the Colour Group website.

4 http://www.colour.org.uk/John%20Gage%20-%20Turner%20Medal%20Lecture%20 2009%20-%20Emulous%20of%20Light.pdf

5 http://www.colour.org.uk/Chevreuls%20Law%20F1%20web%20good.pdf

keynote:
andrew parker

The Cole of Colour in the Evolution of Plants, Animals and Vision

keynote

Andrew PARKER
Natural History Museum, UK

BIOGRAPHY

Born in 1967 in England, Professor Andrew Parker moved to Australia in 1990 where he spent ten years studying marine biology and physics. On returning to the UK as a Royal Society University Research Fellow at Oxford University in 1999, he worked on colour, vision, biomimetics and evolution. In 2000, based on his 'Light Switch Theory' for the cause of the Big Bang in evolution, he was selected as one of the top eight scientists in the UK as a 'Scientist for the New Century' by The Royal Institution (London).

The Light Switch Theory holds that the Big Bang of evolution, 520 million years ago, was triggered by the evolution of the eye. This is the preferred solution to the most dramatic event in the history of life, most famously supported by Francis Crick (co-discoverer of the structure of DNA).

Today he works at Green Templeton College (University of Oxford). He is also Research Leader at The Natural History Museum, London and a Professor at Shanghai Jiao Tong University – China's foremost material science institution. Most recently he has been made a Professor at the Institute of Life Sciences in Swansea.

Andrew Parker's scientific research centres on the evolution of vision and on biomimetics – extracting good design from nature. He has copied the natural nanotechnology behind the metallic-like wings of butterflies and iridescence of hummingbirds to produce commercial products such as security devices (that can't be copied) and non-reflective surfaces for solar panels (providing a 10% increase in energy capture). The water capture device he discovered on Namibian beetles is under development as a commercial device and to collect clean drinking water in Africa.

He wrote the popular science books *In the Blink of an Eye* and *Seven Deadly Colours* (Simon & Schuster), and regularly speaks at literary/arts festivals as well as scientific institutions. He has given the annual Hewlett-Packard lecture on evolution and the Stanford University annual physics lecture on optical biomimetics, and has held an honorary position at MIT on biomimetics.

In 2003 the US Assistant Secretary for Defence and other senior Pentagon officials set up a team to produce predictive software based on the subject of In the Blink of an Eye. It was believed that the Light Switch Theory, which covers the sudden introduction of the greatest weapon of all (vision), could be converted to a computer programme to analyse defence scenarios. This "systems biomimetics" project is ongoing.

colour in art

Analysis of a Red Color on *Nishiki-e* Printings

Takuzi SUZUKI[1,2], Misaki KAN'NO[3], Yoshitsugu MANABE[2], Noriko YATA[2]
[1] National Museum of Japanese History
[2] Graduate School of Advanced Integration Science, Chiba University
[3] Faculty of Engineering, Chiba University

ABSTRACT

Nishiki-e (Japanese traditional polychrome woodblock print) is one of the leading products of color culture in Japan. We tried to detect new vivid red colorants (a kind of aniline dye) that are used on *Nishiki-e* printings in 1860s explosively. First, red colors of 1566 *Nishiki-e* printings made from 1838 to 1900 were analyzed. These printings are owned by the National Museum of Japanese History, and digital images have taken by a digital imaging system with a color chart since 2003. We developed an automatic extraction software program of color chart image for color correction. From color-corrected CIELAB images, strong red colors (0°≤h≤50°, C*≥20) were extracted, and frequency of use of hue was visualized as a histogram. It is clearly observed that the use of pure red hues (0°≤h≤25°) are increased explosively after 1869. Next, 24 *Nishiki-e* printings made from 1852 to 1873 were chosen, and UV-VIS-NIR spectral reflectance data of red colors were analyzed. Two kinds of characteristic spectral reflection density curve are observed. 9 *Nishiki-e* printings made from 1868 to 1873 have possibility of the use of the red aniline dye. These two results indirectly show the usage of the red aniline dye.

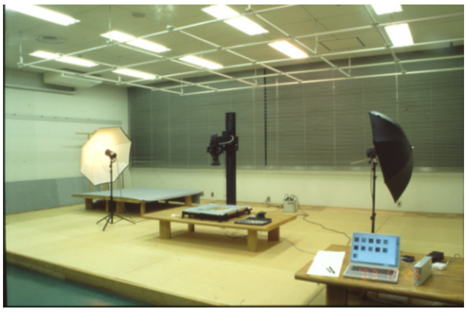
1. INTRODUCTION

Nishiki-e is Japanese polychrome woodblock print of the *Ukiyo-e* school that was made from 1760s to 1910s. *Nishiki-e* is one of the leading products of color culture in Japan. Several kinds of colorants are used in *Nishiki-e*. Our interest is to identify these colorants and to reveal an area and a period that each colorant was used. In this paper, we focus the usage of red color. It is known that new vivid red colorants (a kind of red aniline dye) were used on *Nishiki-e* printings in 1860s explosively. Two analyses for detection of the colorants are described. One is a colorimetric analysis, and the other is a spectral analysis.

2. COLORIMETRIC ANALYSIS OF RED COLORS

2.1 Color Correction of *Nishiki-e* Images

Since 2003, *Nishiki-e* printings owned by the National Museum of Japanese History (NMJH) have been taken using a digital imaging system (Suzuki 2004, Figure 1). Each printing was illuminated uniformly by a flash xenon lamp and was taken with the GretagMacbeth ColorChecker. We developed an automatic extraction software program of a color chart and a *Nishiki-e* image (Kan'no 2013, Figure 2). The RGB-CIEXYZ conversion matrix (Hong 2000) of each image for color correction was calculated from the extracted color chart image. Color-corrected images had CIEXYZ color values. For color analysis under a uniform color space, images which have CIELAB color values were made from them.



Digital still camera unit	
Body	Mamiya RZ67 ProII
Lense	Mamiya SEKOR Z 50mm F4.5W
CCD sensor	Kodak DCS Proback Plus
Pixels	4072×4072
Color depth	32bits (RGB 12bits)
Flash Xenon Lamp unit	
Lamp	COMET CLX-25 mini
Power supply	COMET CB-2400
White point	(x,y)=(0.3312,0.3446)
Color temp.	5555K

Figure 1. Overview of Nishiki-e digital imaging system and its specification.

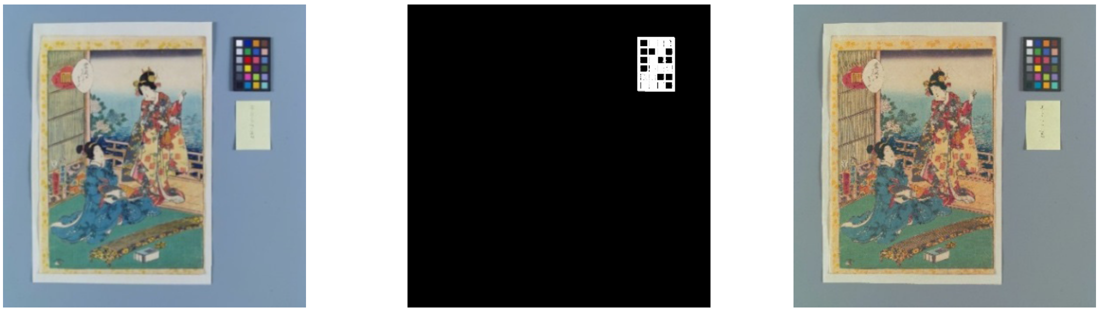


Figure 2. Original Nishiki-e image (left), detection of color chart (middle), and color-corrected image (right).

2.2 Hue Analysis of Red Colors in *Nishiki-e* Images

It is known that new vivid red colorants (a kind of red aniline dye) are used on *Nishiki-e* printings in 1860s explosively. Old red color has yellowish red hue (≈10R Munsell Hue). On the other hand, new red color has pure red hue (≈2.5R). (See Figure 3.)

We analyzed 1566 color-corrected images of *Nishiki-e* printings made from 1838 to 1900. From a *Nishiki-e* printing (figure 4(a)), strong red colors ($0° \leq h \leq 50°$, $C^* \geq 20$, figure 4(b)) were extracted (figure 4(c)), and frequency of use of red hues was visualized as a hue histogram (figure 4(d)). Figure 5 is a graph of vertically serialized hue histograms. Every horizontal monochrome line in the graph expresses one hue histogram. Maximum frequency value of every histogram is normalized to 1, and frequency value (0-1) is expressed by grayscale (black as 0, white as 1). Histograms are vertically serialized in order of the creation year. It is clearly observed that the use of pure red hues ($0° \leq h \leq 25°$) is increased explosively after 1869. Existence of new red colorants was quantitatively testified.

3. SPECTRAL ANALYSIS OF RED COLORS

To investigate the new red colorant more precisely, 24 *Nishiki-e* printings made from 1852 to 1873 were chosen by an expert researcher of *Nishiki-e*. They were candidates that a red aniline dye was used. We measured UV-VIS-NIR (ultraviolet - visible - near infrared) spectral reflectance data (255-1020nm, 5nm step) of red colors of these printings. Two kinds of characteristic spectral reflection density[1] curve are observed (Figure 6). In Figure 6, the left *Nishiki-e* printing was made in 1860, and the right printing was made in 1873.

1 For spectral reflectance , spectral reflection density is defined as .

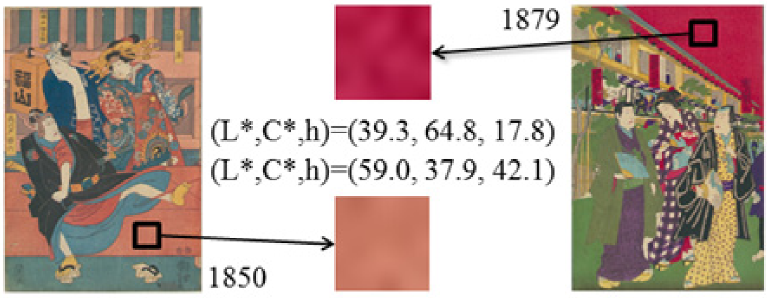


Figure 3. Comparison of old red color and new red color.

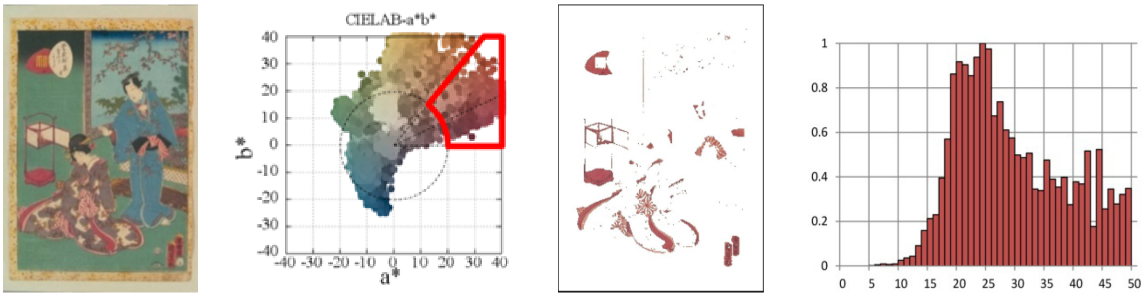


Figure 4. (a) Nishiki-e image (left), (b) color distribution (middle left), (c) extracted red (middle right), (d) hue histogram of red (right).

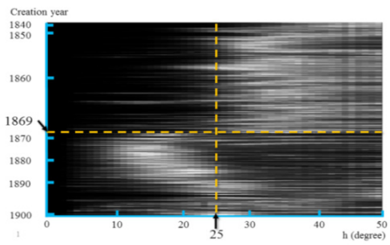


Figure 5. Vertically serialized hue histograms in 1566 Nishiki-e printings.

Figure 7 shows that the comparison of spectral reflection density curves of two groups. The group A consists of 13 *Nishiki-e* printings made from 1852 to 1868. The group B consists of 9 printings made from 1868 to 1873. Spectral curves that are included in same group are similar each other, but spectral curves of the group A and the group B are not similar. The difference of shape of curve indicates the difference of colorants. It is expected that *Nishiki-e* printings in group B use a red aniline dye.

4. CONCLUSIONS

Two analyses for detection of new red colorants were done. These two results indirectly show the usage of a red aniline dye. More precise analysis for identification of colorants (e.g. by Raman spectroscopy (Koseto 2009), or by 3D fluorescence spectroscopy (Shimoyama 1998)) is our future work.

ACKNOWLEDGEMENTS

Prof. Dr. Jun'ichi Okubo in NMJH supports our research as an expert researcher of *Nishiki-e*. Prof. Emi Koseto in NMJH teaches us several scientific analyzing methods such as Raman spectroscopy.

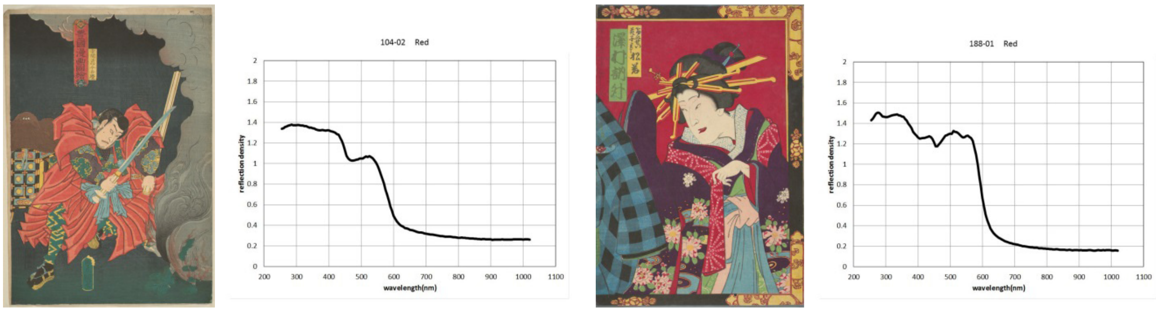


Figure 6. Nishiki-e image and its UV-VIS-NIR reflectance density curve:
(a) creation year is 1860 (left), (b) creation year is 1873 (right).

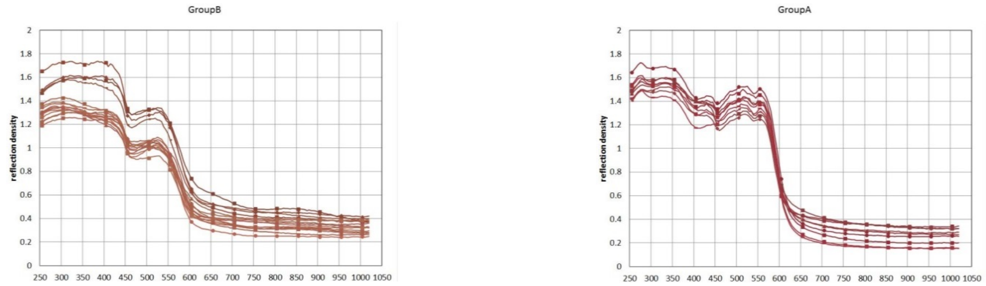


Figure 7. Comparison of UV-VIS-NIR reflectance density curve of red colors:
(a) Group A (left, 1852-1868), (b) Group B (right, 1868-1873).

REFERENCES

Hong G., M.R. Luo, and P.A. Rhodes, 2000. A Study of Digital Camera Colorimetric Characterization Based on Polynomial Modeling. *Color Research and Application* 26(1): 76-84.

Kan'no, M., T. Suzuki, N. Yata, and Y. Manabe, 2013. Automatic Color Correction and Red Color Analysis of Nishiki-e Images. In *Proceedings of 15th CSAJ-sigFVI meeting*: 21-24.

Koseto, E., 2009. *Raman de miru nishiki-e no iro* (Identification of colorants on *Nishiki-e* printings using Raman spectroscopy). In *Nishiki-e wa ikani tukuraretaka* (How had the *Nishiki-e* produced?): Catalogue for the Special Exhibition of the National Museum of Japanese History, 62-69.

Shimoyama, S., Y. Noda, and S. Katsuhara, 1998. Non-destructive determination of colorants used for traditional Japanese ukiyo-e woodblock prints by the three-dimensional fluorescence spectrum using fibre optics. *Bunseki Kagaku* 47(2): 93-100.

Suzuki T., F. Adachi, J. Ōkubo, and M. Kobayas,i 2004. Construction of a Database of Colorimetric Images of *"Nisikie"* and Analysis of Colors in the Images. In *Proceedings of the Computers and the Humanities Symposium "Jinmoncom" 2004*, IPSJ Symposium Series 2004(17): 75-82.

Postal Address: Takuzi Suzuki, National Museum of Japanese History,
117 Jōnai-chō, Sakura-shi, Chiba 285-8502, JAPAN
E-mails: suzuki@rekihaku.ac.jp, manabe@faculty.chiba-u.jp, yata@chiba-u.jp

Imagination, Hallucinations, Visions, Dreams and Drugs – Perception of Colour without External Visual Stimuli

Leonhard OBERASCHER
leoncolor

ABSTRACT

Colour research and science in general is confined to visual sensations caused by external light stimuli. But don't we quite frequently "see" colour also in absence of external light stimuli? Should these phenomena not be included in the field of colour research as well? Are "inwardly" perceived colours identical, similar, or perhaps different from those we see under normal circumstances? What methods can be used to investigate and describe them?

1. INTRODUCTION

The title of this article is deliberately kept wide to stimulate an interdisciplinary discussion (in particular within the AIC) about the "inward" perception of colour: What is the difference between colours perceived as a consequence of (external) light stimuli and those perceived without (external) light stimuli? Are they comparable? Can both modes be called "colour"? Do "inwardly" perceived colours possess identical, similar, or perhaps different or additional qualities? How can we describe and define them? What methods can be used to investigate them? What neuronal processes lie behind these perceptions? Although all these questions seem to me equally challenging, I would like now to address a particularly fascinating one: is it at all possible to perceive colours "inwardly", which are new or different from those we see under normal circumstances?

2. "ENDOGENOUS" COLOUR

There is no doubt that we can "see" colours without (external) light stimulation, provided the visual system is intact. "[..] we can 'see' by using stimuli other than light. [..] Color [..] can be experienced by pressing on our eyeballs, by passing electric currents through the head, by taking drugs, or by having our heads jarred by blows." (Hurvich 1981). Leaving aside forms of visual perception caused by acts of violence, within the following situations a perception of colour without external visual stimuli may occur: imagination, daydream, dream, lucid dream, hallucination, vision (religious), blindness. However, definitions overlap to some extent. For instance, some authors define a dream as a hallucinatory experience during sleep. The essential difference between dream and other hallucinations is that in the latter the waking subject perceives them consciously. Hallucinations in the sane can be induced by e.g. meditation, sensory deprivation, psychoactive substances. Further discussion should be restricted to the phenomena of dreaming and closed-eye, drug-induced hallucinations.

The question of whether or not we dream in colour is controversial. Most people today say they dream in colour, but some state that they see only greyscale, and a few can offer no information. Literature on dream research is accordingly at variance. Schwitzgebel (2002) notes that scientific opinion on the incidence of colour in dreams changed somewhat in the 1960s. Studies before 1960 commonly concluded that dreams were primarily a black-and-white phenomenon, while later studies documented an increase in reports of dreams in colour. Schwitzgebel sees one possible reason for this change over time in the development and spread of b/w TV and film, and later of colour TV and film. In a representative study of

Austrian dream behaviour, the authors establish that older people more often than younger ones say they dream in greyscale (Stepansky et al. 1998). Murzyn (2008) replicated the age differences in the reporting of greyscale dreams, and linked this effect to childhood experience with b/w media. In a follow-up study, however, she cannot confirm this connection, but she does find a significant positive correlation between object imagery skills – the ability to visualise pictorial details – and the frequency of reported dreams in colour (Murzyn, 2012). Schwitzgebel (2002) assumes that it is the reporting of dreams that changed, rather than their content (colour *v* greyscale). The question of whether or not we actually dream in colour cannot be conclusively answered on the basis of these studies. A major problem in dream research to date is that dream images cannot be immediately recorded, but only the retrospective – possibly greatly distorted and shortened – reports by the dreamers.

Many psychoactive plants and substances can induce visual hallucinations (Rätsch 2004). Some hallucinogenic substances (e.g. mescaline, psilocybin, LSD) seem to trigger neuronal processes that will also cause intense inward colour perceptions, as many reports and illustrations clearly confirm. Great attention was attracted by Albert Hofman's account (2001) of his discovery in 1943 of the psychedelic effect of LSD (which he had synthesized for the first time in 1938): *"... little by little I could begin to enjoy the unprecedented colors and plays of shapes that persisted behind my closed eyes. Kaleidoscopic, fantastic images surged in on me, alternating, variegated, opening and then closing themselves in circles and spirals, exploding in colored fountains, rearranging and hybridizing themselves in constant flux..."* The discovery of LSD and psilocybin led, parallel to their growing popularity, to an intensive scientific investigation of the effects of "consciousness-expanding" drugs. However, when most psychedelic substances were declared illegal, in 1966, researchers were forced to drop their work. Since the early 1990s, scientific studies have once more been permitted. In contrast to dreams, with drug-induced hallucinations the subjects are (generally) in a waking state, and can thus describe directly their visual experiences. A precise verbal description of colour impressions is difficult, however, even under normal circumstances, and a simultaneous visual colour comparison (e.g. using a colour atlas) during a visual hallucination is basically impossible.

Neuroimaging opens up new possibilities for using objective data to verify subjective reporting and visualisation. According to some authors, it may soon be possible, with the aid of fMRI (*functional magnetic resonance imaging)*, to "read" mental images directly from the brain. Brouwer and Heeger (2009) showed that stimulus colours presented to 5 observers could be decoded and reconstructed using current fMRI technology. They were able not only to accurately decode stimulus colour from spatial activation patterns in brain regions V1, V2, V3, V4, and VO1, but also to reliably reconstruct novel stimulus colours. Thirion et al. (2006) succeeded in classifying and reconstructing the content of viewed and of merely imagined geometric images from retinotopic activation patterns in the visual cortex. Naselaris et al (2009) extended their research on stimulus reconstruction from human brain activity on to natural images, *"[..] because they are most relevant for daily perception and subjective processes such as imaginary and dreaming*". Nishimoto et al. (2011), who used colour natural movies as visual stimuli, demonstrated that dynamic brain activity measured under naturalistic conditions can be decoded. They suggest that their *"[..] [modelling] framework could potentially be used to decode involuntary subjective mental states (e.g. dreaming or hallucination), though it would be difficult to determine whether the decoded content was accurate."* Recently, Horikawa et al. (2013) demonstrated that it is possible to interpret (hypnagogic) dreams using a fMRI-based "library". Though the "dream decoder" was able to identify the category of images the dreamer had seen, it provided no information about the colour of these images. But taking into consideration the rapid progress in the field of neural imaging, an objective answer to the question of whether dreams are generally coloured or grey might soon be available.

Functional neuroimaging has also been used to study perception during drug-induced hallucinations. For instance, Draulio B. de Araujo (2011) found that after intake of ayahuasca – a hallucinogenic brew usually made from a combination of the liana *banisteriopsis caapi* and the leaves of *psychotria viridis* which has for centuries been used by rain forest shamans of the Amazon – the primary visual cortex was more active during imagination with eyes closed than during viewing of actual images. It seems that ayahuasca lends a kind of hyper-reality to inward perceptions, which may explain the visionary power of these hallucinations. Carhart-Harris et al. (2011) compared brain activities during normal waking consciousness with a psilocybin-induced psychedelic state. In contrast to previous findings, their fMRI data showed a significantly decreased activity with maxima in hub regions, such as the thalamus and the anterior and posterior cingulate cortex, which implies that the consciousness-expanding effect of psilocybin turns many brain circuits down rather than up. Moreover, if these studies were not intended to read the visual content of hallucinations, in future similar research could provide clues to why some psychoactive substances trigger such rich and vivid inward colour perceptions. The problem of verifying whether these endogenous colours do actually differ from those seen under normal circumstances remains unsolved.

Zeki (1993) draws attention to the fact that hallucinations and dreams are visually normal, in the sense that the visual image is coherent and objects maintain their topographic position, just as in normal vision. He assumes that they are integrated, centrally generated images, which must somehow be re-entered into an area with high topographic precision (V1 or V2) as if they were coming from outside. If we apply Zeki's argument of "visual normality" to the question of endogenous colour hallucinations, it is improbable that we can see abnormal or new colours.

There are, however, some studies which assert that (even) in a normal waking state, perception of abnormal or new colours is possible. Crane and Piantanida (1983) and Billock et al. (2001) reported that reddish-green and yellowish-blue colours can be created by visual blending (and perceptual filling-in) of retinally stabilised, equiluminant adjacent fields of opponent hues into a single colour. Observers in Billock's experiment reported seeing overlapping transparent layers of red and green or a gradient between red and green, with a region that seemed both red and green. In order to explain this incompatibility with Hering's theory of colour opponency, they suggest a "*soft-wired model of cortical color opponency (based on winner-take-all competition) whose opponency can be disabled*". Livitz et al. (2011) presented a study in which they explore the perception of 'forbidden' colours using conventional displays and psychophysical methods. With two distinct stimulus sets – one formed using a chromatic grid and neon spreading, the other based on solid coloured regions – they demonstrated that a perception of 'forbidden' reddish-green colours can in fact occur, even in normal viewing conditions.

If our visual system, even in normal viewing conditions, can be "altered", why not also in a state of dream or hallucination? Studies have shown that visual hallucinations are associated with "abnormal" visual cortical activity. What if neural signals re-enter from those regions that generate hallucinations – e.g. have the potential to suspend mechanisms of opponent colour inhibition? Under this premise, we should not rule out the possibility that under certain circumstances – in particular during drug-induced hallucinations – we may indeed perceive colours “inwardly”, which are new or different from those seen under normal conditions.

REFERENCES

Billock, V.A, G.A. Gleason and B.H. Tsou, 2001. Perception of forbidden colors in retinally stabilized equiluminant images: an indication of soft-wired cortical color opponency? *J. Optic. Soc. Amer. A* 18, 2398-2403.

Brouwer, G.J., and D.J. Heeger, 2009. Decoding and Reconstructing Color from Responses in Human Visual Cortex. *The Journal of Neuroscience*, 29(44), 13992-14003.

Carhart-Harris, R.L., D. Erritzoe, T. Williams, J.M. Stone, L.J. Reed, *et al*., 2011. Neural correlates of the psychedelic state as determined by fMRI studies with psilocybin. *Proc Natl Acad Sci USA* 109(6) 2138-2143.

Crane, H.D., and T.P. Piantanida, 1983. On seeing reddish green and yellowish blue, *Science* 221, 1078-1080.

de Araujo, D.B., S. Ribeiro, G.A. Cecchi, F.M. Carvalho, T.A. Sanchez, et al., 2011. Seeing With the Eyes Shut: Neural Basis of Enhanced Imagery Following Ayahuasca Ingestion. *Human Brain Mapping*, DOI:10.1002/hbm.21381

Hoffmann, A., 2001. *LSD – Mein Sorgenkind*. Deutscher Taschenbuch Verlag, 31

Horikawa, T., M. Tamaki, Y. Miyawaki and Y. Kamitani, 2013, Neural Decoding of Visual Imagery During Sleep. DOI:10.1126/science.1234330

Hurvich, L.M., 1981. *Color Vision*. Sunderland, MA, 14-15

Livitz, G., A. Yazdanbakhsh, R.T. Eskew and E. Mingolla, 2010. Perceiving Opponent Hues in Color Induction Displays. *Seeing and* Perceiving 24, 1-17

Murzyn, E., 2008. Do we only dream in color? A comparison of reported dream color in younger and older adults with different experiences of black and white media. *Consciousness and cognition*, 17(4), 1228-37.

Murzyn, E., 2012. Memory for colour, visual imagery preference and reported colour of dreams. *International Journal of Dream Research*, 5(2), 108-113.

Naselaris, T., R.J. Prenger, K.N. Kay, M. Oliver and G. Gallant, 2009. Bayesian reconstruction of natural images from human brain activity. *Neuron* 63, 902–915.

Nishimoto, S., A.T. Vu, T. Naselaris, et al., 2011. Reconstructing Visual Experiences from Brain Activity Evoked by Natural Movies. *Current Biology* 21, 1641–1646

Rätsch, C., 2004. *Enzyklopädie der psychoaktiven Pflanzen*. 7. Auflage, AT-Verlag, Aarau

Schwitzgebel, E., 2002. Why did we think we dreamed in black and white? *Stud. Hist. Phil. Sci.* 33, 649–660,

Stepansky, R., B. Holzinger, A. Schmeiser-Rieder, B. Saletu, M. Kunze and J. Zeitlhofer, 1998. Austrian Dream Behavior: Results of a Representative Population Survey. *Dreaming*, 8(1), 23-30.

Thirion, B., E. Duchesnay, E. Hubbard, et al., 2006. Inverse retinotopy: inferring the visual content of images from brain activation patterns. *Neuroimage 33,*1104-1116.

Zeki S, 1993: *A Vision of the Brain*. Blackwell Scientific Publications, Oxford.

Address: Leonhard Oberascher,
Kaltnergasse 8., 5020 Salzburg, AUSTRIA
E-mail: ecd@leoncolor.com

Serpentine Gallery Pavilions: Essays on Colour Environment

Joaquim SANTOS
Faculty of Architecture and Arts, Lusíada University, Lisbon, Portugal
Architect, Docent in History of Art and Theory of Architecture.
Researcher at the Research Centre in Territory, Architecture and Design,
Colour Laboratory (CITAD) at the same university.
Doctor of Philosophy, Tampere University of Technology, Faculty of Architecture, Finland

ABSTRACT

The bounded magnitude of time that a pavilion-like structure displays makes use of impressive experimental language where colour may have a strong role by attaching our attention to the materiality of architecture and environment. Thus, pavilions as temporary arts works – would this be a suitable concept! – are acts of freedom that may combine all together human relations to colour that other kind of works may eventually not have.

Architects have made great colour exercises on these Serpentine Gallery Pavilions. Their options go from smooth colours to strong colours, transparency to opacity, day to night. These pavilions set forward arguments of *naturalness* and *artificialness* and how they meet and combine. Certainly, colour is a major plastic argument that expresses both figurative and abstract characteristics on a fertile material basis.

Zaha Hadid, Daniel Libeskind, Toyo Ito, Oscar Niemeyer, MDRVD, Alvaro Siza and Eduardo Souto de Moura, Rem Koolhaas and Cecil Balmond, Olafur Eliasson and Kjetil Thordsen, Frank O. Gehry, Sanaa, Jean Novel, Peter Zumthor, Herzog & de Meuron, and Sou Fujimoto, may have made a contemporary history of man environment colour approach and tendencies that combine, for instance, camouflage-like effects, spot arguments, all around--effects, colour-framing environment, openness, closeness, colour resemblance or contrast, that invite and sometimes «impose» a colour experience.

COLOURS & MATERIALITIES

Sou Fujimoto's magestic constuctive *cloud* seems to embrace a *colour-light* envirorment that brigns in a perpectual experience of instant, dayly and season *colour-humidity-temperature-smell* variable experiences that makes us participant actors in the place where we exist. The role of colour in architecture as a constructive material, by exiting on a certain precise place, extends a powerfull multy sensorial experience:

> For the 2013 Pavilion I propose an architectural landscape: a transparent terrain that encourages people to interact with and explore the site in diverse ways. Within the pastoral context of Kensington Gardens, I envisage the vivid greenery of the surrounding plant life woven together with a constructed geometry. (*www.serpentinegallery.org*)

Thus, Sou Fujimoto put forward his basic idea that we could say that meet, somehow all architectura stategies that all pavilions have offered us and that are central to contemporary holystic view of architecture-environment approaches that converge in the building itself as an objective *unique* object. Siza and Souto de Moura, in converstion with Hans Obrist put the *architectural-site-environment* problem on a straightful way:

> I proposed a steel structure but Siza said 'No, what about a wooden structure, something more "poorl" like Arte Povera?' We worked next to each other at a table. Endlessly swapping sketches until the concept appeared. Then when I presented it, everyone asked 'What's the concept?' Because these days the concept is like an alibi for the solution. The pavilion is linked with the other elements – it isn´t an autonomous buildings and it isn´t meant to tell a narative story – so the concept is 'architectue' itself. (Larner 2005, p. 86)

The linkage to other elements takes Herzog & de Meuron to the unseen underground water as fundamental material structure of the colourful of environment that rises at the surface. Thus, bringing up the water to the upper flat surface that covers the pavilion and that links *pavillion-garden-sky* and that which wind may texturize, is a holistic exercise of thinking on enviroment as a perfect ultimate material to be humanized. Water is understood as fundamental for life as well as fundamental to create a dialog through colours. The contrast between the inner darker shelter atmosphere provided by digging that ground to it it liveable and the outer environment is a meterialization of a colour-textural-material.

The strong geometry that Jean Novel used to create, not a single red, but an impressive set of reds may be understood as a complex reading of architecture-environment. The use of objective artificial materials stressed by the sharp geometry is able to recreate natural coulor--ligh-wind phenomena to be the centre of an architectural promenade. *Colour-geometry-matter-concept* become meaningful and instrinsically built on building as concept. The tilt covers certainly vibrate under the wind on a way that policarbonate boards do not. Opacity, transluscendency and tranparency are to be transformed by overlapping or supperimposition of views and materials.

Koolhaas-Balmonds's *cinerama-like building-dome* was keen on catching all arround envirornment colour motion to be perceived as such even from the outside due to the translucent boundary panels. From the inside, translucent panels could transform sharp shapes on colour moments that seemed to be materialized on the panels themselves, because translucendy creates a distortion on depth perception. Tranlucendenty acts as *colour-texture-construction* and, also, as *matterless* constructive *material*.

We could say that Toyo Ito also used a architecture as a *inside-outide screen-frame*. A perfect order of geometry exists in both projects, but materials are deeply different. Ito emphasizes the artificiality of architecture as constructive and structural. If we take the approach poetically, the solid-void discourse that he uses is not that far from the intricate order of bushes and trees branches and leaves. These *natural objects* make sensible my motion through the environment and any change on the position of an individual inside the pavilion was actually stressed by the innumerous solids and voids. White on such a context is never perceived alone and it reflects or diffuses light and colour that act as constructive materials on the white. And, last but not least, creating a pedestal emphasizes architecture as an artificial gesture that created both, a tension, or a dialog with the ground below.

This temple-pedestal strategy was, somehow, general used. On the extreme case of MVRDV proposal there was a metaphoric creation in which nature is the perfect pedestal of itself. In this sense, the metaphoric artificial hill and the green cover are two symbols of what an environment should be. The flatness of the plan where the hill was meant to rise would bring the all garden environment together. Inner nature could be found *in* the hill.

The classical strategy of the pedestal was used effectively by Oscar Niemeyer. What might be seen as a superimposition of architecture over nature might have other readings.

He had, like Roberto Burle Marx, a sense of the respect for nature, a nature whose life time transcends that of architecture. On his own house, in Alagoas, he simply explained that, then, natures came and made all what was left. In this sense, architecture does not need to fear natures, it colours and shapes. Niemeyer's pavilion stressed the curve he liked and nature has no straight lines. White is combined with red and the natural green. Nature is not shy to colours, so why should architecture be? Can architecture really learn from nature the constructive character of colour on the environment?

On Olafur Eliasson's aproach individuals were invited to a cinerama-like architectural promenade that may remid Koolhaas-Balmonds, that shares some of the wooden materiality of Siza-Moura, but that ends on a final enclosure that may make us think on Zumptor. Eliasson's use of colour is precise otherwise he could not emphasize colour as a constructive *thing* that springs out from a complex poliedra. When on take the twenty four daily hours we may reflex on the absolute nature of coating, but how it turns into a full relative construtive material on architecture. Curiosly, both, the absolute and relative nature of colour, are native to natural environments.

Being born from an education in which ornament was crime, Gehry uses natural timber, natural wood, glass and works on basic elements of architecture, materials that must mean construction, texture and colour. In this sense, he works on natural environments as they original are. Than, explicit geometry organizes the basic topograpfic relations that bring the individual into architectural space, an close-open space like, in general, nature provides. Technical detail works as a final gesture that enphasizes human technical hability to build. The displacement from the Modern is than achived by creating a *collage* of building strategies that simbolise the criation of architecture.

We could say that Daniel Libeskind's attitude goes closely to Gehry because there is a construtive principle, the exploration of materials and empasis on the technical details of sheets, beams and rivets, to construct panels that construct space that we can trace back to the roots of Modern Architecture. The general use of geometry to sharp architectural options is also present. Curiously, the exploration that Koolhaas-Balmonds made on tranlucent properties of material to transform envirormental perception, Libeskind transfered to the controled properties of metal sheets, that have a colour of their own, but that can be transformed by texture and, especially, by the way in which they are placed psysically, when they are assumed as constructive matirials that construct space to be lived. The inner and outer spaces contrast. By walking through inner space, we could see outside finishing and thus being acquaited with an active colour space. The sharp use of geometry constrasted with the difusion-reflection of light and colour on the panels surface giving individuals a sense of relative experinece of space and time.

Perhaps Zumptor prefered an intimated world envirorment. As he put it:

> The *hortus conclusus* that I dream of is enclosed all around and open to the sky. Every time I imagine a garden in an architectural setting, it turns into a magical place. (*www.serpentinegallery.org* – 2013.05.08)

He constructed a built-in dense sensorial garden that shares sky with the continous environment. Yet, he stresses artificial pure colours of architecture. Black is a strong *texture-colour-matter* that makes *environment-architecture* that frames the living colours of flowers. Humidity, temperature, sound, wind are controlled but they are there right in the core of the garden. The interface between an outer and inner world conveyed by architecture, the mundane world of colours and the sacred relaxing intimated natural world of natural colours is put on a dense way to be experienced as colour *artificial-natural environmental-architectural* elements to provide a full colour-smell-temperature-humidity-sound-light experience.

Zaha Hadid has worked on a thin surface that works together with its support by creating a dinamic spatial polymetric sense that creates an intricated perception of void and solid, transparency and opacity, *materiality* and *matterlessness* In that sense, its experience made all arround environment participating on the experinece. This certainly was a central issue to all pavilions and it will be explored on the future pavilions.

Finally, we could say that Saana impressive pavillion is a wonderful play with the environment. The perfcet ondulating surface that is both shelter and open outwards even came closer to the ground. The reflective surface might be the most impressive detail. A dinamic perfect *trompe l'oeil* reflects either the sky or the ground and made individuals participant of the multidimentionality of architecture where Man and Environment meet.

CONCLUSION

Serpentine Gallery Pavilions seem to open many ways of thinking on architecture starting from the basic fact that all are deeply different and, simultaneously, all are great architecture and discuss their inner issues. Colour naturally rises as fundamental along with other intrinsic characteristics of architecture such as its destiny, its materiality and built structure. Curiously we may even stress that within a colour environment, colour is what we firstly see and within such realm of colour, colour arrangements guide us through other architectural or environmental arguments that our perception selects. We can than think on how Serpentine Gallery Pavilions have synthesized and put forward colour discussion on architecture and environment and, last but not least, how we actually fashion colour.

ACKNOWLEDGEMENTS

Professor Isabel Braz de Oliveira, Head of the Colour Laboratory, Research Centre in Territory, Architecture and Design Lusíada University, Lisbon.

Lusíada University, Faculty of Architecture and Arts, Lisbon, and Minerva Foundation.

Portuguese Foundation for Science and Technology (FCT).

Gareth Griffiths, Architect, Helsinki.

REFERENCES

Jodidio, P., 2011. Serpentine Gallery Pavilions. Köln.

Larner, M., Ed., 2005. Serpentine Gallery Pavillion Designed by Álvaro Siza, Eduardo Souto de Moura with Cecil Balmond – ARUP. 2005. Serpentine Gallery and Trolley Books, London.

www.serpentinegallery.org (2013.05.08. 20.00 GMT)

Address: Joaquim Marcelino Santos
Rua Maria Lamas, 4 – 6º Esq.1500-438 Lisboa. Portugal.
E-mail: marcelino.c.santos@gmail.com

Conceptual Art and the Liberation of Colour

Paul GREEN-ARMYTAGE, Curtin University

ABSTRACT

For conceptual artist Sol LeWitt, “the idea or concept is the most important aspect of the work …. What the work of art looks like isn’t too important” (LeWitt 1967). By switching the emphasis from form as an aim to form as the result of working through an idea, conceptual artists paved the way for the liberation of colour from its traditional roles in description, symbolism and expression. Colours could be set free to be nothing but themsleves – just colours.

1. CONCEPTUAL ART

‘Conceptual art’ is a term associated particularly with the work of artists in the late 1960s and early ’70s. For Lucy Lippard, writing at the time, conceptual art means “work in which the idea is paramount and the material form is secondary, lightweight, ephemeral, cheap, unpretentious and/or ‘dematerialised’” (Lippard 1973/1997: vii). Christopher Hill explains how conceptual art was, in part, a reaction against formalism where the formal properties of a work were all that mattered and reference to anything beyond the work, any ‘content’, was irrelevant (Hill 1985: 13).

1.1 Form and idea

In one of his *Aphorisms on Architecture and Form*, Ludwig Mies van der Rohe (1947) states that “Form is not the aim of our work, but only the result… Form as an aim is formalism; and that we reject.” The distinction between form as an aim and form as a result can be seen when comparing a painting by Wassily Kandinsky with a geological map. When Kandinsky produced the first abstract paintings as arrangements of non-representational shapes and colours, form was the aim. In a geological map the shapes and colours are determined by the geology and by the key adopted for identifying the different kinds of rock. Form is the result. The form of a conceptual artwork would not be the artist’s aim, it would be the result of working through a particular idea. In the words of Sol LeWitt “The idea becomes a machine that makes the art.” (LeWitt 1967).

1.2 LeWitt’s wall drawings

The relationship between idea and physical outcome is nicely illustrated in LeWitt’s wall drawings. For each of these LeWitt prepared a set of instructions and it was these instructions that were the essence of the artwork. It did not make any difference whether LeWitt himself or other people followed the instructions and produced the actual wall drawing. This has made it possible for the Massachusetts Museum of Contemporary Art to mount the massive *Sol LeWitt: A Wall Drawing Retrospective* which opened in 2008 and is to remain on view for 25 years. The press release (Massachusetts Museum of Contemporary Art 2008) includes this statement: “The works in the exhibition are on loan from numerous private and public collections worldwide.” This means that what the lenders had to lend were the instructions, as acquired from the artist, rather than anything that was already drawn on a wall. For the exhibition a team of some 65 artists and art students, working over a period of about six months, simply carried out LeWitt’s instructions.

2. THE COLOR CHART EXHIBITION

Although it could be argued that the term 'conceptual art' should only be applied to work produced by a particular group of artists during the late '60s and early '70s, the spirit of conceptual art can be seen in earlier work and this spirit lives on today (Schellekens 2007: 3). LeWitt was one of the artists represented in the exhibition *Color Chart: Reinventing Color, 1950 to Today* held at the Museum of Modern Art, New York, in 2008. Curator Ann Temkin, having noticed that many artists were turning their backs on traditional colour theory, was prompted to ask "What defines color *after* color theory?" (Temkin 2008: 8). Many, if not all, of the works in the exhibition could be described as anti-theory conceptual art. The earliest work in the exhibition was *Tu m'* painted by Marcel Duchamp (his last painting) in 1918; one of the most recent was *Color* by Cory Arcangel (2005). For *Color* a data projector was used and the fluctuating colour combinations were controlled by a computer programme. All Arcangel did was write the computer programme – a perfect example of an idea becoming 'a machine that makes the art.' Among the other artists represented in the *Color Chart* exhibition were Gerhard Richter and Damien Hirst.

2.1 Gerhard Richter

Colour charts from a paint or hardware store come with little theoretical baggage. Gerhard Richter had a 'eureka moment' when he saw such a chart. In her catalogue notes Temkin explains how "the color charts provided an answer to a question that Richter had in mind: not only how to dissociate color from its traditional descriptive, symbolic, or expressive ends, but also how to avoid the dogma that surrounds geometric abstraction." (Temkin 2008: 90). Richter's colour chart paintings from the 1960s and '70s are one aspect of an extremely varied body of work. He returned to grids of flat colour in 2007 with *4,900 Colours*. The basic units for this work are panels with 25 colours arranged in a 5 x 5 square grid. These can be shown separately or in combinations to form larger paintings. The positions of individual colours, and the way that separate panels are combined to form larger paintings, were determined by chance processes involving computers and the roll of a dice. Commenting on this work, Richter says: "They are the only paintings which tell no story. …They are simply there, pure visual objects." (Pelzer 2008: 127).

2.2 Damien Hirst

Damien Hirst's spot paintings could also be described as 'pure visual objects'. The spot paintings are mass produced by teams of assistants who follow rules set down by Hirst (Temkin 2008: 208). Every spot on a painting is the result of a different paint mixture – in that sense no two colours are the same. And the position of each colour is entirely random. The grid provides an illusion of order which is negated by the absence of order in the placement of the colours. Hirst has been quoted as saying: "I was always a colourist…I mean, I just move color around on its own. So that's where the spot paintings come from ….I suddenly got what I wanted. It was just a way of pinning down the joy of color." (Gagosian Gallery 2012)

3. CONCEPTUALISM TODAY

Conceptual art has had an influence on my own ideas as well as on the work of other artists including Perth-based artist Siné MacPherson whose work provides a good illustration of how conceptual methods can be applied.

3.1 Democratic Art and Chromagrams

The ideas in the catalogue for the *Color Chart* exhibition and the format of one of the paintings, Ellsworth Kelly's *Colors for a Large Wall*, were the inspiration for my *Democratic Art* project and that led, in turn, to my idea for what I call *Chromagrams*.

To produce a work of *Democratic Art* we begin with six paint colour charts, one for each of the six people who are to participate in producing the work, and an 8 × 8 grid of squares or rectangles, that are the same size as the colour samples on the charts, drawn lightly on a sheet of white card. Participants choose six colours that they like from their charts and take turns to stick them down on the grid, the positions for the colours being determined by the roll of a dice (Figure 1). For the *Chromagrams* I use my colour alphabet, developed from ideas first presented at AIC 2009 (Green-Armytage 2010). This enables me to convert letters into coloured squares and then spell out words and sentences which are set out in a square grid (Figure 2).

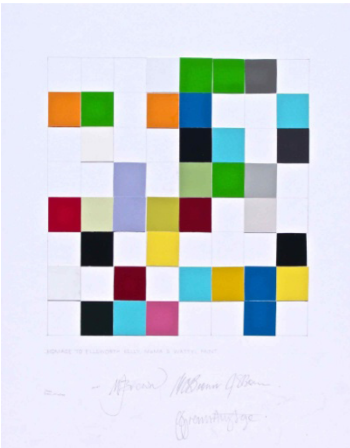


Figure 1: Democratic Art

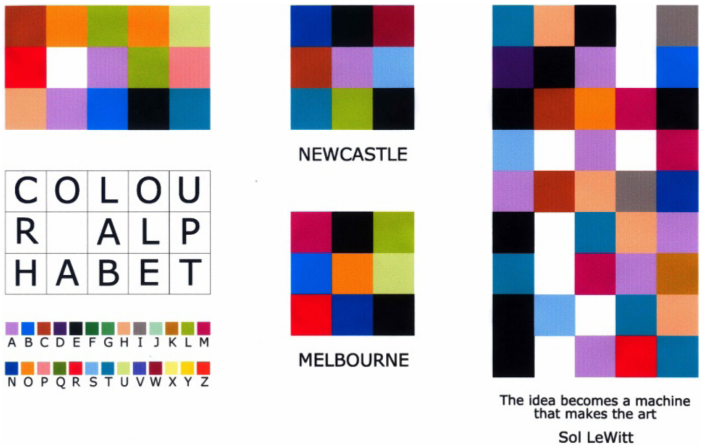


Figure 2: Chromagrams

3.2 Siné MacPherson

The source document for MacPherson's *Shark Colours* was the *Field identification guide to Western Australian Sharks and Shark-like Rays*, published online by the Department of Fisheries (McAuley, Newbound and Ashworth 2002).

Figure 3: Siné MacPherson Shark Colours 2011

The basic structure of the painting is a 9 × 6 grid with 54 horizontal rectangles each representing one shark species. But the painting is not to be viewed as a kind of scientific document or an accurate record of the colours as they appear on the sharks themselves. The colours are not taken from observations in the field, or even from photographs, but from the verbal descriptions in the guide. They are MacPherson's interpretation of those colour names. The rectangles for each shark are a single colour or are divided into stripes, with one stripe for each colour mentioned for that species. For example the description of the dogfish (top left) includes "… large round eyes that are often green. … Dorsal colour may be pink, brown, greyish or black. … white fin tips". Each of these colours has equal status and the shark/rectangles are arranged in order as they are described in the guide. That was MacPherson's 'machine that made the art' and, as she says, "What you get is what you get."

4. THE LIBERATION OF COLOUR

The role of chance in the processes of conceptual art gives colours a new status and colour relationships a new vitality. Colours are liberated. They are no longer required to represent what we see in the world, to symbolise the ideas of a culture, to express the feelings of an artist or to follow theoretical rules. When the form of a work is not the aim but the result of applying an idea as a 'machine' the colours are set free to be nothing but themselves, and free to relate to each other without past constraints.

REFERENCES

Gagosian Gallery 2012. *Damien Hirst The Complete Spot Paintings 1986-2011*. Available: http://www.gagosian.com/exhibitions/damien-hirst--january-12-2012-3 Accessed: Apr 29 2013

Green-Armytage, P., 2010. A Colour Alphabet and the Limits of Colour Coding. *Colour: Design and Creativity* 5 (10): **1-23**. Available: http://aic-colour-journal.org/index.php/JAIC/article/view/19 Accessed: Apr 29 2013

Hill, C., 1985. Reality Made Strange. *Praxis M*. No 10.

LeWitt, S., 1967. Paragraphs on Conceptual Art. *Artforum* 6 (10): **79-83**.

Lippard, L., 1997. *Six Years*. Berkeley: University of California Press.

Massachusetts Museum of Contemporary Art 2008. *Sol LeWitt: Wall Drawing Retrospective.* Available: http://www.massmoca.org/event_details.php?id=27 Accessed: Apr 29 2013

McAuley, R., D. Newbound and R. Ashworth, 2002. *Field identification guide to Western Australian Sharks and Shark-like Rays.* Perth: Department of Fisheries. http://www.fish.wa.gov.au/Documents/occasional_publications/fop001.pdf.

Mies van der Rohe, L., 1947. Aphorisms on Architecture and Form. In *Mies van der Rohe*. Philip Johnson. New York: The Museum of Modern Art.

Pelzer, B., 2008. The Asymptote of Chance. In *Gerhard Richter 4900 Colours*. Serpentine Gallery. Ostfildern, Germany: Hatje Cantz Verlag.

Schellekens, E., 2007. Conceptual Art. *Stanford Encyclopedia of Philosophy*. Available: http://plato.stanford.edu/entries/conceptual-art/ Accessed: Apr 29 2013

Temkin, A., 2008. *Color Chart: Reinventing Color, 1950 to Today*. New York: The Museum of Modern Art.

Address: Dr Paul Green-Armytage, School of Design and Art, Curtin University.
Home address: 55 Evans Street, Shenton Park, 6008, Western Australia
Email: p.green-armytage@curtin.edu.au

Who's Not Afraid of Displaying Kurt Schwitters' Collages? A Microfadometry Study to Determine the Sensitivity to Light of Five Examples

Joyce H. TOWNSEND,[1] Bruce FORD,[2] Piers TOWNSHEND[1]
[1] Conservation Dept, Tate, London
[2] Art & Archival Pty Ltd & National Museum of Australia

ABSTRACT

A technical study was undertaken of paper-based ephemera used in Germany 1920s-30s by Kurt Schwitters to create mixed-media, sometimes three-dimenional, collages. Microfadometry, a rapid and non-destructive accelerated light-fading method for informing display duration decisions, was carried out on all distinct paper-based elements in 5 of Schwitters' and 2 contemporary collages by Raoul Hausmann and by Julian Trevelyan. Many coloured components in this small sample were more lightfast than had been feared.

1. INTRODUCTION

Some artists carefully select stable and durable materials, while others incorporate the medium into their message and embrace ephemera or poor-quality materials. Kurt Schwitters (German 1887–1948) used ephemera to convey a political message. He created 3-D collages made from *c*.50-100 elements, including: newsprint, B&W and coloured magazine illustrations, bus and theatre tickets, envelopes and other scraps of writing, sweet wrappers, papers painted with watercolour, painted wood fragments, and fabric.

Without assessing the light sensitivity of each element in mixed-media works like these, display duration decisions are, at best, estimates based on observation of damage that has already occurred under conditions that are largely unknowable. While the newsprint elements of the works described here have obviously yellowed with age, it is difficult to predict how other components might have altered over time. There is no published technical information on Schwitters' materials, save one study on the construction (not stability) of a similar collage of 1921, *The Cherry Picture* (King 1992).

Prior to a 2-venue exhibition (Chambers and Orchard 2013), the vulnerability to light of five 1920s-30s Schwitters collages was assessed using microfadeometry, an accelerated technique developed by Whitmore *et al.* (1999) to identify light-sensitive objects. The method exposes a sub-millimetre area of material to megalux levels of UV- and IR-free visible light for a few minutes, while the resultant colour change is measured in real time using reflectance spectroscopy. The results are compared to the response of ISO Blue Wool Fading Standards (BWs) under the same conditions, then used to assign individual materials to fading risk categories within which recommended display periods are proportional to fading rates (Pretzel 2008, Ford and Smith 2011). The least lightfast element of a work is usually used to determine the appropriate light exposure. In this study, the context for the fading data is a body of potentially light-sensitive, previously microfaded, 20th-century mixed-media works on paper, including two contemporary collages, made in Germany by Raoul Hausmann and in the UK by Julian Trevelyan.

2. METHOD

The microfader employed a filtered xenon source to project a 600um spot of UV- and IR-free visible light at approximately 6Mlx on to the material. Colour change was calculated according to the CIEDE2000 colour difference formula (CIE 2001) from Lab values derived from normalised reflectance spectra collected at 1 min intervals over 10 mins. The colour differences (ΔE_{00}) were compared with the three most fugitive BWs, namely BW1-BW3, exposed under the same conditions. Each BW fades approximately 2-3 times more rapidly than its next highest numbered equivalent, BW1 being the most fugitive.

3. RESULTS

'Acceptable' rates of colour change vary quite widely, and a number of lighting guidelines exist based on fading rates of colourants and similarly exposed BWs. For colourants more fugitive than about BW3-4, described as 'highly sensitive' or of 'high responsivity' to light for museum purposes, the Victoria and Albert Museum (V&A's) recommendation is 2 years display in 10 (Ashley-Smith *et al.* 2002), while the CIE *Control of Damage to Museum Objects by Optical Radiation* (CIE 2004) is more conservative at 1 year in 10, both at 50 lux. Tate currently allows a maximum of 2 years display in 4 at 50-80 lux (UV-free) for works on paper. With the more accurate data from microfading, Tate is considering further restricting works interpreted as less lightfast than BW2, for example to 1 year in 4 or less.

Figure 1 illustrates the microfading of Schwitters T03863 collage (an image of T03863 etc. can be located on www.tate.org.uk by searching under this number). The most light-sensitive component was a brown, probably irongall-type ink, already so pale that the handwritten address on a torn fragment of envelope, neither written by the artist nor addressed to him, has little or no impact at normal viewing distance. The reasonably high BW equivalent rating for un-printed or unpainted poor quality papers, which invariably bleach when exposed to UV-free light during museum display, may be disregarded because they will re-yellow in the dark post-exposure, a process which not observable during microfading. Likewise microfading has no predictive role in assessing the structural degradation of paper or other organic materials, which although related to light exposure in some cases, cannot be correlated with colour change over the course of a brief accelerated light exposure. Table 1 summarises the results for all 7 collages.

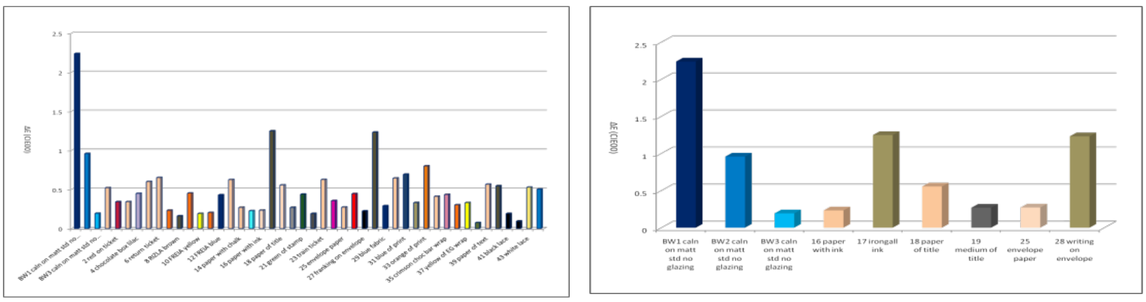


Figure 1: ΔE_{00} for all elements of T03863. Left, papers (shown in pink and buff, their present colours), and colour printing (represented in its present colour). Right, the most light-sensitive elements are shown in detail. The 3 leftmost bars in each bar chart show BW1-3 microfaded under the same conditions, with respective colour changes of 2.2, 1.1, 0.2.

Table 1: Summary of microfading of paper elements, and interpretation, for 7 collages.

Artist, *Title* [date, accession number]	Paper elements in addition to pink and white/ buff newsprint	Least lightfast elements	Condition in 2012	Display recommendation
HAUSMANN, Raoul *The Art Critic (Der Kunstkritiker)* [1919-20, T01918] Black & white magazine images, banknote, postage stamp, crayon – German		Pale blue crayon BW2-3	Little colour change	2 years in 4 years
SCHWITTERS *Table Salt (Tafelsalz)* [1922, T12391]	Paper support	all equal at BW2-3	Little colour change	2 years in 4 years
SCHWITTERS *Picture of Spatial Growths - Picture with Two Small Dogs* (*Bild mit Raumgewächsen-Bild mit 2 kleinen Hunden)* [1920 & 1939, T03863]	Theatre and bus tickets, coloured paper, printed sweet wrappers, chocolate box, postage stamps, printed wrapping paper – all Norwegian	Irongall ink, handwriting and franking lines on 2 white envelopes BW1-2	All papers slightly yellowed. Coloured paper easily distinguished from white	2 years in 4, but for irongall ink components 6 months in 4 years
SCHWITTERS *Koi* [1932, T12395]	tracing paper - German	Blank paper, BW2-3	Little colour change	2 years in 4 years
SCHWITTERS *Magic* [*c*.1936-40, T12396]	Colour printing from magazines in English	Cyan halftone BW2-3	Little colour change	2 years in 4 years
Trevelyan, Julian *Rubbish may be Shot Here* [1937, T12162]	Coloured papers, applied watercolour, black & white and green-only colour printing	Ink used for the title BW2-3	Little or no colour change	2 years in 4 years
SCHWITTERS *Opened by Customs* (*Zollamtlich geöffnet*) [1937–38, T00214]	White, buff, grey, brown wrapping, printed tissue paper, watercolour on paper, transparent; postage stamps – Norwegian	Irongall ink, faded and pale brown address on brown envelope BW1-2	As for T03863	2 years in 4, but for irongall ink components 3 months in 4 years

4. DISCUSSION AND CONCLUSIONS

Leaving aside the newsprint components, these results are somewhat reassuring. Because fading generally slows as it proceeds, and the original intensity of the coloured elements are unknowable, some of the apparent stability could be due to fading having already run much of its course. But close visual inspection suggests this is unlikely for most elements.

One class of materials is an exception. Probable iron gall inks in T03863 (3 examples) and T00214 (1 example), presently a pale buff colour, show so little contrast on naturally off-white/buff papers that only very close viewing reveals their presence. Irongall inks are often blue-black but can be brown when applied, and turn dark brown as they age. Newly-written examples are always dark and therefore legible, hence this ink has been widely used for official documents. Prior loss of most of the colour here is likely, and irreversible.

Microfading studies of Tate mixed-media works indicate that the average lightfastness of the 52 potentially light-sensitive paper-based works is about mid BW2-3 (CIE2000), or BW3 in terms of CIELAB1976 colour space. If this is taken as the lighfastness upon which the 2 years in 4 policy is based, the policy is appropriate for the 32 (62%) which are more lightfast than this. However for the 8 works (15%) in the BW1-2 range something like 1 year in 4 is probably more prudent and the 12 (23%) less lightfast than BW1 would require even shorter cumulative display periods. This last group contained (probable) irongall inks (8 examples), or else fibre-tipped pen ink or fluorescent screen printing inks (1 of each).

In a similar study, Ford and Smith (2011) reported that among over 200 objects from the National Museum of Australia (NMA) assessed by microfading, the existing 2 years in 10 exposure recommendation based on the V&A criteria were appropriate for 40% of the objects, while 50% could be displayed longer, and about 10% warranted in some cases much shorter periods of display. At its most basic, microfading is a valuable method of identifying the works most vulnerable to fading when exposed even to UV-free light. It can also provide evidence for increasing (for the NGA) or maintaining (for Tate) current access levels for a substantial majority of objects.

This study offers an interesting window into the light sensitivity of a selection of paper-based 20th-century ephemera including colour printed catalogues, bus tickets, and theatre programmes – also well represented in archives, libraries and social history museums. Based on a small sample set (*c*.150 paper-based elements microfaded), it is not necessarily the case that these types of ephemera are so fugitive they warrant highly restricted access, though each requires specific assessment of the kind microfading was designed to provide.

ACKNOWLEDGEMENTS

BF's introduction of his microfading procedure to Tate during 2011 was funded by the Public Sector Research Exploitation Fund (PSRE). Dr Mark Underhill microfaded T01918.

REFERENCES

Ashley-Smith, J., A. Derbyshire and B. Pretzel, 2002. The Continuing Development of a Practical Lighting Policy for Works of Art on Paper and Other Object Types at the Victoria and Albert Museum, in *ICOM-CC 13th Triennial Meeting Rio de Janeiro Preprints*, ed. R. Vontobel, London: James and James, 3-8.

CIE, 2001. *Improvement to Industrial Colour-difference Evaluation*. CIE Publication No. 142-2001, Vienna: Central Bureau of the CIE.

CIE, 2004. CIE157: *Control of Damage to Museum Objects by Optical Radiation*. Vienna: Central Bureau of the CIE.

Ford, B., and N. Smith, 2011. Lighting Guidelines and the Lightfastness of Australian Indigenous Objects at the National Museum of Australia, in *ICOM-CC 16th Triennial Meeting Lisbon Preprints*, ed. J. Bridgland, Paris: ICOM-CC [CD only].

Chambers, E., and K. Orchard, 2013. *Schwitters in Britain*, Tate, London.

King, A., 1992. Kurt Schwitters's Cherry Picture: Material Change and an Ethical Problem, in *Essays on Assemblage* ed. J Elderfield, New York: Museum of Modern Art, 31-42.

Pretzel, B., 2008. Now you See It, Now you Don't: Lighting Decisions for the Ardabil Carpet Based on the Probability of Visual Perception and Rates of Fading, in *ICOM-CC15th Triennial Conference New Delhi Preprints*, ed J Bridgland, London: James and James, 759-765.

Whitmore, P.M., X. Pan, and C. Bailie, 1999. Predicting the Fading of Objects: Identification of Fugitive Colorants through Direct Non-destructive Lightfastness Measurements, *Journal of the American Institute for Conservation* 38 395-409.

Address: Dr Joyce H Townsend, Conservation Dept.,
Tate Britain, Millbank, London SW1P 4RG, UK
Email: joyce.townsend@tate.org.uk

A New Approach to the Debate between Color and Form in Relation to the Chromatic Circles and Models from the Early Nineteenth Century

Ingrid CALVO
Área Plástica, Departamento de Diseño, Universidad de Chile.

ABSTRACT

For many centuries in art, color had a secondary place in relation to drawing. It was only considered as an application or an element of the appearance of the form. Historically, drawing and line were the protagonists of fundamental moments of Art History and the great artists of drawing were brought to the level of genius. It didn't happen the same with the great colorists. However, in the nineteenth century, with the rise of Romanticism and the inner revelation of man, color, became the main resource for expression and was elevated to the status of substance of light and painting, in the work of artists such as P.O. Runge or J.W.M. Turner. In an unprecedented moment in the unceasing debate between color and line, the balance tipped toward the chromatic matters. Intellectuals of the most diverse disciplines (Goethe, Otto Runge, Schopenhauer, von Helmholtz, Chevreul, Maxwell, among others) attempted to explain the phenomenon of color through numerous theories and by creating various color models and systems, denoting the importance given to color in this moment of human knowledge. These color models, nevertheless, pose an interesting paradox because, from the moment of their conception, most of them are presented as geometric drawings, drawn in a strict way in their formal proposals. This could make us think that the growing assertion of the place of color as more important than drawing (and even the place of drawing as more relevant than color) can never be considered as a total separation of both resources.

1. INTRODUCTION

Since ancient times, the relationship between color and form –form expressed as the line or drawing– has been part of numerous theoretical discussions, mainly from pictorial field, but it has been gradually extended to other disciplines. The dispute of *"color against form"* has been articulated mostly by a historical tendency to seek and identify a supremacy of one resource over the other, which resulted in an overriding place of form over color until the arrival of the eighteenth century.

The eighteenth century, mainly because of the figure of Isaac Newton and his optical discoveries, had prepared a field of interest in color from an objective, physicist and scientist standpoint. (Jiménez, 1991:17). Towards the end of the century and due to the emergence of the Romantic thought, a greater concern for human temperament and the subjective condition of the human being was developed. This changed the paradigm regarding the *color-shape* dispute and, from this moment color, in its intimate relationship with light, acquired a central place as it was considered as a resource for the expression of the artist's subjectivity. Color could arouse a direct and unmediated effect in mind and feelings of people. The Romanticism thought revived color symbolism. The search for a new "morality of color" among painters tended to acquire a more psychological nuance. (Gage, 1993: 204).

In this new stage of thought, numerous theories were originated by intellectuals from different disciplines who sought to understand the phenomenon of color considering the subjective dimension of human beings. These searches formed the basis of what would later become the modern color theory. These theories are a series of treatises that, following the epistemological tradition of visualizing the phenomenon of color, are usually accompanied by some diagrams and color models, understood as topological systems or relational geometric units, designed to represent the chromatic phenomenon, contemplating all the colors arranged in space, and establishing specific positions through an organized logic (Caivano, 1995: 1). The large number of theories and color models generated in the context of Romanticism are a very valuable material to try to understand the way in which this visual resource was present in the philosophical discussion of those times.

However, at a first glance, these color models were generated in a moment when color as an aesthetic resource took precedence over form; it is easy to realize that it is precisely the form what became relevant in the construction of these visual explanations of the chromatic phenomenon. These color models are presented mostly as geometric figures, known shapes as the circle, the sphere or the star, and they constitute the fundamental support to explain the phenomenon. From a first point of view, it seems that in the Romanticism, the line disappeared from the paintings where clearly color won the debate; but we can't declare the same triumph of color when it comes to representing the phenomenon itself visually, where both resources weren't really separated, and the dispute remained in a tie.

All this raises the following question: Is the supremacy of color over form present in the romantic way of explaining color visually? And if so, how? There is no doubt that this question could trigger a more extensive research, but a brief look into some emblematic cases of the romantic color theory can be useful in order to open the discussion for further development.

2. THE "ROSE OF TEMPERAMENTS"

In the late eighteenth century, the German poet Johann Wolfgang von Goethe and his friend, the philosopher Friedrich Schiller, mulled together about nature, art and customs, and represented their dialogues and reflections through symbolic drawings and tables. In their attempt to include the study of color into their reflections, in the year 1799 they developed "The Rose of Temperaments": a geometric color model aimed to relate the chromatic polarities –taken from the theory of the polarities belonging to the philosophy of nature or *Naturphilosophie*– with the four traditional temperaments: sanguine, melancholic, phlegmatic and choleric. This was made with regard to the sensual-moral effect of colors that Goethe was looking for. The same way complementary colors are opposed in the color wheel, the four humors are opposed in pairs, interacting with the colors. Each humor is assigned to three types of human character. In the sense of progression on the active –red– side, there are adventurers, heroes, and tyrants, while on the passive –blue– side, there are teachers, philosophers, and pedants. Purple as the combination of the intensified poles of the color wheel represents the ruler, who is opposed by the poet as his harmonic complement. Goethe, however, insisted that the architect of this organization was Schiller, who agreed with the superiority of the line against color in its relation with the depiction of truth.

Subsequently, through the publication of his Theory of Colors (Zur Farbenlehre) in 1810, Goethe would deepen in the aesthetic, moral and allegorical effects of color, based on the belief that colors could touch the mind and feelings of the human being. His modern theory would serve mostly to painters because of the psychological meanings related to color, a subject that hadn't been explored in a deep way, until then. (Miguel-Pueyo, 2009:30).

Through this first case it's possible to realize that one of the main contributions of the romantic color theory to the design of color models is related to the inclusion of emotional or temperamental variables in the visualization of the chromatic phenomenon, what emphasizes the capabilities of color to invoke emotion over the capabilities of shape. The romantic artists looked for new meanings of colors depending on the positions they occupied in space.

3. RUNGE'S SPHERE OF COLORS

Phillip Otto Runge was one of the main recipients of Goethe's color theory. Like the German poet, Runge expected to pictorially illustrate the color functions. In his paintings he exposed a quasi-mystical regard of color as a natural power, as a manifestation of divine revelation, while in Die Farben-Kugel his book published in 1810, he sketched geometrical models that showed the relationships between colors and helped to understand the color harmonies. Runge gave these color models a more objective approach than to his paintings. His sphere, one of the first attempts made by a painter of coordinating the complementary colors with the poles of light and dark, found so little opposition that became one of the major influences in the development of color order systems throughout the century (Gage, 1993).

Runge also used figures like the star in a more mystical way, to indicate the contrast between the ideal world of love –red–, and the real world –green–. The warm side of his spheres –yellow and orange– represents the male passions and the cold side –blue and violet– represents the feminine. Although Runge establishes some relationships between color and psychological meanings within his theory, his real contribution is the classification of colors attributes in terms of the contrasting attributes of light and dark, and how he articulated his complete theory starting from this polarity, reflecting one of the main characteristic of the romantic thought applied to color.

This second case helps to understand how the attributes of color in their relation to the lightness or darkness –visual and conceptual– determined the valuation and position of colors within the geometric shape that supports it. Is the color, with its theoretical complexity, which forced Runge to move from flat to three-dimensional shapes. Is the color what determines the shape, what takes precedence?

4. THE CHROMATIC CIRCLES OF TURNER

Goethe's Theory of Colors also had reception in the English romantic painter J.M.W. Turner, who was a thorough reader of the work of the German poet. Always interested in the interaction between light and color, in 1812, nearly thirty years before reading the theory of Goethe, Turner described one of his paintings in terms of active and passive colors, suggesting that the painter was interested in the effects of color. From his reading of the Farbenlehre, he was particularly interested in the table of polarities in which Goethe sought to show that color unlike light, is always specific, significant and characteristic.

These polarities and Turner's interest in understanding the phenomenon of color in the practice of painting, led him to create their own color models: simple chromatic circles that initially took as morphological reference the chromatic system of Moses Harris, but Turner would focus his circles to represent the principles of light and shadow, day and night (Gage, 2009). Turner saw a universal meaning in the three primary colors, subordinating them to the light. Like Runge, also devoted part of his later pictorial work to the polarities of color in their relation to value attributes.

Turner's chromatic circles are an attempt by the artist to contribute to the color theory from his own practical experience. Although morphologically his models are constructed on the basis of the circle and the triangle, they are carefully configured by suppressing the line and drawing and setting the visual limits only by the use of color contrast. They are an interesting case because visually, it seems that Turner rejected the idea of drawing a color wheel, and he decided to generate it by painting. The absence of the line and drawing in their color models comes to confirm the supremacy of color as the main way of expression, both in his paintings and in his explanations of the color phenomenon.

5. CONCLUSIONS

In all the three cases proposed we can see different ways to approach the visualization of color theory in the romantic thought of the early nineteenth century. The new way of thinking about the phenomenon of color, with an emphasis on the perceptual attributes and the subjective experience of the viewer, characteristic of the philosophy of the those days, meant new complexities to the ones who tried, with varying success, to propose color models and systems that would help to explain the phenomenon in a comprehensively and fairly way. From the point of view of the practice of painting in the Romanticism, the supremacy of color over line is almost indisputable, but the translation of that primacy to the color theory and the visualization of it was definitely a difficult task, in which the equivalence of both resources is a background to the issues raised by contemporary theories: color and form are usually presented as distinct but strongly inseparable resources, fundamental in visual representation.

There is no doubt that from this first stage of discussion it will be possible to study in greater depth a wider universe of images and theories that will fully articulate the translation of the *color-form* dispute through the more relevant color models of the nineteenth century.

REFERENCES

Caivano, J.L., 1995. *Sistemas de orden del color*. Buenos Aires: Secretaría de Investigaciones en Ciencia y Técnica, FADU, Universidad de Buenos Aires. 62 p.

Gage, J., 1993. *Los colores de la mente: el legado de Goethe En: Color y cultura; la práctica y el significado del color de la antigüedad a la abstracción*. 3a ed. Madrid, Editorial Siruela. pp. 191-212.

Gage, J., 2009. *Emulous of Light: Turner's Color Revisited*. Lecture given on the occasion of receiving the silver Turner Medal from The Color Group (Great Britain). London.

Gerritsen, F., 1988. *Evolution in color*. Atglen: Schiffer Publishing. 88 p.

Jiménez, A., 1991. *La primacía del color*. Caracas: Monte Ávila Editores. 133 p.

Stromer, K., 1999. *Color Systems in Art and Science*. New York: Golden Artists Colors, 221 p.

Address: Ingrid Calvo Ivanovic, Departamento de Diseño,
Facultad de Arquitectura y Urbanismo
Universidad de Chile. Portugal 84, C.P. 8331051, Santiago de Chile.
Email: ingridcalvo@uchilefau.cl

Displaying Artwork with Tuneable Colour Quality

Arūnas TUZIKAS,[1] Anqing LIU,[2] Artūras ŽUKAUSKAS,[1] Rimantas VAICEKAUSKAS,[3]
Pranciškus VITTA,[1,3] Andrius PETRULIS,[1] Michael S. SHUR[2,4]
[1] Institute of Applied Research, Vilnius University
[2] Smart Lighting Engineering Research Center and Department of Physics, Applied Physics, and Astronomy, Rensselaer Polytechnic Institute
[3] Department of Computer Science, Vilnius University
[4] Department of Electrical, Computer and System Engineering, Rensselaer Polytechnic Institute

ABSTRACT

We report on a tuneable quadrichromatic (red-amber-green-blue, RAGB) solid-state lighting device (colour rendition engine) with the following functions implemented: i) control of colour rendition by balancing metameric RAGB spectra between the colour saturation, colour fidelity, and colour desaturation ability of light; ii) variation of correlated colour temperature and luminance with the photochemical damage potential maintained at a constant value; and iii) generating quasi-white light for chromatic correction. We demonstrate several applications of the engine for advanced display of artwork.

1. INTRODUCTION

Advanced artwork illumination must have a low photo damage potential (Cuttle 1998), appropriate colour temperature (Pinto et al. 2008), and suitable colour rendition with the possibility to correct faded colours. In contrast to incandescent and fluorescent lamps presently widely used for art display, polychromatic clusters of direct-emission and phosphor-conversion LEDs can be optimized to meet most requirements for the illumination of paintings and other light-sensitive objects. The spectral power distribution (SPD) of such clusters can be intelligently controlled and adjusted for the appropriate display of individual pieces of art and for meeting individual preferences of the viewers. Here we report on displaying artwork with tuneable colour quality using a solid-state lighting device with a versatile SPD control.

2. METHOD

The light source used in our work is a tetrachromatic (RAGB) cluster of direct emission and phosphor-converted LEDs, which allows for generating light with metameric spectra (colour rendition engine, Žukauskas et al. 2012). The engine colour rendition properties are continuously changed by varying the weight parameter σ, which determines the relative contribution of the trichromatic RGB and AGB blends to the overall SPD:

$$S_{\mathrm{RAGB}}(\lambda) = \sigma S_{\mathrm{AGB}}(\lambda) + (1-\sigma) S_{\mathrm{RGB}}(\lambda) \quad (1)$$

Provided that the two trichromatic lights have the same chromaticity, tuning σ within the interval of (0,1) allows for continuously traversing all possible metameric RAGB blends. The RGB blend (σ = 0) and the AGB blend (σ = 1) correspond to the most colour saturating and most colour dulling light, respectively. The in-between blends can be adjusted to the highest colour fidelity or to any other individual preferences in colour quality. An intelligent control of the engine also allows for the variation of correlated colour temperature (CCT) and luminance maintaining the photo damage potential at a constant value and/or generating quasi-white light for chromatic correction.

3. RESULTS AND DISCUSSION

We demonstrate several applications of the engine for advanced display of artwork as follows.

3.1 "Restoration" of an aged painting

Lithuanian fantasist and mystic M. K. Čiurlionis painted "Fantasy" (1908) by crayon on low-grade cardboard. After one hundred years of exhibiting, the painting suffered from the severe brownishing of the cardboard. By adjusting the chromaticity of quasi-white light, we shifted all colours in order to compensate for the brownishing effect and to make the most of the restoration of the original shades. Then, by traversing all possible metameric blends, we increased the chromatic contrast to an appropriate extent (Figure 1). This revealed many additional details of the painting.

Figure 1: "Fantasy" by M. K. Čiurlionis (1908). View under original illumination by a halogen lamp (left); same painting under colour rendition engine (CCT = 6500K) with the shifted colour gamut and increased chromatic contrast (right).

3.2 Colour-rendition needs vs. cultural background

Subjects from two cultural groups (Chinese and Americans) were asked to adjust the engine to the most preferred CCT and the desaturation vs. saturation balance (AGB vs. RGB weight σ) for three different paintings. The first painting (Figure 2(I); unknown author) was painted by acryl on canvas. It depicts a colourful fire theme that was assumed to be equally familiar to subjects with different cultural backgrounds. The second artwork (Figure 2(II); unknown author) was painted on a cardboard. It depicted Saint George fighting a dragon in somewhat faded colours. This topic was assumed to be more familiar to subjects with Christian or multicultural background, such as Americans rather than to Chinese. The third artwork used in the experiment (Figure 2(III); by E. Kuokštis) was a post-impressionistic watercolour painting displaying a medieval downtown scene in Vilnius, Lithuania. The theme of the painting was assumed to be unfamiliar to all subjects, since none of them have been to Vilnius nor were acquainted with the style of the artist.

Figure 2 shows the experimental results on finding the preferential colour quality conditions. Figures 2(a), (c), and (e) and Figs. 2(b), (d), and (f) demonstrate the selection rates as functions of the AGB vs. RGB weight and CCT, respectively.

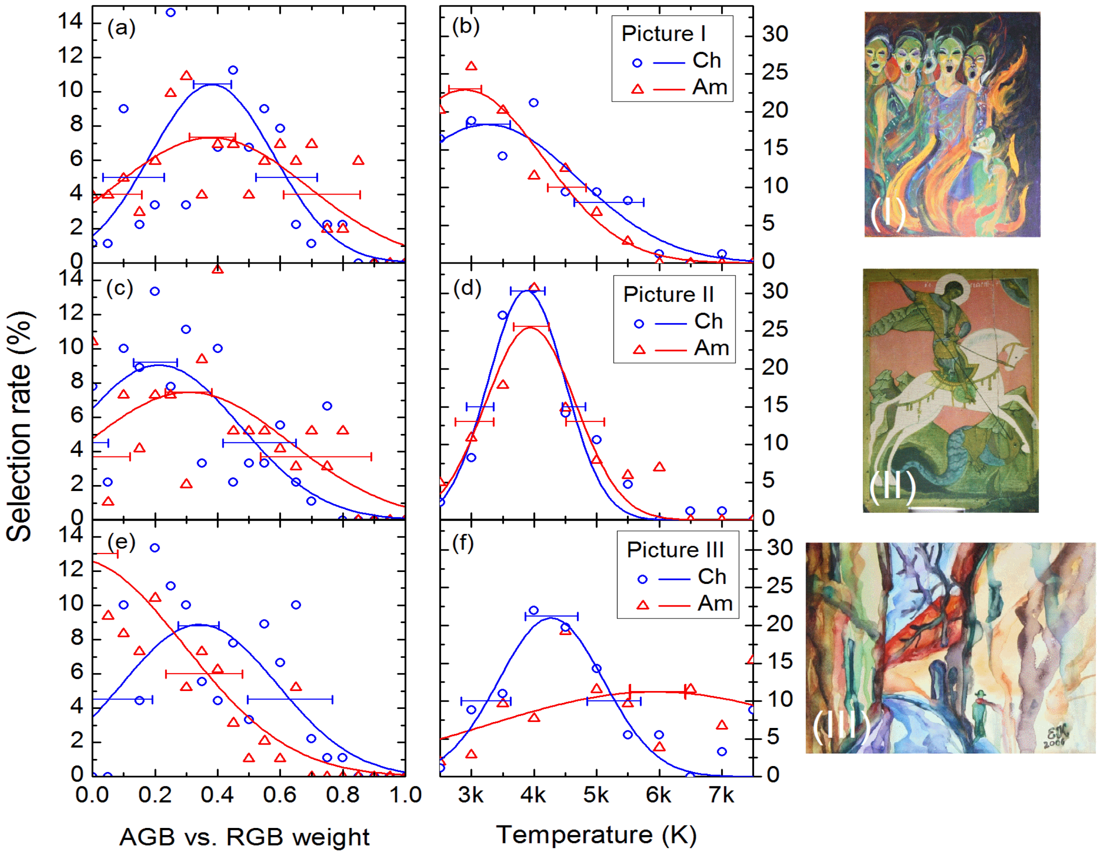


Figure 2: Points, percentage of the subjective selections of the weight parameter σ (a, c, and e) and CCT (b, d, and f) for the most preferred illumination of paintings with various level of familiarity. Blue circles and red triangles, data obtained from Chinese and American subjects, respectively. Lines, Gaussian distributions obtained by least-squares fitting. Horizontal bars, the 95% confidence intervals for the peak weights and widths of the distributions.

Research with different cultural groups shoved that for painting I, which is assumed to have the most familiar and culturally neutral content, no significant difference in the average selection rate of AGB vs. RGB weight was observed, however the American group of subjects showed a noticeably wider distribution of the selection rates than the Chinese subjects. For painting II, which is assumed to be less familiar to subjects with the Chinese cultural background, the distributions of AGB vs. RGB weight differ in both the width and peak position. For these two paintings, the distributions of the CCT selection rate show almost no cultural differences within the experimental uncertainty. However, the average selected CCT is seen to depend on painting content: the fire topic required considerably lower CCT than the Saint George topic. For painting III, which is assumed to be unfamiliar to both cultural groups, the selection rate distributions show cultural differences for both AGB vs. RGB weight and CCT. As compared to Americans, the Chinese group of subjects selected less saturated colours and lower CCT on average. For both σ and CCT, the American group of subjects showed wider distributions.

4. CONCLUSIONS

We introduced a tuneable RAGB colour rendition engine for advanced display of artwork. The engine allows for the versatile control of colour rendition characteristics (fidelity, saturation, desaturation), maintaining the photochemical damage potential at a constant value, and generating quasi-white light for chromatic correction.

Several applications of the engine have been presented. In one application, an aged painting has been "restored" by shifting the colour gamut in order to compensate the brownishing of the substrate and by increasing the chromatic contrast. Viewing together the aged and illumination-restored painting is expected to provide an additional aesthetic dimension to the viewers. In another application, the selection of the preferences to the colour quality of illumination by groups of subjects with different cultural background has been demonstrated for paintings with different level of familiarity. Significant variations in preferred SPDs depending on the painting under illumination were revealed. This suggests a completely new approach to artwork illumination in galleries and museums.

ACKNOWLEDGEMENTS

The work at VU was funded in part by a grant (No. MIP-098/2012) from the Research Council of Lithuania. A.T. acknowledges partial support by project "Promotion of Student Scientific Activities" (VP1-3.1-ŠMM-01-V-02-003) from the Research Council of Lithuania funded by Republic of Lithuania and European Social Fund under the 2007-2013 Human Resources Development Operational Programme's Priority 3. P.V. acknowledges a postdoctoral fellowship funded by the European Union Structural Funds project "Postdoctoral Fellowship Implementation in Lithuania." The work at RPI was supported primarily by the Engineering Research Centers Program (ERC) of the National Science Foundation under NSF Cooperative Agreement No. EEC-0812056 and in part by New York State under NYSTAR contract C090145.

REFERENCES

Cuttle, C., 1988. Lighting works of art for exhibition and conservation. *Lighting Research and Technology* 20(2): 43-53.

Pinto, P.D., J.M.M. Linhares and S.M.C. Nascimento, 2008. Correlated color temperature preferred by observers for illumination of artistic paintings. *Journal of the Optical Society of America A* 25(3): 623-630.

Žukauskas, A., R. Vaicekauskas, P. Vitta, A. Tuzikas, A. Petrulis and M. Shur, 2012. Color rendition engine. *Optics Express* 20(5): 5356-5367.

Address: Arūnas Tuzikas, Department of Semiconductor Optoelectronics
Institute of Applied Research, Vilnius University,
Saulėtekio al. 9, bldg. III, Vilnius, LT-10222, Lithuania
E-mails: arunas.tuzikas@tmi.vu.lt, anqing.liu21@gmail.com, arturas.zukauskas@ff.vu.lt,
rimantas.vaicekauskas@mif.vu.lt, pranciskus.vitta@ff.vu.lt, andrius.petrulis@gmail.com,
shurm13@gmail.com

The Material of Colour

Helen BAKER
Department of Arts, Faculty of Arts,
Design and Social Sciences, Northumbria University

ABSTRACT

This presentation seeks to explore how colour and material communicate and the ways contemporary painters are continuing a dialogue and craft that is both medieval and of current significance.

As painters we learn to indicate our own attitude towards our subject through the way we offer the paint as a substance. Paint, is not only explored through gesture, through mixing, through different pigments, through glazing, through the interruption of the supports and through different consistency of mediums. It is explored within subject readings so that the material presence of the paint offers up the subtle layers of interpretation that we are able to negotiate.

Donald Judd has become an important figure for those of us interested in paint and colour. Judd understood and attempted to articulate the wider implications of colour, material and space in the world we are building around ourselves. What is it we are responding to when we consider innately coloured material against the painted or customised? There is something that can only be described as "made" about those beautiful Amtrak American trains in polished steel. Alternatively, there is something oddly archaic but continually compelling in the power of paint to transform whether it's a car chassis or a canvas.

> "….Colour is so unknown it would have to start with a spot. How large is it? Is it on a flat surface? How large is that? What colour is that? What colour is the spot? Red. If a second spot is placed on the surface what colour is it?..................."

Donald Judd has recently become an important figure for me in thinking about colour.. Judd understood and attempted to articulate the wider implications of colour, material and space in the world we are building around ourselves. What is it we are responding to when we consider innately coloured material against the painted or customised? There is something that can only be described as "made" about those Amtrak American trains in polished steel. Alternatively, there is something oddly archaic but continually compelling in the power of paint to transform whether it's a car chassis or a canvas.

As a painter it is this sense of the innateness of colour in relation to material that I am currently interested in and how we understand it. I have been interested in looking at the material presence of a block of colour, a colour that could be read as an image of an object or a square of colour. A colour that can be read as an image or as a painted side of an object.

How do we relate these two images?

I always liked the way Philip Guston made the shapes ape things but it still remained abstract and flat. It is endlessly fascinating to artists in the same way trompe l'oeil once was. We are no longer interested in the ability to generate images that fool the eye as objects in the same way as we were with our camera obscura . But that link between the interior and exterior worlds of reality continues to facinate. The possibility that the support is part of the image is part of that bridge.

I wanted to take the block of colour through different relationships with the support and so I guess that's what I have been about. In doing this I have ended up making the support more dominant at times. Sometimes stretching it or making it turn corners like the wall. Sometimes grow outwards like rings on a tree so that it becomes a lovely block of plywood; and this material more recently has tried to do the job of the paint.

This has made everything the paint does more important and therefore it has been necessary to limit the paint to thin it and make it monochrome.

I believe that colour is used in painting as a material presence. That paint offers always itself primarily as material and it is the presentation of its materiality that informs the meaning and significance of the colour.

I am going to talk a little bit about the mark in this synthesis of the material presence and how it offers more than just texture. How the mark offers the spectator a specific encounter with the material they are viewing. An encounter that is left open for them by the artist.

The painters mark is created by gesture. That gesture may for example be a very small event created by a size 0 sable brush or brash and overladen .

As it,the gesture, meets the material called paint. this combination or event can be created in a million different ways and this impacts on the reception of the recording of that colour.A strong gesture may be received as theatrical or merely a precisely made but quick removal of what lies underneath. How do we as the spectator read that ? How do we know.

We know because the art of knowing about substance is also something we all are continually involved with whether we are making a piece of knitting or laying a wall , balancing the bricks one on top of another. We are reading colour, substance, weight, smell etc. and documenting it for future reference. From this very basic but important task of engaging with substance we have the possibility to imagine .When we view a work we view not only the object or event as a sign but we view the way it is made.

When we go to the theatre we are aware of the rehearsals and discipline involved. As spectators or audience we get involved in who the actor is and perhaps how she uses a her own difference or similarity to the character being played. As with film or music, we are interested in the way it is made, the context or inspiration, we the spectator are in a continual state of researching and building our own set of references.

As viewers we are in a continual state of building, making and replacing.

The artist, the painter, is the blind spectator. They are there before the mark is revealed to the maker. They have to work with the blindfolding of the mark by the brush . With a pencil they can see the journey it will take far easier; but there remains the potential of tone and shake. The sensations we engage with are therefore understood through these bodily movements, and through the speed of production. And strangely instead of wanting to know where we are going before we go we anticipate. We anticipate everything the scale the shake the speed but we do not want to know. To know would be to deaden it.

I am interested in how some people can participate in this process and others cannot.

How, when making a piece of work there can be participation or not and what that participation consists of.

Laura Cull in discussing performance talks about what Deleuze called a moment of recognition an “encounter” that makes us think and particularly, makes us participate in the artwork as active viewers rather than passive viewers.

She cites Sontags description of Artaud “Situation of the Flesh”where the artist Antonin Artaud would speak to the “mind in the flesh”.

Artaud denounced as a coward anyone who refused to remake themselves. His philosophy I think was one of confronting your assumptions and refusing to accept the accepted order. He wanted to present his audience with a problem to engage the audience to participate.

She cites Allan Kaprow and his Happenings

Kaprow would give his participants jobs to do like putting your hands in two different temperatures of water to feel differently…. He did not want anything complex but he wanted it given without any preconceived agenda.

Happenings were seen as ways of waking up people from ordinary life. Cull says that like Deleuze , Kaprow wanted the audience to retrain perception itself to tune it to different speeds and in different scales.

And finally at the end of the essay she cites Henri Bergsons description of someone waiting for sugar sherbet to dissolve in a glass of water before drinking it. Watching it dissolve and participating in its immobility we are aware of our own speed and our impatience for it to catch up with our speed. I have a similar sensation watching ships move on the sea we are outside that speed but we enter it.

When we paint do we enter that different speed of being? We seem to spend a lot of time learning how to make a slow mark and a quicker mark. We spend time learning how the colour might offer a cool sugar like spread within a dissolve or turn within another mark one colour inhabiting the other.

The mark is laid on the support it covers but it covers in a way that offers an experience of both what was there before and what is there now. We see the act and in doing so we see what was not there before.

The act engages with something in the world. It may be a sensation of an object but it is always a sensation.

Innate colour , the colour that is wood that is canvas that is paper , that is gesso offers a sense of that which was before.

REFERENCES

Cull, L., 2009. *Performance Now & Then*, Arts and Social Sciences Academic Press Northumbria University.

Address: Helen Baker, Director of Gallery North, Professor of Fine Art
Department of Arts, Faculty of Arts, Design and Social Sciences,
Northumbria University, Newcastle upon Tyne NE1 8ST
E-mails: Helen.baker@northumbria.ac.uk, www.helenbaker.org

colour and food

Consumer Expectation on Preference and Taste of Fresh-Cut Fruit Influence by Package Colours

Somporn JENKUNAWAT,[1] Pratoomtong TRIRAT[2]
[1] Faculty of Agricultural Technology,
[2] Faculty of Mass Communication Technology,
Rajamangala University of Technology Thanyaburi

ABSTRACT

This study was aimed to investigate the effects of package colours on consumers' expectation on the product taste and preference, as well as purchasing decision. Data were collected by questionnaire from two groups of participants of ≤ 25 and >25 years old. Two groups of fresh-cut fruits were packed in packages of various colours for testing. The first group included three kinds of fruit: orange, pineapple and green apple; all of which the fruit-cut tastes ranged from sweet to sour. The second was watermelon, green cantaloupe and dragon fruit; all of which the fruit-cut tastes ranged from sweet to tasteless or not sweet at all. The results showed that fresh-cut fruit with sweet to sour tastes packed in pink packages were rated as very sweet and more preferred by both groups while most of the purchasing decision was influenced by the taste rated as sweet – sour, except for the green apple which was rated as very sweet and more preferred by participants of >25 years old. For fruit with sweet to not sweet tastes at all, it was found that fresh-cut fruit packed in pink packages were rated at very sweet and most of the preference rating was for pink packages as well. Most participants' purchasing decision was influenced by the packages rated as very sweet and more preferred.

1. INTRODUCTION

Fresh-cut fruit products are those that have been cleaned, peeled, sliced, cubed or otherwise prepared for convenient consumption and remain in living conditions. Growing trends towards vegetarianism and healthy eating have resulted in an increasing demand for convenient products that fit into the modern consumer lifestyle. Fresh-cut products, especially fruit, have thus become increasingly popular. There were many researches about packaging method and the most studied was modified atmosphere packaging that allowed the quality of fresh-cut produce to be preserved and prolonged its shelf life (Valero & Serrano, 2010). Colour of fresh-cut fruit is the key factor in the perception of fruit. It is an indicator of taste and quality such as freshness. It is also the primary attribute consumers consider in making purchasing decisions. Packages for fresh-cut produce are different from snack packages as they would allow consumers to see the produce as clearly as possible; thus, the package colour will play an important role in the consumers' purchasing decision. Many research studied colour of food that reflected the taste (Clydesdale, 1993; Lawrence et al, 2000; Park et al, 2012; Caivano et al, 2012). Scientists and marketers have long known that colour can affect how we perceive food. However, there are limited research about the expectation of the consumer, especially the influence of package colour on tastes and preference of fresh-cut fruit.

2. METHOD

The CIE L*a*b* values of all packages and fresh-cut fruit were measured using a colorimeter (CS-100 Konica Minolta). The CIE L*a*b* value consisted of: the lightness (L*), the position between red and green (a*: +a*= red, -a*= green), and the position between yellow and blue (b*: +b*= yellow, -b*=blue). Two groups of fruit were tested. The first group included three kinds of fresh-cut fruit: pineapple (*Ananas comosus* L.), orange (*Citrus sinensis* Navel) and green apple (*Malus domestica* Borkh); all of which the tastes ranged from sweet to sour. The second included: watermelon (*Citrullus lanatus*), green cantaloupe (*Cucumis melo* L. var. cantaloupensis) and dragon fruit (*Hylocercus undatus* (Haw) Brit.); all of which the tastes ranged from sweet to tasteless or not sweet at all. Fresh-cut fruit were prepared, packed on trays and then covered with plastic wrap. Seventy participants consisting of students and officials of the Faculty of Mass Communication Technology were divided into two groups by age: ≤ 25 and >25 years old. They observed and rated the expectation scales of taste and preference by viewing each treatment using 1 – 5 rating scale. The intention of purchase was also investigated.

3. RESULTS AND DISCUSSION

The CIE L*a*b* of packages and fresh-cut fruit were shown in tables 1 and 2. The results showed that fresh-cut fruit with the taste range from sweet to sour scored at very sweet in pink packages by both groups while the group of ≤ 25 years old rated blue packages for oranges and green apples as very sweet, and the group of >25 years old rated white packages as very sweet for oranges and pineapples. The rest were rated as sweet – sour. All fresh-cut fruit packed in pink packages were rated as more preferred. The highest percentage of purchasing decision of the ≤ 25 year-old group was on the sweet – sour taste, but the fruit packages did not gain highest preference. Similarly, purchasing decision of the >25 year-old group was highest on the sweet – sour taste and more preferred for all package colours (Table 1).

Concerning the fresh-cut fruit with the taste range from sweet to not sweet at all or tasteless, it was found that the pink packages of all kinds of fruit were rated as very sweet by both groups while the participants of ≤ 25 years old rated more preferred for green, blue and pink packages. The highest percentage of purchasing decision of both groups was the same as the rating of taste and package colour preference (Table 2).

The experiment clearly shows that a combination of package and fruit colour influences the customer's expectation on the taste and preference, and purchasing decision. If the expectation created by package colour is high, the consumer may choose to buy the product. In point of purchasing decision, it worth to mention that personal experiences, culture and socialization for their environment also play the important role. However, the expectation on the taste and preference could also affect the consumer response when tasting the product. When the product is tasted, the expectation and real characteristics are compared and this may lead to expectation confirmation or disconfirmation. The confirmation may lead to continuous purchase while the disconfirmation may stop the purchase. Therefore, marketers should not only use packages to attract consumers' attention in order to increase their interest in buying the product but also generate taste and preference expectations that match the products' real characteristic (Gaston & Deliza, 2010).

*Table 1. The CIE L*a*b* of packages and fresh-cut fruits taste sweet to sour and average score of taste and preference of fresh-cut fruit on each package and purchasing decision.*

Fruit (L*a*b*)	Package colour (L*a*b*)	Taste		Preference		Purchasing decision	
		≤ 25	>25	≤ 25	>25	≤ 25	>25
						%	%
Orange (58.32,8.24,59.60)	White (100,-6.17,6.16)	3.26 ±0.98	3.45±0.94	3.06±1.21	3.95±0.88	40	14
	Orange(66.21,61.24,61.65)	3.22±0.99	3.00±0.79	3.66±0.91	3.60±0.82	20	36
	Green(84.38,-43.85,86.76)	2.78±1.20	2.70±1.03	3.66±1.00	3.75±0.85	25	22
	Blue(59.53,-17.09,-40.34)	3.54±1.07	3.25±0.85	3.16±1.01	3.45±0.99	10	24
	Pink (51.61,64.46,-6.62)	3.80±1.26	3.80±1.00	3.42±1.16	3.65±0.81	5	4
Pineapple (75.34,0.40,52.86)	White (100,-6.17,6.16)	2.94±1.20	3.55±1.23	3.00±1.29	3.60±1.14	35	22
	Orange (66.21,61.24,61.65)	3.10±1.01	2.90±0.71	3.72±0.85	3.65±0.87	25	22
	Green (84.38,-43.85,86.76)	3.06±1.23	3.20±0.95	3.74±1.04	3.65±0.98	20	30
	Blue (59.53,-17.09,-40.34)	3.30±0.90	3.15±1.04	3.44±0.99	3.35±0.93	10	16
	Pink (51.61,64.46,-6.62)	3.60±1.61	3.60±0.68	3.54±1.07	3.60±0.88	10	10
Green apple (78.15,-9.39,32.07)	White (100,-6.17,6.16)	2.96±1.04	3.15±1.13	2.68±1.34	3.15±1.13	**5**	**2**
	Orange (66.21,61.24,61.65)	3.20±0.92	2.85±0.74	3.64±1.00	2.85±0.74	**10**	**10**
	Green (84.38,-43.85,86.76)	2.98±1.33	3.05±0.82	3.90±1.01	3.05±0.82	**40**	**20**
	Blue (59.53,-17.09,-40.34)	3.50±1.05	3.20±0.89	3.50±1.05	3.20±0.89	**30**	**20**
	Pink (51.61,64.46,-6.62)	3.74±1.25	3.75±0.78	3.78±1.20	3.75±0.78	**15**	**48**

Taste score 4.21 – 5 = extremely sweet, 3.41 – 4.20 = very sweet, 2.61 – 3.40 = sweet-sour, 1.81 – 2.60 = very sour, 1.00 – 1.80 = extremely sour

Preference score 4.21 – 5 = most preferred, 3.41 – 4.20 = more preferred, 2.61 – 3.40 = moderate preferred, 1.81 – 2.60 = less preferred, 1.00 – 1.80 = least preferred

*Table 2 The CIE L*a*b* of packages and fresh-cut fruits taste sweet to tasteless and average score of taste and preference of fresh-cut fruits on each package and purchasing decision.*

Fruit (L*a*b*)	Package colour (L*a*b*)	Taste		Preference		Purchasing decision	
		≤ 25	>25	≤ 25	>25	≤ 25	>25
						%	%
Watermelon (39.50,25.85,26.06)	White (100,-6.17,6.16)	3.58±1.14	3.40±1.27	2.86±1.42	3.35±1.34	5	6
	Orange (66.21,61.24,61.65)	3.22±0.81	3.20±0.76	3.22±0.88	3.10±0.71	10	22
	Green (84.38,-43.85,86.76)	3.36±1.08	3.05±0.99	3.70±1.01	3.40±0.94	25	22
	Blue (59.53,-17.09,-40.34)	3.30±1.11	3.05±1.09	3.66±0.77	3.10±0.78	15	18
	Pink (51.61,64.46,-6.62)	3.62±1.04	3.65±1.04	3.46±0.90	3.30±1.03	45	32
Dragon fruit (50.60,-2.11,8.80)	White (100,-6.17,6.16)	2.44±1.24	2.70±1.12	2.46±1.11	3.10±1.33	15	6
	Orange (66.21,61.24,61.65)	3.44±0.78	3.25±0.98	3.48±1.27	3.35±1.34	45	20
	Green (84.38,-43.85,86.76)	3.40±0.99	3.75±0.71	3.94±0.91	3.50±1.00	25	38
	Blue (59.53,-17.09,-40.34)	3.78±1.07	3.00±0.85	3.58±0.92	3.50±0.94	5	20
	Pink (51.61,64.46,-6.62)	3.78±1.26	3.65±0.81	3.94±1.03	3.90±0.91	10	16
Green cantaloupe (64.43,-11.96,28.39)	White (100,-6.17,6.16)	2.72±1.24	3.55±1.19	3.24±1.27	3.70±0.92	20	34
	Orange (66.21,61.24,61.65)	3.60±0.83	3.25±0.78	3.62±0.87	3.40±0.75	25	10
	Green (84.38,-43.85,86.76)	3.62±0.92	3.70±0,97	3.82±0.96	3.80±0.83	40	42
	Blue (59.53,-17.09,-40.34)	3.66±0.91	3.20±1.05	3.44±1.03	3.25±0.63	10	6
	Pink (51.61,64.46,-6.62)	3.68±1.18	3.60±0.88	3.62±1.06	3.30±1.12	5	8

Taste score 4.21 – 5.00 = extremely sweet, 3.41 – 4.20 = very sweet, 2.61 – 3.40 = moderate sweet, 1.81 – 2.60 = slightly sweet, 1.00 – 1.80 = not sweet at all (tasteless)

Preference score 4.21 – 5 = most preferred, 3.41 – 4.20 = more preferred, 2.61 – 3.40 = moderate preferred, 1.81 – 2.60 = less preferred, 1.00 – 1.80 = least preferred

4. CONCLUSIONS

Package colour influences the consumer expectation on the taste and preference. Fruit with taste range from sweet to sour – orange (L*=58.32, a*=8.24, b* =59.60), pineapple (L*=75.34, a*=0.40, b* =52.86) and green apple (L*=78.15, a*=-9.39, b* =32.07) that are in pink (L* =51.61, a*=64.46, b*= -6.62) packages reflect sweeter taste than those in other colours. Similarly, the fresh-cut fruit in this group when packed in pink packages are more preferred than in other colours. But the purchasing decision was for sweet-sour taste. Fruit with taste range from sweet to not sweet at all – watermelon (L*=39.50, a*=25.85, b*= 26.06), dragon fruit (L*=50.60, a*=-2.11, b*= 8.80) and green cantaloupe (L*=64.43, a*=-11.96, b*= 28.39) that are in pink packages also reflect sweeter taste and are more preferred than in other colours. The purchasing decision goes along with the taste and preference scored.

ACKNOWLEDGEMENTS

The authours would like to thanks students and officials that took part in the experiment. We would also like to thank the Faculty of Agricultural Technology, Faculty of Mass Communication, Rajamangala University of Technology Thanyaburi, Thailand for their support on our research and travel expense for the conference.

REFERENCES

Caivano, J.L., M.P. Buera and C. Schebor, 2012. Interaction of colour and taste: Colour synthesia in the food environment. In *AIC 2012 Color we live: Color and Environment*, Proceedings, Taipei, 96-99.

Clydesdale, M., 1993. Colour as a Factor in Food Choice, *Critical Reviews in Food Science and Nutrition*, 33(1): 83-101.

Ares, G., and R. Deliza, 2010. Study the influence of package shape and colour on consumer expectations of milk desserts using word association and conjoint analysis. *Food quality and preference* 21: 930-937.

GarberJr., L.L., E.M. Hyatt and R.G. Starr Jr., 2000. The affects of food color on perceived flavor. *Journal of Marketing Theory and Practice*. 56-72.

Park, G-L., J. Lee and H-J. Suk, 2012. Prediction of a taste from color and its practical application. In *AIC 2012 Color we live: Color and Environment*, Proceedings, Taipei, 156-159.

Valero, D., and M. Serrano, 2010. *Postharvest Biology and Technology for Preserving Fruit Quality*. CRC Press, New York.

Address: Somporn Jenkunawat, Faculty of Agricultural Technology,
Rajamangala University of Technology Thanyaburi,
39 Moo 1, Rangsit-Nakornayok Road., Klong 6,
Thanyaburi, Pathumthanee 12110, Thailand
E-mail: sompornjen@gmail.com

Sensory Evaluation of Preference of Baked Food Color

Hideki SAKAI,[1] Hiroyuki IYOTA[2]
[1] Graduate School of Human Life Science, Osaka City University
[2] Graduate School of Engineering, Osaka City University

ABSTRACT

We conducted sensory tests to determine the preference of baked food color of a plain cookie and sliced bread. They are initially white (L* is about 90), which is the color of wheat flour, and become darker (browning) as baking progresses. A total of 93 Japanese subjects (40 males and 53 females, average 31.8 years old) evaluated the browning colors from raw to overcooked and answered the most preferred color, and the upper (not too raw) and lower (not overcooked) limits as a food to eat. The results were highly individual. There is, however, only one peak in each frequency distribution. Thus, we can determine the range of browning color that most (eg. 75 percent) people can accept. That is between L*=77.5 and 62.5 for plain cookies and between L*=81.2 and 63.5 for sliced bread.

1. INTRODUCTION

Color is one of the important factors in determining food quality. For example, we judge the ripeness of fruits by their colors. We check the doneness of cooked food by their browning. Furthermore, the color itself is important for us. Properly browned toast looks delicious. To stimulate the appetite, artificial colors are often added to food products. That is why food color and appearance have been studied intensively so far (Hutchings 1999).

In this study, we focus our attention on the baked food color, browning, because it is becoming a hot topic in the food industry. The situation is much like in the lighting industry. To meet a strong demand for energy-saving products, LED lighting systems are rapidly introduced. They, however, cause some problems such as the incompatibility of the color rendering index. In the food industry, new types of cooking equipments are more and more introduced for the same reason. These new equipments, however, cook foods differently from the way conventional ones do. To steam ovens, for example, it is often pointed out that the cooked foods with them are not properly browned. We eat our eyes first. So, producing delicious-looking food is one of the qualities required of cooking equipment. Food color preference data obtained in this study are useful and necessary to check the adequateness of food appearance in a baking machine.

2. METHOD

We measured the colors of plain cookies and sliced bread at various stages of baking and have developed their browning scales (Sakai 2012). Then, using the scales, we conducted sensory tests to determine the color preferences of a plain cookie and sliced bread.

2.1 Development of Browning Scale of Plain Cookies and Sliced Bread

We prepared plain cookies and sliced bread at various stages of baking. Plain cookies were made from dough; cookie dough was prepared by mixing margarine, sugar, eggs, soft wheat flour and baking powder; it was cut into square-shape (30×30 mm). Sliced breads (Shikishima Baking Co., Ltd) were obtained in the market. Then, we baked them in the oven and prepared samples from completely raw to overcooked.

For measuring colors, we used a color image photographing system. It has a spherical dome with a diameter of 600 mm, whose inner surface was painted white. Food samples were placed in the middle of the dome and recorded their colors by the digital camera (Panasonic LUMIX DMC-G1). As the light sources, two D65 fluorescent lamps powered by a high-frequency inverter power supply were placed below the sample stage. Thus, the samples could only be illuminated by indirect light. A White Balance Card was used for shading correction and the X-Rite ColorChecker Mini (57x82.5 mm) was used for color correction. The color-corrected images have three values R, G, and B in sRGB format for each pixel. We converted these sRGB values to CIE 1976 L*a*b* values. The D65/2 deg. observer was assumed in calculation. The mean color differences between 24 ColorChecker's reference values and their measured values of L*, a*, b* were 0.91, 3.36, and 5.83. Some examples of sample images used are shown in Figure 1.

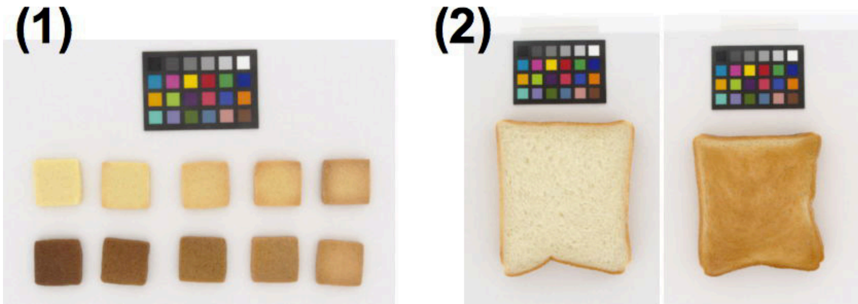


Figure 1: Examples of sample images: (1) Plain cookies; (2) Sliced bread. The size of the ColorChecker is 57×82.5 mm.

By using measured data at various stages of baking, we made the regression equations among L*, a* and b*. Then, a browning scale of plain cookies was calculated between L*=90 (completely raw) and 35 (overcooked) with 12 steps (5.0-L* interval); that of sliced bread was calculated between L*=90 (completely raw) and 25 (overcooked) with 12 steps (5.91-L* interval). The calculated values of L*, a* and b* are listed from the 2nd to the 4th column in Table 1 for plain cookies and in Table 2 for sliced bread.

2.2 Sensory Evaluation of Preference Color of Plain Cookies and Sliced Bread

For the sensory test, the browning scales were printed out on the ink-jet color printer (Figure 2). Their L*a*b* values were checked by the luminance and color meter (Konica Minolta CS-100A) in the experimental booth described below; the meter was set at the same position of the subject's eyes. We took the trial-and-error process to get the printed browning scales with accurate color reproduction. The measured L*a*b* values of the final versions are shown from the 5th to the 7th column in Tables 1 and 2. Note that, for sliced bread, the CIELAB color differences (ΔE^*_{ab}) between targeted and measured colors increase as L* decreases. These large differences were caused mainly by the b* differences. It was difficult to reproduce the targeted b* values at lower L* region. L* values were, however, reproduced accurately except at item L.

The sensory experiments were run in a small booth (1500 mm high x 750 mm wide x 1500 mm deep) with a desk and a chair. The booth was covered by blackout curtains, and the only illuminations were the D65 fluorescent lamps. The illuminance level of the desktop was about 1,000 lux. The browning scales of cookies and breads (Figure 2) were placed on the desk, which was at a distance of 700 mm from the subject's eyes. The size of each color patch in the scales was 35×35mm.

*Table 1. The targeted and measured L*a*b* values of the browning scale of plain cookies.*

Plain Cookie	Target Values			Measured Values			L*a*b* Differences			Color Diff.
Item	L*	a*	b*	L*mea	a*mea	b*mea	ΔL*	Δa*	Δb*	ΔE*ab
A	90.0	-4.0	34.6	89.4	-4.6	33.0	-0.6	-0.6	-1.6	1.8
B	85.0	0.5	34.5	85.1	1.7	35.5	0.1	1.2	1.0	1.6
C	80.0	5.0	34.3	80.7	5.3	35.1	0.7	0.3	0.8	1.1
D	75.0	9.5	34.2	75.8	9.8	34.4	0.8	0.3	0.2	0.9
E	70.0	12.9	34.0	71.0	12.7	34.4	1.0	-0.2	0.4	1.1
F	65.0	13.1	33.9	65.6	13.0	34.8	0.6	-0.1	0.9	1.0
G	60.0	13.2	33.7	60.1	13.4	35.5	0.1	0.2	1.8	1.8
H	55.0	13.4	33.6	55.3	14.0	36.9	0.3	0.6	3.3	3.4
I	50.0	13.5	30.0	50.6	14.4	32.2	0.6	0.9	2.2	2.5
J	45.0	13.7	26.4	45.6	14.6	26.9	0.6	0.9	0.5	1.2
K	40.0	13.8	22.7	40.8	14.4	20.9	0.8	0.6	-1.8	2.0
L	35.0	13.9	19.1	36.6	14.2	15.6	1.6	0.3	-3.5	3.9

*Table 2. The targeted and measured L*a*b* values of the browning scale of sliced bread.*

Sliced Bread	Target Values			Measured Values			L*a*b* Differences			Color Diff.
Item	L*	a*	b*	L*mea	a*mea	b*mea	ΔL*	Δa*	Δb*	ΔE*ab
A	90.0	-3.2	17.4	90.1	-4.0	18.0	0.1	-0.8	0.6	1.0
B	84.1	0.7	22.8	84.8	0.3	22.3	0.7	-0.4	-0.5	1.0
C	78.2	4.6	28.2	79.0	4.5	26.9	0.7	-0.1	-1.3	1.5
D	72.3	8.5	33.6	72.8	8.6	34.0	0.5	0.1	0.4	0.7
E	66.4	12.4	38.9	66.5	12.7	42.5	0.1	0.3	3.6	3.6
F	60.5	16.2	43.7	59.8	18.4	42.2	-0.7	2.2	-1.5	2.7
G	54.5	16.6	39.7	53.4	18.4	36.5	-1.1	1.8	-3.2	3.8
H	48.6	16.9	35.7	47.9	19.3	29.6	-0.7	2.4	-6.1	6.6
I	42.7	17.3	31.7	42.4	18.0	23.3	-0.3	0.7	-8.4	8.4
J	36.8	17.6	27.6	37.3	18.1	16.4	0.5	0.5	-11.2	11.2
K	30.9	18.0	23.6	32.2	17.4	8.8	1.3	-0.6	-14.8	14.8
L	25.0	18.4	19.6	28.7	11.7	5.0	3.7	-6.7	-14.6	16.5

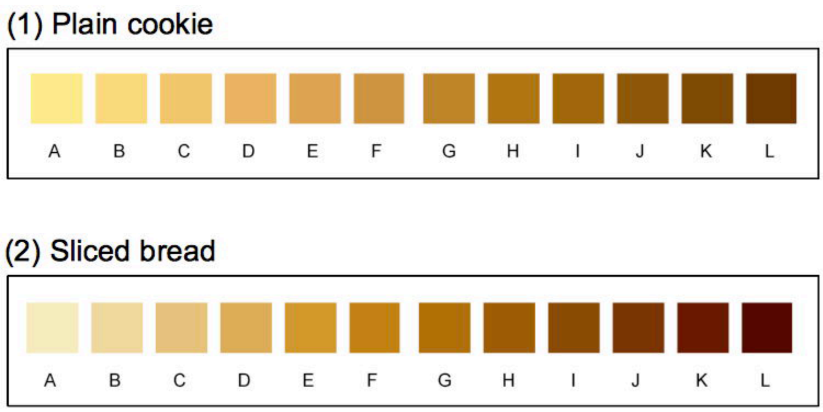


Figure 2: The browning scales used in the sensory test.
(1) Plain cookies. (2) Sliced bread.

Each subject with a black drape was guided to the chair in the booth and was asked to look at the N5 gray color of the desktop for adaptation. After three minutes, color chart was set on the desk, and he/she was asked, as a plain cookie, which item (A to L) was your favorite color and which range was acceptable to eat, i.e., not too raw (upper limit) and not too overcooked (lower limit). The same questions were repeated for sliced bread. A total of 93 Japanese subjects (40 males, 53 females) aged 21-60 (average 31.8 years) participated in the study.

3. RESULTS AND DISCUSSION

Experimental results are shown in Figure 3 for plain cookies (1) and sliced bread (2) as graphs of frequency distribution. The results are highly individual, and the answers are widely distributed. Therefore, it may be difficult to determine the best browning color. There is, however, only one peak in each distribution (most preferred, upper/lower limits). Thus, we can determine the range of browning color, which most people can accept.

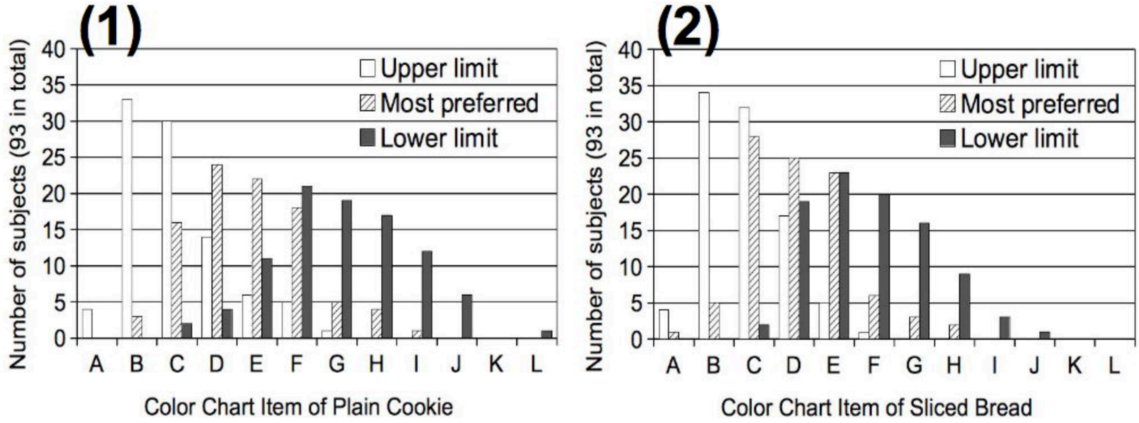


Figure 3: Results of sensory test. White bars show the number of subjects answering that item is the upper limit, hatched bars the most preferred, black bars the lower limit.

For plain cookies, the cumulative frequency of upper limit reaches 81 at item D from A, and that of lower limit reaches 76 at item F from L. Thus, if "most" means three out of four (75 percent of 93 subjects, i.e., 69.8), the acceptable range is between L*=77.5 (item D) and L*=62.5 (item F). For sliced bread, the cumulative frequency of upper limit reaches 70 at item C from A, and that of lower limit reaches 72 at item E from L. Thus, the acceptable range is between L*=81.2 (item C) and L*=63.5 (item E). These data can be used to check the adequateness of food appearance in a baking machine.

ACKNOWLEDGEMENTS

The authors thank Messrs. Yusuke Mamiya, Hiroyuki Takasago, Hideya Shimada, and Ms. Junko Yamagata, as well as Panasonic Corporation Home Appliances Development Center for their kind assistance in performing the experiments. This research was partly supported by a Grant-in-Aid for Scientific Research, KAKENHI (No. 23500934).

REFERENCES

Hutchings, J.B., 1999. *Food Color and Appearance Second Edition*. Aspen Publishers, Inc.

Sakai, H., and H. Iyota, 2012. Development of Browning Scale of Baked Foods Based on Color Measurement. In *AIC 2012, Proceedings*, ed. by TR. Lee and J. Shyu. Taipei: Chinese Culture University, 258-261.

Address: Dr. Hideki Sakai, Graduate School of Human Life Science,
Osaka City University, Sugimoto 3, Sumiyoshi-ku, Osaka City, 558-8585 Japan
E-mails: hsakai@life.osaka-cu.ac.jp, iyota@mech.eng.osaka-cu.ac.jp

Banana Ripening: Colour, Physical and Sensory Changes

Wei JI[1], Mahmood AKHTAR[2], Georgios KOUTSIDIS[3], Ronnier LUO[4], John HUTCHINGS[4], Francisco MEGIAS[5], Mick BUTTERWORTH[6]
[1] College of Physics & Electronic Information Engineering, Wenzhou University, Wenzhou, PR China
[2] School of Food Science and Nutrition, University of Leeds, Leeds, UK
[3] School of Life Sciences, Northumbria University, Newcastle upon Tyne, UK
[4] Colour Imaging and Design Centre, University of Leeds, Leeds, UK
[5]now of the Wm Morrison Supermarkets Plc, Bradford, UK
[6]VeriVide Limited, Enderby, Leicester, UK

ABSTRACT

We recently reported a novel digital imaging methodology for determining the colour of banana hands and fingers with the aim of using such methodology to routinely determine fruit ripening stages (Ji et al, 2010, 2012). In the present investigation, a number of physicochemical and sensory assessments were performed to evaluate relationships between appearance and biochemical traits related to fruit quality. A clear correlation trend with ripeness was observed for colour (green and yellow) and degree brix (sugar content). Sensory evaluation also revealed that greenness, yellowness, gloss, sweetness, sourness, bitterness (astringency) and texture were related with the ripening stage as defined by digital imaging. The ripening life of the banana can be followed and defined in terms of colour, physical and chemical properties, the digital imaging performing as well as the presently used hard copy colour chart.

1. INTRODUCTION

Appearance of fresh produce is one of the main parameters affecting purchasing and consumer choice (Hutchings, 1999) while other sensory properties, such as aroma, taste and texture, also contribute to consumer acceptability. The fresh produce industry is currently employing a range of tools to assess quality as well as the ripening stage of fruits. These include sensory evaluation, determination of sugar and acid contents, and mechanical in-mouth texture. In certain cases, where colour uniformity allows, the use of printed colour charts is also employed as a tool to assess the ripening stage and the visually perceived quality of fruit. The aim of this research was to investigate the relationships occurring between various fruit properties during ripening and to evaluate the potential application of previously described digital imaging methods (Ji et al, 2012).

2. METHOD

Nine crates of bananas of each ASDA ripeness grade 1 to 7 were supplied by ASDA each week for 3 consecutive weeks. Each crate contained approximately 20 hands with 5 or 6 fingers which were subsequently numbered from left to right and face to back as 1 to 5 or 6. Images of each hand were taken both at face and back positions. The middle two fingers (No. 2 and 5) were then detached and imaged. These fingers were used for the visual assessment, taste panel and other physicochemical measurements. In each session, images were captured of all banana hands and detached fingers using a lighting cabinet with a D65 fluorescent lamp simulator and a Nikon® D80 digital camera (Ji et al, 2012).

Banana firmness was measured using a texture analyzer TAXT2i (Exponent Stable Microsystems, U.K.) fitted with a 5 kg force sensor and connected to a data acquisition system. Sugars were measured using a Quick-Brix 90 digital refractometer (Mettler-Toledo AG, Schwerzenbach, Switzerland) and acidity and pH were determined using an autotitrator, Titration Excellence T50 (Mettler-Toledo AG, Schwerzenbach, Switzerland). For each of the three trials the two sets of measurements were made on two consecutive days. On the first day the samples were organised and the digital measurements carried out. On the second day the physiochemical measurements were performed.

Two separate test panels were used for assessment. The first one, including the imaging work, was carried out in the former Department of Colour Science (DCS). The second test was performed by the panellists who had participated in the taste panel conducted in the School of Food Science and Nutrition (FS&N). In DCS a viewing cabinet equipped with a cool-white fluorescent lamp having a correlated colour temperature of 6500K and an illuminance of 285 lux was used. It also had a mid-grey background with a CIE L* of 50. The same viewing cabinet was used in the second experiment at FS&N.

The assessors were asked to score ripeness in terms of 9 categories based on the ASDA Banana Ripeness Chart and to visually assess appearance attributes using the magnitude estimation method. Panel members were asked to treat each banana as a whole and to assess the average surface colour while assessing lightness, colourfulness and hue composition, the gloss, the ASDA grade using the chart provided, and percentage of green, yellow and brown coloration.

Prior to the visual assessment, panel members were given five minutes to adapt to the viewing environment while being given experimental instructions. These included the definitions for glossiness, lightness, colourfulness, and hue. A training session was held before the real experiment using bananas as test samples. All the samples were viewed by a panel of 10 observers who had been screened for colour deficiency. The observers consisted of an equal number of males and females, and Europeans and Asians. Their ages ranged between 21 and 50, and were staff or research students at the DCS. All of the panellists were experienced in judging the colour appearance of surface colours and gloss.

On the second day the experiment was conducted at the FS&N. The sensory panel assessment was comprised of two consecutive parts: the visual appearance and the taste evaluation. To ensure the consistency of sampling, visual and taste assessments were made of the middle 60% of the banana length. The visual assessment was based on the same middle section of the banana for assessing gloss, ASDA grade, percentages of green, yellow and brown. This was followed by physicochemical analyses made on the same samples. There are two types of freckle: scar and sugar spots. Sugar spots only were judged in this work.

The taste panel was run for consecutive 3 weeks, one session per week and 12 panellists with prior experience of evaluating fresh fruits were used in each session. Most of the assessors were trained in the taste panel procedures and were informed of the primary reason for the investigation. Panellists were aged between 25 and 53 and had been screened for colour vision deficiency. There were equal numbers of males and females, and of Europeans and Asians. As part of the assessment, panellists were invited to provide additional written comments on the samples and the assessment procedure.

The banana samples were stored at room temperature prior to assessment. Samples were tested in a regulated presentation sequence and coded with random numbers. The order of samples presented to the panellists was also varied randomly across sessions. Panel members were asked to rate 'sweetness', 'bitterness', 'sourness', and 'firmness' on a scale of 1–10 where 10 corresponds to the highest rating.

3. RESULTS AND DISCUSSION

The ASDA scale visual assessment was used as the benchmark scale to compare with other sensory results. This is primarily because it is the current industrial practice. Figure 1 reveals the visual results of gloss, %freckle and image hue of hands and fingers plotted as functions of ASDA scale. The left diagram indicates that banana skin gloss increases during ripening to reach a peak value, it then decreases as ripening continues. This probably coincides with the increase then decrease in skin wax. The middle diagram shows the increase in freckle (brown sugar spots) percentage as the banana ripens. The right hand diagram show two highly correlated linear functions of banana image hue values of hands and fingers against the ASDA scale. When calculating average hue values, the freckle pixels were excluded. This confirms that that the ASDA scale is based on hue change and that image hue values can be confidently used to specify banana ripening stage.

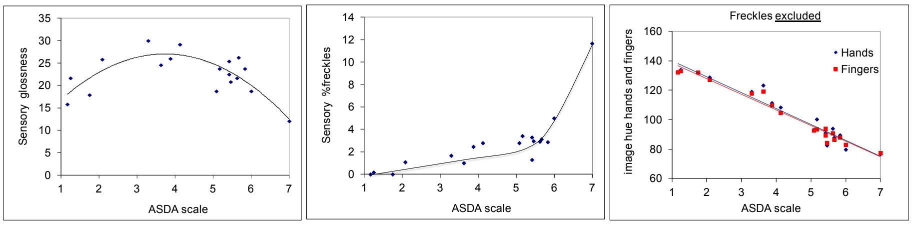


Figure 1: Left: banana gloss vs. ASDA scale; middle: banana %freckle vs. ASDA scale; right: banana image hue of hands (blue, diamond) and fingers (red, square) vs. ASDA scale.

Figure 2 contains plots of sensory attributes as functions of the ASDA scale. The left diagram shows banana green, yellow and brown colour as percentages versus the ASDA scale. It shows colour changes occurring during ripening over the life of the experiment. At the maximum ASDA grade of 7 the brown content reaches approximately 12% when it is commercially considered to be out of shelf life. The diagram in the middle shows that sensory sweetness increases when bananas ripen while bitterness and sourness decrease. There is some evidence that sourness and bitterness are scored differently for very under ripe fruit. There is no significant difference at higher ripeness. Banana firmness reduces consistently with ripeness as indicated in the right hand diagram.

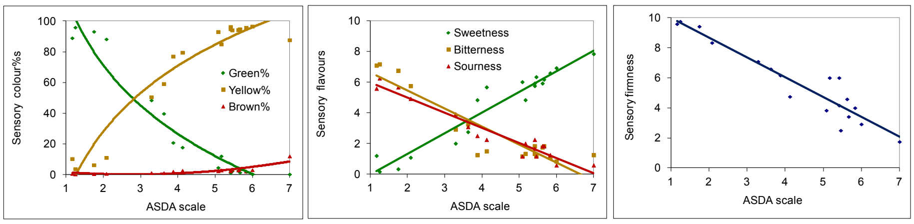


Figure 2: Left: banana colours (green, yellow and brown) vs. ASDA scale; middle: sensory sweetness, bitterness and sourness vs. ASDA scale; right: sensory firmness vs. ASDA scale.

Figure 3 indicates relationships occurring between physical and chemical measurements and the sensory score. The left diagram compares measured compression force at a pre defined area with the time as a function of sensory firmness. This shows a linear function and indicates that it may become possible to use the measurement to reduce the work of panel members in future. The middle diagram shows a less well correlated linear function between measured brix (sugar content) and sensory sweetness. The major variation occurred at the un-ripened stages (stages 1-4). This probably arises from the experimental comparative insensitivity to low levels of sugar. The relationships occurring between the sensory sourness and possible measurement correlate methods of acidity and pH are not consistent, as shown in the right hand diagram. This may be caused by weakness in the experimental methodology and shows that neither of these two measurements can at present be used to indicate sensory sourness.

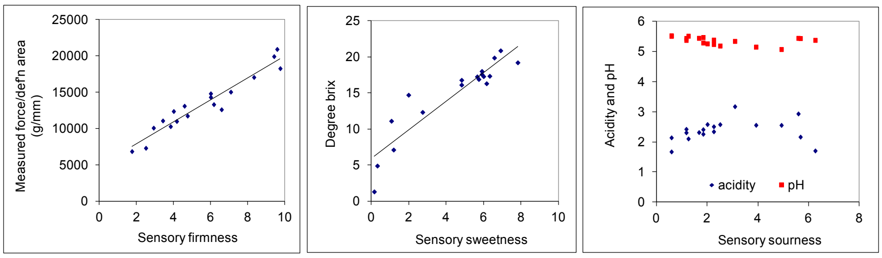


Figure 3: Comparing sensory firmness and measured firmness of banana (left), sensory sweetness and brix (middle) and sensory sourness and measured acidity and pH (right).

Figure 4 is a comparison between the %freckle and hue results obtained from the two panels and shows that they are highly related. Freckle percentage is one of the major quality indicators of shelf life and, when it reaches approximately 14% is considered to have too short a home shelf life.

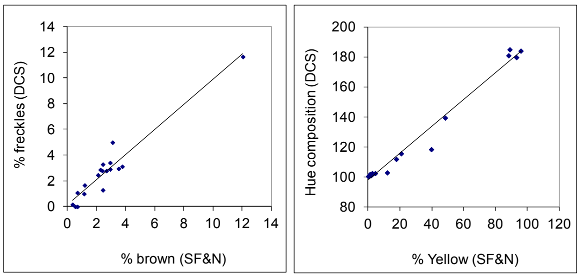


Figure 4: Two groups of sensory panels were agreed with each other. Left: Sensory %brown from SF&N are highly correlated with sensory %freckles from DCS. Right: Sensory %Yellow values from SF&N are also highly correlated with sensory hue composition (percentage of yellow and green colours) values.

4. CONCLUSIONS

The ripening life of the banana can be followed and defined in terms of colour, physical and chemical properties, Digital imaging performed as well as the presently used ASDA colour chart in defining ripening stages of bananas. Sensory evaluation also revealed that greenness, yellowness, sweetness, sourness, bitterness (astringency) and texture were correlated with the ripening stage as defined by digital imaging.

REFERENCES

Hutchings, J.B., 1999. *Food colour and appearance*, 2nd ed. USA: Aspen Publishers Inc.

Ji, W., M.R. Luo, and J.B. Hutchings, 2010. Measuring Banana Appearance Aspects Using Spectrophotometer and Digital Camera, *Proceedings of the Color and Food, Interim Meeting of the International Color Association*, p401-404, Mar del Plata, Argentina.

Ji, W., G. Koutsidis, M.R. Luo, J.B. Hutchings, M. Akhtar, F. Megias and M. Butterworth, 2012. Digital Method for Measuring Banana Ripeness, *Color Research and Application*, Online: 14 APR 2012, DOI: 10.1002/col.21741.

Address: Dr. Wei Ji,
the College of Physics & Electronic Information Engineering, Wenzhou University
Chashan University district, Wenzhou City, Zhejiang Province, PR China, 325035
E-mail: wji@wzu.edu.cn

Color Change with Thickness in Liquid Foods: Dichromism

Rafael HUERTAS,[1] Luis GOMEZ-ROBLEDO,[1] Alejandro LAPRESTA-FERNÁNDEZ,[2] José Antonio GARCÍA,[1] Javier ROMERO[1]
[1] Department of Optics. Campus Fuentenueva, Faculty of Sciences, University of Granada, E-18071 Granada, Spain.
[2] Solid Phase Spectrometry Research Group, Department of Analytical Chemistry. Campus Fuentenueva, Faculty of Sciences, University of Granada, E-18071 Granada, Spain.

ABSTRACT

Some materials show the property of change in color with thickness. Kreft and Kreft (2009) have called this property dichromatism. However, this term is used to define a kind of colorblindness long since. Thus, we propose the new term *dichromism* to name the mentioned property. On the other hand, Kreft and Kreft have developed a method to quantify the dichromism based on the Bouger-Lambert-Beer law, defining two dichromism factors. These factors are not related with the perceived visual hue difference. In this work theirs method is applied to 20 liquids samples. The results show that any transparent substance will result dichromic because of the Bouger-Lambert-Beer law, which is not always valid as has been reported by Gómez-Robledo et al. (2008).

1. INTRODUCTION

In some transparent materials, usually liquids, color changes with thickness, as have been reported by Huertas, Melgosa and Negueruela (2005) for wine. According to the Bouger-Lambert-Beer law, the change in color with concentration is formally equivalent to the change in color with thickness. This law explains this change with an exponential dependency between transmittance and both magnitudes thickness and concentration. Recently, this property has been called dichromatism in a paper by Kreft and Kreft (2009).

> Specifically, dichromatism is defined as a phenomenon where the hue of the color in materials or solutions is dependent on both the concentration of the absorbing substance and the depth or thickness of the medium traversed. In most substances which are not dichromatic, the brightness and saturation of the color depend on their concentration and layer thickness (http://en.wikipedia.org/wiki/Dichromatism).

However, usually dichromatism refers to a form of colorblindness in which only two of the three fundamental colors can be distinguished due to a lack of one of the retinal cone pigments as can be seen in the book of Mollon, Pokorny and Knoblauch (2003). Thus, the same word is defining two very different concepts, which must be avoided in any scientific discipline. Therefore, we propose the term *dichromism* to refer to the phenomenon of change of hue with thickness or concentration, as a new form of *chromism*, similar to termochromism, photochromism, electrochromism or solvatochromism, which are examples of chromogenic materials in accordance with Gunde (2010).

On the other hand, Kreft and Kreft (2009) have proposed a method to quantify the level of dichromism in transparent materials by mean of a *dichromaticity index* (*DI*). Further on we will refer it as *dichromism index*. We have applied this method to different liquid foods measured at 5 mm path length with a spectrophotometer.

2. METHOD

The dichromism index (*DI*) proposed by Kreft and Kreft (2009) quantifies the dichromism in transparent materials from the absorption spectra of the substance assuming the validity of the Bouger-Lambert-Beer law for all thicknesses and/or concentrations. In this method firstly the absorption spectra of a transparent material is measured at 10 mm pathlength. Then the absorption spectra at 10 nm pathlength is computed through the Bouger-Lambert-Beer law. Be careful with the huge difference between measured and computed path lengths. Once the spectrum at the lowest thickness (10 nm) is obtained the next spectrum computed, assuming Bouger-Lambert-Beert, corresponds to $2^{0.1}$ (1.07177) times the path length of the previous one. Therefore, two steps are equal to 2.14 times the former thickness, approximately twice path length. This process is repeated 200 times, ranging from 10 nm to 10.485760 cm.

Subsequently, the CIE1931 tristimulus values *X*, *Y* and *Z* are calculated from each spectrum assuming the illuminant D65 and the CIE 1964 Supplementary Standard Observer. From these tristimulus values CIELAB coordinates are obtained for each absorption spectrum. Among all the absorption spectra, the thickness (or concentration) corresponding to the absorbance with the maximum CIELAB chroma (C^*_{ab}) is selected. The difference in degrees between the hue angle corresponding to the selected thickness and the hue angle corresponding to absorbance 4 times thinner/thicker (or more diluted/concentrated) is called dichromism index toward lighter DI_L and dichromism index toward darker DI_D, respectively. As have been stated before, 4 times thinner or thicker corresponds to a change in the thickness of a factor 10^4 or 10^{-4} the initial one. Finally, the dichromism index (*DI*) can be worked out as the average of DI_L and DI_D.

In this work, we have applied the described method, but instead of from 10 nm to about 10 cm, we have expanded this range computing the absorption spectra from 1 nm to 1 m approximately. Thus, a total of 300 different spectra have been obtained and each one is $10^{0.1}$ (1.0717) thicker than the previous one.

Note that the definition of DI_D and DI_L given by Kreft and Kreft is just between the hue angles (in degrees), but these indexes does not consider the chroma. On the contrary, chroma is included in the computation of hue differences in almost all color difference formulae. This could lead to important hue angle differences, and dichromism indexes, with insignificant visual differences in case of samples close to be achromatic. In order to quantify this effect we have also computed the CIELAB hue difference toward lighter (ΔH_L) and the CIELAB hue difference toward darker (ΔH_D). These indexes correspond to the CIELAB hue difference between the spectrum with maximum-chroma thickness and the spectrum with four times thinner (lighter) and thicker (darker) thickness, respectively.

The proposed method has been tested using 19 different liquid foods and the liquid standards of the bromthymol blue (BTB) method, which currently is Spain's official method for color characterization of virgin olive oils (Gutierrez 1986). Specifically, ten samples of olive oils, four samples of red wine, four samples of corozo juice, one sample of blackberry juice and the whole BTB oil scale, which comprises 60 standards. The absorbance of these samples was measured at 5 mm pathlength by a spectrophotometer, in the range 380-770 nm, with a bandwidth of $\Delta\lambda$=2 nm. The spectrophotometer was a Hewlett-Packard 8452 UV-visible light diode array employing quartz cells of 5 mm path length. All these liquid foods were measured in the same conditions that they are used by consumers, which means that they were measured as they were bought without any chemical or physical treatment before their measurement.

3. RESULTS AND DISCUSSION

Table 1 shows for the 19 liquid foods the computed values for dichromism index toward lighter DI_L and dichromism index toward darker DI_D. The thickness corresponding to maximum chroma, the CIELAB hue difference toward lighter and the CIELAB hue difference toward darker are also shown. In the case of BTB scale Table 1 shows the mean value of the 60 standards.

Table 1. Dichromism indexes DI_L and DI_D for the selected 20 liquid samples.

Sample	Thickness (cm)	DI_L (º)	DI_D (º)	ΔH_L (CIELAB UNITS)	ΔH_D (CIELAB UNITS)
Blackberry	1.59	26.21	19.20	32.10	21.78
Oil 1	2.58	-5.57	9.29	15.02	11.98
Oil 2	1.96	-5.99	12.82	15.70	14.77
Oil 3	1.83	-6.02	12.56	15.41	14.29
Oil 4	1.38	-6.01	8.05	15.12	10.11
Oil 5	1.38	-5.81	17.16	8.93	9.12
Oil 6	1.59	-6.12	22.37	10.28	13.31
Oil 7	1.70	-6.56	14.18	13.58	13.77
Oil 8	1.48	-6.34	17.55	12.16	14.25
Oil 9	1.38	-6.75	18.26	11.92	13.67
Oil 10	1.48	-6.18	17.44	11.00	12.74
Corozo 1	1.59	27.26	18.93	29.61	20.48
Corozo 2	2.41	32.68	9.78	39.21	15.67
Corozo 3	2.10	36.27	11.22	45.21	20.65
Corozo 4	1.59	29.95	14.00	39.44	19.42
Red Wine 1	0.60	23.58	17.56	22.65	16.98
Red Wine 2	0.52	19.36	18.31	17.22	14.10
Red Wine 3	2.97	23.69	16.38	23.26	17.08
Red Wine 4	2.10	22.23	16.10	20.27	15.03
BTB	4.21	-8.12	27.60	26.54	20.36

These results state some dichromism in all the analyzed substances. It is remarkable the difference in the sign of DI_L for olive oil and BTB and the rest of the substances.

A closer analysis of the results shows some inconsistencies in this method if we compare the CIELAB hue difference and the dichromism indexes. The difference just in the hue angle is not a good index to quantify the effect of changes in hue when the thickness/concentration changes in a substance, because the chroma value is very important in this effect. Therefore, there is a low correlation between the CIELAB hue differences and the dichromism indexes.

4. CONCLUSIONS

The change in color with the thickness/concentration happens with lightness, chroma and hue. If only changes in hue must be reported in the dichromism factor, the CIELAB hue difference including the chroma instead of the hue angle difference must be considered to have a better correlation with visual perception.

In addition, this method is strongly based in the validity of the Bouger-Lambert-Beer law for all thicknesses and/or concentrations. Thus, any liquid substance will be dichromic because Bouger-Lambert-Beer law will predict changes in hue with thickness or concentration independently of the initial measured absorption spectra. However, the Bouger-Lambert-Beer law is not always valid, as has been recently reported in the case of olive oils by Gómez-Robledo et al. (2008). Hence, further analysis of this method comparing with experimental results is claimed.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge financial support from the Research Group FQM 151 of the Junta de Andalucía (Spain).

REFERENCES

Gómez-Robledo, L., M. Melgosa, R. Huertas, R. Roa, M. J. Moyano and F. J. Heredia, 2008. Virgin-Olive-Oil Color in Relation to Sample Thickness and the Measurement Method. *Journal of the American Oil Chemists' Society* 85: 1063-1071.

Gunde, M. K., 2010. Dynamic colour of chromogenic materials. In *IX Congreso Nacional del Color, Proceedings*, ed. by SEDOPTICA. Alicante: Universidad de Alicante, 1-4.

Gutiérrez, R. and F. Gutiérrez, 1986. Método Rápido para Definir y Clasificar el Color de los Aceites de Oliva Vírgenes, *Grasas y Aceites* 37:282-284.

Huertas, R., M. Melgosa and A. I. Negueruela, 2005. Color coordinates of wine samples with different thicknesses. *Color Research and Application* 30: 149-152.

Kreft, S., and M. Kreft, 2009. Quantification of dichromatism: a characteristic of color in transparent materials. *Journal of the Optical Society of America* 26 (7): 1576-1581.

Mollon, J. D., J. Pokorny, and K. Knoblauch, 2003. *Normal and defective colour vision*. New York: Oxford University Press.

Address: Prof. Rafael Huertas, Department of Optics, Faculty of Science,
Campus de Fuentenueva, University of Granada, 18071 Granada, Spain.
E-mails: rhuertas@ugr.es, luisgrobledo@ugr.es,
lapresta@ugr.es, jgarcia@ugr.es, jromero@ugr.es

Psychophysical Assessment of Best Lighting for Naturalness and Preference by Monitor Viewing of Commercial Food Counters

Osamu MASUDA, Sergio NASCIMENTO
Centre of Physics, Gualtar Campus, University of Minho, 4710-057 Braga, Portugal

ABSTRACT

We studied spectral optimization of illumination for commercial food counters containing a variety of fruits, vegetables, meat, and fish. The scenes were simulated with high chromatic precision on a calibrated computer monitor with hyperspectral images obtained in a local supermarket. The illuminants were daylight-like and their metamers with nearly arbitrary spectra. Six color normal observers, all but one of the authors were naïve, participated in the experiments. In the first experiment, only daylight-like illuminants were used and the observers adjusted the chromaticity on and around the Planckian locus such that the scenes looked the most natural or the most preferable. The most natural scenes were produced with illuminants with an average correlated color temperature (CCT) of 4400 K and the most preferred scenes 6040 K. In the second experiment, spectral metamers with almost arbitrary spectra at five chromaticities at and around the chromaticity obtained for each scene in the first experiment were tested for the same criteria. The CCT of the optimized metamers were a little higher and the spectra were considerably different from daylight. It was hypothesized that naturalness may be affected by the symmetry of the color distribution rendered by the illuminant and that the preference by the volume of the distribution in a color space.

1. INTRODUCTION

The color rendering of lighting is typically evaluate by how natural the scenes look, but aesthetics of the scenes is another important aspect to consider. Many quality indices to quantify color rendering have been proposed (for a review, see Guo and Houser, 2004). The advent of modern solid state lighting enabled almost any spectrum for lighting and a wide range of possibilities in color rendering. However, conventional studies have been constrained to physical existing light sources (e.g., Schanda and Madár, 2007). The goal of the present study is to determine psychophysically the best spectral power distributions to render natural scenes the most natural and the most preferable. The experiments were based on images simulating real food counters obtained by hyperspectral imaging carried out in a local supermarket and the illuminants tested had a wide range of chromaticities and almost arbitrary spectral distribution.

2. GENERAL METHOD

2.1 Hyperspectral imaging

Twelve hyperspectral images (400-720 nm at 10 nm intervals) of commercial food counters (fruits, vegetables, meat, and fish) were acquired in a local supermarket with a fast-tunable liquid-crystal filter (VariSpec VIS-10; Cambridge Research & Instrumentation; Hopkinton, MA) and a low-noise Peltier-cooled digital camera (ORCA-AG CA4742-80-12AG; Hamamatsu Photonics; Hamamatsu, Japan). The spectral reflectance of each pixel was estimated from the hyperspectral data by dividing the image data for each wavelength by the spectrum of the light reflected from a gray reference surface with a known spectral reflectance placed in the scene.

2.2 Stimuli

Stimuli for the experiments were synthetized by multiplying the spectral reflectance functions estimated for each pixel from the hyperspectral data by the spectral distributions of the illuminants. The images were displayed on an LCD monitor (CA750; Samsung, Seoul, South Korea) controlled by a video board (ViSaGe Visual Stimulus Generator; Cambridge Research Systems, Rochester, Kent, UK). The monitor was calibrated with a telespectroradiometer (PR-650 SpectraScan Colorimeter; Photo Research, Chatsworth, CA). The images subtended 40×30 degree visual angle and were observed at 60 cm distance. The average luminance of each displayed image across pixels was 15 cd/m^2 (for details, see Masuda and Nascimento, 2013).

3. EXPERIMENT 1: DAYLIGHTS

In Exp. 1 the goal was to determine the daylight-like illuminants, synthetized from Judd's daylight spectral basis functions, producing the most natural and the most preferable appearance. The illuminants were chosen from the grid points showin in Figure 1. The grid points had correlated color temperature (CCT) in the range 2,222 to 20,000 K. The points on the lines orthogonal to the Planckian locus were in the range +0.01 to -0.01 from the locus at an interval of 0.002 in chromaticity difference (DC).

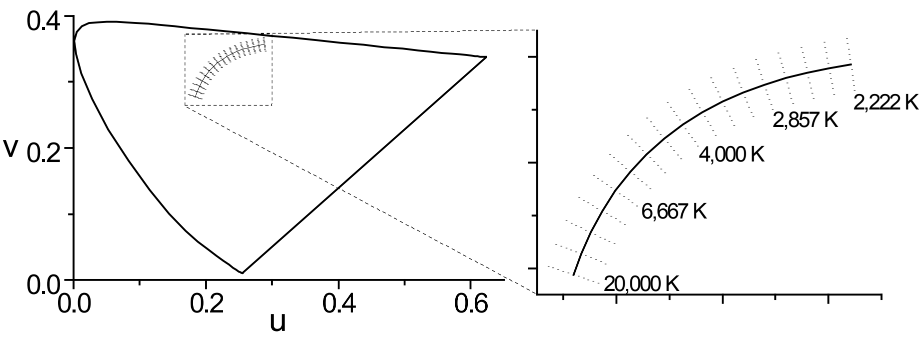


Figure 1: *Illuminant chromaticities tested expressed in the CIE 1960 UCS diagram.*

Open symbols in Figure 2 shows the results obtained in the two conditions averaged across all images and observers. The CCT of the most natural daylight was 6040 K and the CCT of the most preferred one was 4410 K. Both daylights are shifted to a purplish direction below the Planckian locus. Dotted curves in Figure 3 show the spectra of the daylights.

4. EXPERIMENT 2: METAMERS

In Exp. 2, observers were able to select illuminants with almost arbitrary distributions. The chromaticities of the illuminants tested were at 5 points on the grid. The center of the five points was the average chromaticity obtained in Exp.1 for each image, observer, and condition. Remaining four points were at a distance from the center, and the distance was one standard deviation of matching in Exp. 1. At each grid point in Figure 1, 1000 metamers were generated. The observer chose a metamer for each criterion and image from the metamer set at each test points 6 times. Then, chosen metamers at each test points were averaged and the observer chose the best one from these five average metemers six times. The final metamers as shown in Figure 3 were calculated as the average of the six trials. Filled symbols in Figure 2 shows the CCT (6200K for naturalness and 4550K for preference) and DC of these metamers.

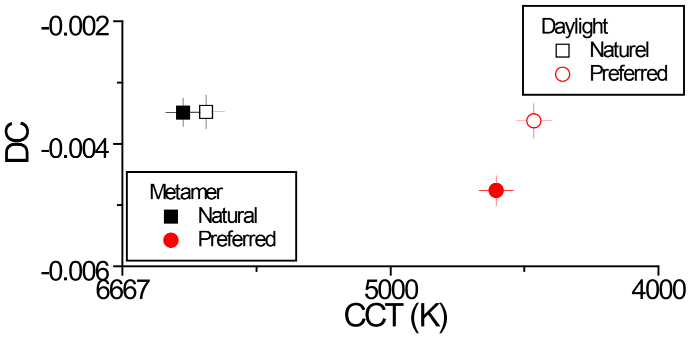


Figure 2: Results in Exps. 1 and 2. Open symbols: Exp. 1(daylights), Filled symbols: Exp. 2(metamers), Squares: Naturalness, Circles: Preference.

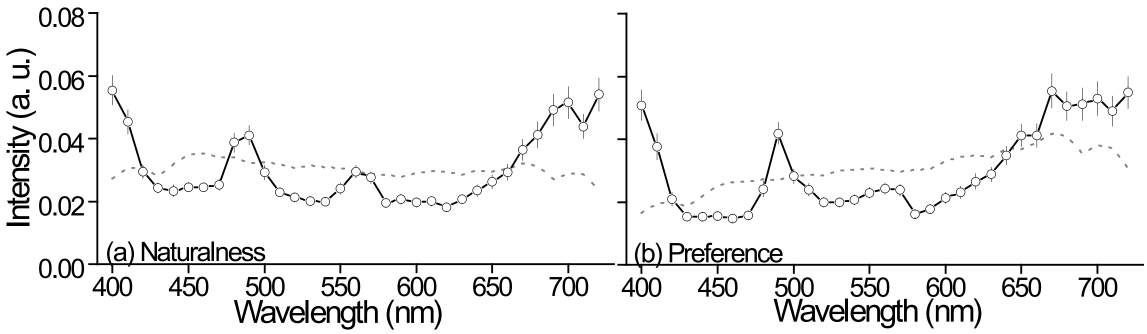


Figure 3: Daylights obtained in Exp. 1(dotted curves) and metamers obtained in Exp.2 (solid curves). (a) naturalness. (b) preference.

5. DISCUSSION

Why does the preferred CCT have a lower value than natural CCT? A possible reason for this effect is that observers prefer scenes more colorful. The contour maps in Figure 4 show the convex hull volumes of the Munsell chips in CIELAB space rendered by the daylights and metamers that have the maximum volumes at each grid point. The preferred illuminants are close to the peak of the volume than natural ones. The shit of the CCT to higher temperature with metamer can also be explained the color volume.

The reason the natural CCT were higher than preferred ones can be explained by the symmetry of the color distribution. Contour maps in Figure 5(a) shows the aspect ratios of the ellipses fitted to the Munsell chips projected on the $L^*=0$ plane in CIELAB space rendered by the daylights. Figure 5(b) shows the average aspect ratios by the metamers with top 5% aspect ratios. The natural illuminants are closer to the peak of the map than preferred ones. The peak of the map is also shifted to higher temperature with metamers.

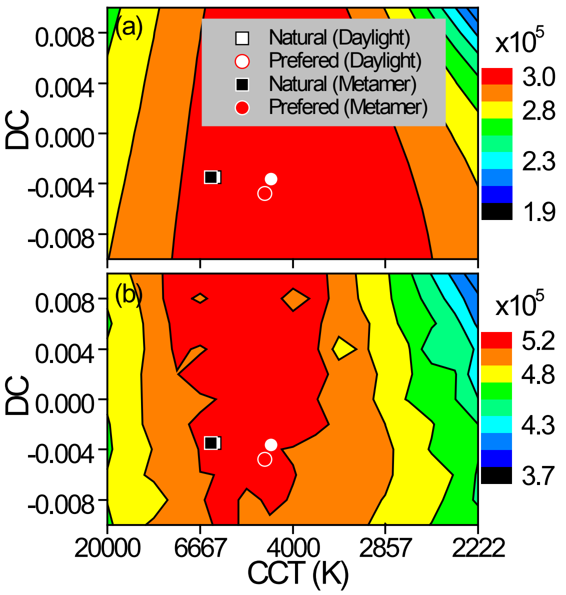


Figure 4: Color volumes of (a) daylights and (b) metamers.

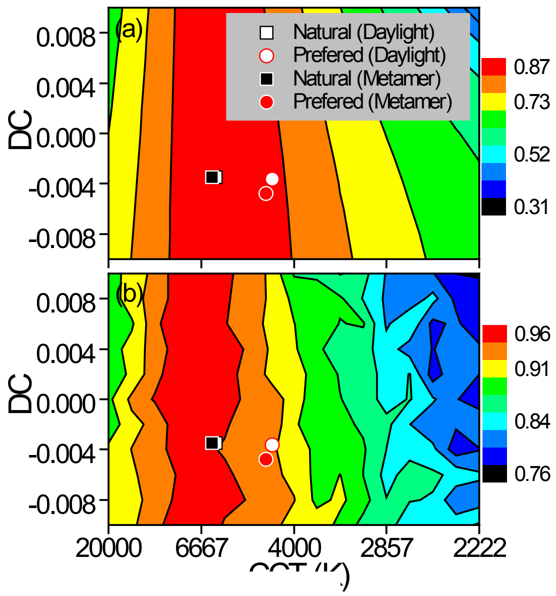


Figure 5: Aspect ratios of (a) daylights and (b) metamers.

ACKNOWLEDGEMENTS

This work was supported by the European Regional Development Fund through Program COMPETE (FCOMP-01-0124-FEDER-009858) and by National Portuguese funds through Fundação para a Ciência e a Tecnologia (grantPTDC/EEA-EEL/098572/2008).

REFERENCES

Guo, X., and K.W. Houser, 2004. A review of colour rendering indices and their application to commercial light sources. *Lighting Research and Technology* 36(3): 183-199.

Schanda, J., and G. Madár, 2007. Light source quality assessment. *CIE 26th Session*, D1–72–75. Beijing, China: Commission Internationale de l'Éclairage.

Masuda, O., and S.M.C. Nascimento, 2013. Best lighting for naturalness and preference, *Journal of Vision*. In press.

Address: Osamu Masuda, Centre of Physics, Gualtar Campus,
University of Minho, 4710-057 Braga, Portugal
E-mails: masudaosamu3@gmail.com, smcn@fisica.uminho.pt

colour and wellbeing

Colour in the Cause of Emotion

Diane HUMPHREY, Monica RIVAS , Connie HERMSEN
Department of Psychology, King's University College
at The University of Western Ontario

ABSTRACT

Colour-emotion associations show typical use of specific colour ranges to express specific named emotions in both free-hand drawings and in colouring books. Red is most often used to show anger, love and embarrassment. Orange is typically used for surprise and pride. Yellow usually depicts happiness or pride. Green is used for disgust, blue for sadness and empathy, purple for empathy and guilt and black is used to depict fear. We have obtained these results in abstract drawings, painting, pointing to colours, drawings of emotional situations, and colouring books using both animal and human "characters". Most recently we have used colouring books to depict emotional situations in which both an "Actor" and a "Cause" (see Parkinson, 1996) of each emotion are depicted in drawings of anger, surprise, happiness, disgust, sadness, fear, love, embarrassment, pride, guilt and empathy. In most of the colouring books clothing and body features showed expressive use of colour while backgrounds were not coloured in as frequently. Generally both "Actor" and "Cause" were coloured in colour ranges similar to those used in our previous studies. In an analysis of CIE variables of colours used it was found that more red (X) components were present in colours used to depict the "Actor" of the emotion. The "Cause" of the emotion had higher luminance colours on average and more yellow-green (Y) components on average. It is suggested that these associations may have biological bases, likely coming together in orbito-frontal activity in the cerebral cortex as well as in other areas connected to the frontal lobes in an "aesthetic" network (see Vartarian, 2009). These common associations may be the basis of the aesthetic and emotional significance of colours in representations.

1. INTRODUCTION

Colour-grapheme synaesthesia can depend on the meaning of the grapheme (Dixon, Smilek, Duffy, Zanna and Merikle, 2006). If the same figural pattern shown as a letter is also seen as a number in the context of other numbers, the colour synaesthesia seen for the letter is not seen for the number, although the visual configurations are identical. This means that synaesthetic associations are not just related to visual-spatial pattern, but have wider cognitive associations. These synaesthetic associations may be related to early "naturally-biased" associations between colours and letters seen in children as well as adults (Spector and Maurer, 2011). It can then be argued that colour-emotion associations may be naturally-biased as well.

In a series of studies of colour-emotion associations it has been shown that there are consistent associations in pointing naming drawing painting and colouring tasks with both abstract patterns and representational drawings of animals and humans (Humphrey and Vandewiel, 2010). These results have been obtained in children, adults, art students, Chinese-Canadian students and the elderly. The most frequent emotion-colour associations are anger-red, surprise–orange, happiness-yellow, disgust-green, sadness-blue, fear-black, love-red, embarrassment-red, pride-yellow, guilt-purple, empathy-purple.

Drawing tasks have revealed that colours were used differentially to express emotional feelings in drawings of human characters representing the "Cause" and the "Actor" of emotions (after Parkinson, 1996) depicted in emotional situations (Humphrey and Vandewiel, 2010). In the present study colouring books were used to observe the choice of colour to depict the Actor and Cause of an emotion in drawings of eleven emotional scenarios. It was predicted that the colour used to depict the Actor would be similar to colours used in previous studies to express emotion, but that the colour used to depict the Cause of the emotion would be less predictable.

2. METHOD

2.1 Participants

A convenience sample of twenty adults (10 females) with a mean age of 23.3 years agreed to complete colouring books.

2.2 Materials

Colouring books consisted of 22 line drawings in randomized orders depicting eleven emotional scenarios with male or female characters. Each page had a title with the named emotion, and a short description of the scenario as follows ; Anger. You are angry because your friend is ignoring you. Surprise. You are surprised when your friend brings you a cake. Happiness. You are happy to be with your friend. Disgust. You are disgusted when your friend jumps in a puddle and splashes you. Sadness. You are sad because your friend is leaving. Fear. You are afraid when your friend tries to touch a skunk. Love. You love your friend. Embarrassment. You are embarrassed when your friend laughs at you because you fell. Pride. You are proud of your friend for graduating. Guilt. You feel guilt because you broke your friend's posession. Empathy. You feel bad for your friend who is upset.

A box of twenty four Crayola coloured crayons were also provided for each participant.

2.3 Procedure

Participants were given colouring books and crayons to take away and complete on their own time. Books were collected when they were finished.

Figure 1: Examples of colouring book pages.

3. RESULTS AND DISCUSSION

Most participants coloured in only the clothing and skin areas of drawings. Most of the differences between Actor and Cause colours were found in clothing colours. Analyses of differences using a Wilcoxon Signed-Ranks test were conducted on the CIE variables in the Crayon Colours used in clothing. It was found that there was greater use of colours with higher proportions of the X variable, which is in the red range of colours, in the Cause character in drawings depicting males in Anger, Pride and Guilt drawings (p < .10, .05,.05 respectively). The Actor character was more often of higher luminance in Surprise, Sadness, Guilt and Empathy drawings (p< .01, 10, .10, .01 respectively). The Cause was of higher luminance in Disgust drawings (p< .05) (Analyses are available from the authors).

4. CONCLUSIONS

The hypothesis that colours used to depict Actors and Causes of emotions will reflect previous results with colour-emotion associations mostly in the Actor character is not entirely supported. In particular, the use of redder colours to depict the Cause of Anger, Pride and Guilt illustrates the salience of the Cause of these emotions. The role of luminance or brightness in depicting the Actor in drawings of emotions is seen in Surprise and Sadness which are sometimes considered to be "basic" emotions (Eckman, 1999). Brighter colours are also used to depict the Actor in Guilt and Empathy drawings, considered to be "social" (Lewis, 2000) emotions. As Parkinson (1996) has argued, the distinction between basic and social emotions may be false. If the use of colour to portray emotion is an indicator, the expression of social and basic emotions may have a great deal in common.

The question remains whether emotion-colour associations have a biological basis. Evolutionary arguments can be made about the significance of colours for approach and avoidance behaviours (eg N. Humphrey, 1976). Palmer and Schloss (2010) have provided evidence for the relationship between colour preference and colour properties of objects having specific valences. If one likes apples, one likes red and so on. Emotional associations in colours have also been related to colour preference (Burkitt, 2008). One prefers colours which are associated with positive emotions, for example. But quite aside from individual differences in specific preferences there may be "naturally-biased" associations which occur because of the way perception and emotion are related in an aesthetic network such as that proposed by Vartarian (2009). Part of this network seems to involve reward centres in the orbital frontal lobes. This might explain preference for colours of objects with positive emotional valence. Associations of colours with a full range of emotions is harder to explain without invoking emotional centres in the brain related to negative valences, such as the amygdala and other related areas. (See Phillips, Devrets, Rauch and Lane, 2003, for a review.)

ACKNOWLEDGEMENTS

The original data are from the Honors Thesis of Connie Hermsen, Department of Psychology, King's University College at Western University and have been reanalyzed here.

REFERENCES

Burkitt, E., (2008). Children's choice of color to depict metaphorical and affective information pp 107-120 In C. Milbrath and H.M. Trautner (Eds.) *Children's understanding and production of pictures, drawings and art*. Cambridge, MA: Hogrefe.

Dixon, M., D. Smilek, P. Duffy, M.P. Zanna, and P.M. Merikle, 2006. The role of meaning in grapheme-colour synaesthesia. *Cortex* 42, 243-252.

Ekman, P., 1999. Basic emotions. In T. Dalgleish & M.J. Power (Eds.) *Handbook of cognition* *and emotion*. (pp. 45-60) Toronto: Wiley.

Humphrey, D., and T. Vandewiel, 2010. *Colour and emotion associations in elders*. Paper presented at the Canadian Society for Brain, Behavioural and Cognitive Science, Halifax.

Humphrey, N., 1976. The colour currency of nature. In T. Porter & B. Mikellides (Eds.) *Colour for architecture* (pp. 95-98). London: Studio Vista.

Lewis, M., 2000. The emergence of human emotions. In M. Lewis & J. Haviland-Jones (Eds.) *Handbook of emotions* (2nd ed.) (pp. 265-280. New York: Guilford.

Palmer, S., and K.B. Schloss, 2010. An ecological valence theory of human color preference. *Proceedings of the National Academy of Sciences*, 107, 8877-8882.

Parkinson, B., 1996. Emotions are social. *British Journal of Psychology*, 87, 663-683.

Phillips, M.L., W.C. Devrets, S.L. Rauch, R. Lane, 2003. Neurobiology of emotion perception I: The neural babsis of normal emotion perception. *Biological Psychiatry* 54, 504-514.

Spector, F., and D. Maurer, 2011.The colors of the alphabet: Naturally-biased associations between shape and color. *Journal of Experimental Psychology: Human Perception and Performance*. 37, 484-495.

Vartarian, O., 2009. Conscious experience of pleasure in art. In M. Skov and O. Vartarian (Eds.) *Amityville*, New York: Baywood Publishing Company, Inc.

Address: Diane Humphrey, Department of Psychology,
King's University College at Western,
266 Epworth Avenue, London, Ontario, N6A 2M3, Canada
Email: dianeh@uwo.ca

Colour Energy and Wellbeing: the Lessons of the Orient

Ines KLEMM
University of Edinburgh, Latrace GmbH

ABSTRACT

Colour, with a particular focus on its latent energy, has not yet been sufficiently explored, and although continuously researched and discussed, colour remains one of the great mysteries of perception. Our body records millions of impressions per minute across all five senses. The five senses keep us alive; they warn, nurture, and alert us, and human perception is based on receiving the vibrations caused by energy fields. These sensory vibrations are directly linked with the human body and it is through them that experiences like "I am feeling good in this space", and even unconscious memory are triggered. Architecture, however, in most academic programs allows little or no time for the in-depth study of perception, psychology, colour energy, or wellbeing.

1. INTRODUCTION

Light is essential for life, for without light, nothing can grow, develop or live. Light and colour are inseparable and the energy of sunlight contains the spectral colours, which nourish all natural growth on earth. The sun provides 7,000 times more energy per day than needed by man (TV 2011) and is the source of all life on earth. Without doubt the sun has a huge impact on wellbeing. Its energy is received through the eye in the form of electromagnetic radiation and then transmitted to our body and organs. Although there are many definitions of colour, it can be concluded that colour is a sensation which why feeling colour is prior to seeing colour. All of the five senses are like antennae through which vibrations are recorded and they connect body, spirit and soul with the environment. Vision is only one of the five senses, yet the most important one with regard to evolution.

> Seventy percent of the body's sense receptors cluster in the eyes, and it is mainly through seeing the world that we appraise and understand it. (…), we are relying on our sense of vision to capture the action or the mood. Seeing is proof positive. (…) See with our own naked eyes, that is. (Ackerman 1991)

Despite growing colour-awareness, there still exists a great uncertainty about what colour is, how it works, and why it should have power on perception beyond surface level. Therefore and due to lack of written evidence, the focus of this work remains on architectural colour and its impact on individual perception and wellbeing. The research aim is in considering colour, and more specifically its energetic properties, as an efficient tool for healthy, sustainable, delightful and individual design concepts that go beyond geometry, beauty and subjective taste.

2. COLOUR ENERGY

> Every single surface in the world, whether mineral, plant, animal or man, is light sensitive. (...) Without light there could be no life. (Bek and Wilson 1987)

One cannot be without a space. Space is perceived visually and vision is expressed through colour. Andrée Putman referred to colour as the kingdom of the eye and indeed, the subject of colour, even just in architecture and design, is vast. It comprises artistic and spiritual as well as physical, physiological, psychological and emotional observations and also embraces subjective, objective, individual as well as cultural perception.

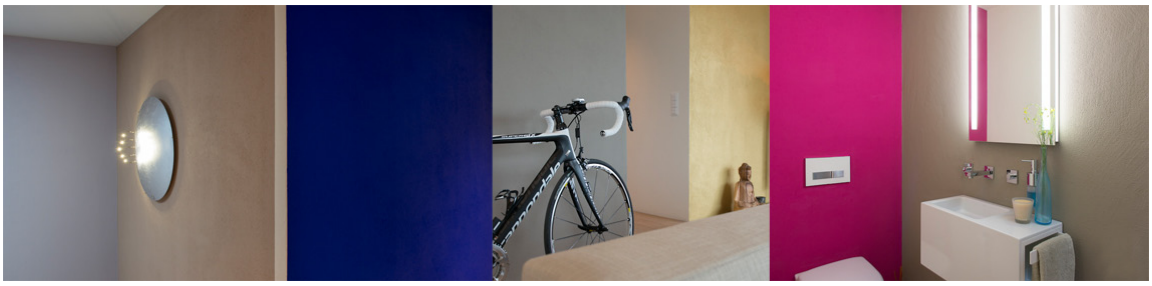


Figure 1: Latrace project based on mineral and artistic pigments, Lachen Switzerland.

2.1 Architectural colour and polychrome space

Many architects are overwhelmed and do not perform detailed research, clarification, or investigation into colours and their properties, or if they do so, technical aspects are predominant. As colour education is scarce and because architecture and pigment manufacture have been for a long time dissociated knowledge, many architects base their design on subjective choice rather than on objective principles of colour theory. (McLachlan 2012) It is only recently that the teachings of colour theorists such as Johann Wolfgang Goethe, Josef Albers, Johannes Itten and Rudolf Steiner are re-considered and that Le Corbusier colours were relaunced in its original mineral-based composition.

> There are two kinds of colours. The ones that are integral to a material, or a substance – they cannot be changed – and the ones that are artificial, that can be applied and that transform the appearance of things. The difference of colour and paint (...). Most [OMA people] imagined their colours as a treatment, a way to affect reality in a more subtle conditioning, a layer that alters the state of the painted object. It is only logical that, with incredible sensorial onslaught that bombards us every day and the artificial intensities that we encounter in the virtual world, the nature of colour should change, no longer just a thin layer of change, but something that genuinely alters perception. In this sense, the future of colours is looking bright. (Koolhaas 2001)

Origin and chemical composition of colour-giving substances are key to the appearance, impact and quality of paint because they influence light, polychromy and perception of a space. Polychrome environments have greater potential to inspire wellbeing than predominantly monochrome spaces because they represent the polychrome nature of light and contain a wider spectrum of colours to which a person can connect through invisible sensorial vibrations. Monochrome environments, if perceived over time, are harmful to wellbeing because both light energy and the nature of the human body is polychrome and should resonate in balanced vibration with the environment because a

> (…) perfect correspondence links our heart to our respiration. Everything in nature, every person on earth has a beat and, if the rhythm is too fast or too slow, illness ensues. (Bek and Pullar 1987)

2.2 Atmosphere, Perception, Wellbeing

The word ‘atmosphere’, used to describe the mood of a space and a surrounding, is originally derived from the Sanskrit word *atman*, which means *air*, *breath*, and *soul*. In Greek, *atmos* was translated with *vapour* and *sphaira (sphere)* described a layer of gases that surrounded a material body. The ancient Greek word for breath and mind was *psyche*. (Jawer and Micozzi 2009) These definitions show that the oriental cultures linked the individual's wellbeing and feeling with the perception of a space. On the contrary in the Occident the perception of space was linked to the cognitive understanding of its constituting elements rather than the relation between space and one's individual mood or feeling. In the broader context of wellbeing, colour directly stimulates the perception of a space in relation to the memories and experiences of its users. When these vibes are perceived as positive, the overall perception of the space is considered positive and one feels good. If these vibes create the feeling of uncertainty, insecurity, or fear, even on a subconscious level, the ambience would be referred to as unpleasant. Inside the human body, linear patterns are reflected and connected through centres of interchange of energy from one frequency to another.

> The human being produces a complex and specialised energy field, a living network. The chakras are significant centres within this living network. The channels, which make up this network, are often likened to rivers. Like rivers, these lines of energy may be blocked by obstruction, drained empty, full and nourishing. Where many rivers meet, a confluence is formed. It is a powerful pooling of energies, a whirling vortex of force. This is the chakra: the confluence where life energies meet. It is the wheel of life. (Ozaniec 2003)

Chakra theory offers essentials keys for both the process of decoding emotional patterns and beliefs as well as for creating user-supportive environments.

3. RESULTS AND DISCUSSION

Table 1. Case study 1. Room-colour-feeling overview.

Room type	Activity	Feeling / Emotion	Chakras	Assigned colours
living, dining	TV, reading, guests, socialising	convivial, cheerful, entertaining	3. Solar plexus, yellow, gold; 4. Heart, green	gold, umber, yellow ochre; pale green
open kitchen	cooking, eating	appetite, inspiration, creativity, audacity	2. Sacral, orange; 3. Solar plexus; yellow, gold;	orange; gold, yellow ochre, umber
circulation	circulation	welcoming, inspiring, friendly	3. Solar plexus; yellow, gold; 6. Brow centre; indigo	umber; champagne silver, lapis lazuli, ultramarine
guest bathroom	shower, toilet	inviting, bold, different, cool, fresh, light	3. Solar plexus; yellow, gold; 5. throat, pale blue, turquoise	light beige, umber; pale lapis lazuli; hot magenta
massage room	oasis, deep relaxation	relaxing, piece of mind, soothing	3. Solar plexus; yellow, gold; 5. throat, pale blue, turquoise; 7. crown, purple	maroon, brown-bronze; pale lapis lazuli; lavender, deep purple
master bedroom	sleeping, love	calmness, tranquillity, passion, lust, love, relaxation	1. base, red; 3. Solar plexus; yellow, gold;	ruby red; light lime, maroon, lavender umber

This research proposes that wellbeing and the creation of a predictable brand perception and spatial atmosphere, including its emotional impact on the user, should be given the highest priority. The application of oriental and occidental colour theory is therefore suggested as an essential part of the design strategy. Through colour, one can plan consciously what others decide, feel and think subconsciously. The first step of the proposed integrated design approach is understanding the client's needs and expectations by investigating potential risks and fears and previous memories or patterns. Secondly, colour theory is applied strategically for the process of creating meaning and planning the emotional experience based on oriental colour theory (chakras, five elements). Thirdly, one can proceed with the actual physical and structural design. During this stage, the selected colour scheme is applied to the design in form of sensorial stimuli such as material, fragrance or sound and according to physical and structural conditions. The more coherent the design elements are in their energetic properties, the more they strengthen the scheme.

4. CONCLUSIONS

The application of over 6000 years of oriental colour knowledge in combination with more than 2000 years of occidental research provide a sound and complex basis for creating wellbeing through design. With regards to the relation of colour energy, wellbeing and space in Occident and Orient, it is concluded that one of the most essential misunderstandings between Orient and Occident is the word *harmony*. In Asia, harmony addresses the inner balance of body, spirit and soul, which contributes to feeling happiness and delight. Greek philosophers, however, understood and translated harmony in terms of balanced proportions of the body, which introduced constructed order and the concepts of external beauty. Due to this entirely different, although originally unified, understanding of wellbeing, balance, body and perception, education on colour as well as perception of colour energy drifted apart in a territorial as well as on a time-related scale. Whereas in the Orient colour is an expression of life, in the Occident it is merely considered as an expression of decoration and beauty. This hesitancy in adopting a more holistic and integrated approach affects the application of colour and colour energy in design.

REFERENCES

Ackerman, D., 1991. *A Natural History of the Senses*. New York, Vintage Books, p. 230.

Bek, L., and P. Pullar, 1987. *Seven levels of healing.* London, Century, p. 42.

Bek, L., and A. Wilson, 1987. *What colour are you?* Wellingborough, Aquarian, p. 10.

Jawer, M.A., and M.S. Micozzi, 2009. *The Spiritual Anatomy of Emotion. How Feelings Link the Brain, the Body, and the Sixth Sense*. Rochester, VT, Park Street Press, p. 165-166.

Koolhaas, R., 2001. The future of colours is looking bright. *Colours Rem Koolhaas / OMA, Norman Foster, Alessandro Mendini*. N. Foster, A. Mendini, R. Koolhaas and O. f. M.A. (Rotterdam). Basel, Birkäuser**:** p. 11

McLachlan, F., 2012. *Architectural colour in the professional palette*. London, Routledge, p. 5.

Ozaniec, N., 2003. *Chakras*. London, Hodder Mobius, p. 4.

TV, S., 2011. Schweizer Solarstrom aus der spanischen Wüste. *Sendung vom 29.09.2011, 21.12pm.* Einstein. Retrieved 06/26, 10.22am, 2012, from http://www.videoportal.sf.tv/video?id=af951e50-cb03-45d9-a867-e2074691918d.

Ines Klemm PhD candidate at the University of Edinburgh, Latrace GmbH
Trottenstrasse 3, 8037 Zurich Switzerland
E-mail: ik@latrace.cc

Colour and Well-being in Occupational Therapy

Vanessa VOLPE, Jacqueline H. PARKES
School of Health, University of Northampton

ABSTRACT

This evaluation was undertaken to explore the therapeutic application of colour within community mental health intervention. A series of classes designed and facilitated by an occupational therapist aimed to raise awareness of mood and behavior in response to colour, and to utilise colour as a therapeutic medium. One year after the colour for well-being course was completed a focus group evaluation with 4 participants found that individuals extended their range and use of coloured items in order to improve mood and introduce new aspects of identity and associated behaviors. However, introducing new, previously unthought-of coloured accessories could also be challenging and remain unused. The colour for well-being program introduces a potential framework for health and social care professionals to utilise colour as a therapeutic medium with adults who are experiencing mild to moderate mental health symptoms.

1. INTRODUCTION

This paper discusses the application of colour as a therapeutic medium within a community mental health pilot project, designed and facilitated by an occupational therapist. Symptoms of mild to moderate mental health disorders such as depression, anxiety and panic can include feelings of hopelessness, loss of interest and pleasure in life[1]. The background to this project will be outlined, and a brief introduction to clinical activities, the evaluation process, and the results, will be given. We will conclude with recommendations for future practice. Colour is an inherent component of many activities of daily living, or 'occupations'. For example, selecting appropriate clothes to wear, choosing healthy food to prepare for a family, or selecting coloured medium for doing a creative activity. Occupational therapists (OTs) are skilled in the analysis of occupation in order to facilitate therapy and improve well-being[2], and they utilise appropriate frameworks[3] to facilitate intervention. Colour has been identified as important within occupational therapy, red for example can incite activity (Goldstein 1942:151), and specific colour choice has been linked with mood in depressed and anxious individuals (Carruthers et al. 2010). However, a search of occupational therapy literature reveals a scarcity of evidence as to the therapeutic application of colour for well-being within health and social care context. A small, culturally specific evaluation was undertaken in order to explore the use of colour as a therapeutic medium, the findings of which will be the focus of this paper. This evaluation offers some insight into the lives of people who actively increase their range and use of colour to enhance well being during daily occupations and contributes to the evidence base regarding the clinical application of colour within therapy.

1 National Institute for Health and Clinical Excellence (NICE) clinical guideline 123.

2 Occupational therapy is a client centered health profession concerned with promoting health and well being through occupation (WFOT 2011).

3 E.g. The Transtheoretical Model of Behavior Change (TTM) (Prochaska and Prochska 2011)

2. METHOD

2.1 Background

Non-medical treatments were offered as part of a Stepped-care, 3 year pilot project using qualitative and quantitative methods of analysis (Mental Health Foundation 2010:14). Accredited adult learning tutors offered courses for adults experiencing mild to moderate mental health problems ways to improve mental health and well-being. Courses were free at point of contact.

As part of intervention, the colour for wellbeing (CfWB) pilot program, facilitated by an OT offered sessions, averaging 9 weeks, that began with an assessment process. The assessment process raised awareness about mood and associations with colour, and is the first process of change according to TTM (2011:28). Following the assessment, activity, group and individual goals were identified. Therapy intervention included written, creative and verbal activities to explore perceived response to colour. As homework, learners were encouraged to consider these perceptions alongside their actual or desired occupations and trial new, better feeling options.

2.2 Methods used

In response to anecdotal evidence from learners specifically regarding CfWB, 1 year after the final CfWB course was completed, a focus group evaluation, with 4 learners elicited further qualitative data. This was an opportune sample of individuals who had completed a CfWB course and stated positive outcomes. In the CfWB evaluation 3 females and 1 male contributed to a semi-structured discussion facilitated by the first author. Themes were analyzed in response to the occupational therapy perspective and to evaluate how attending the CfWB course had impacted on mood and behavior.

3. RESULTS AND DISCUSSION

3.1 Findings

The overall evaluation found adult learning within the community is a cost effective option engaging high levels of participation with a statistically significant reduction in depression scores. The cost of running classes is lower than cognitive behavioral therapy, or standard anti-depressant medication (MHF 2010:30).

Attendance for CfWB was very good, and anecdotal evidence suggests CfWB outcomes include: eating more fresh fruit and vegetables, reduced frequency of panic attacks, increased calmness when driving and greater confidence to consider starting voluntary and community work. As a result of anecdotal positive outcomes an evaluative focus group was undertaken.

3.2 Findings from CfWB evaluation focus group

Concepts of meaning, occupation and analysis provided the basis for thematic analysis of the evaluation group that consisted of 3 females and 1 male.

The outcomes of the focus group found that as a result of attending CfWB learners had; developed meaning, increased personal awareness, made personal lifestyle changes, added colour to the world of others and had noted gender influences in response to colour (Parkes and Volpe 2012).

In accordance with TTM (2011:28), becoming more conscious of mood and responses to colour prompted individuals to reevaluate the colours associated with their moods and activities of everyday living, including items of clothing worn. Having been introduced to the assessment process which utilised the spectrum colours, one participant applied this framework to clothing, with an aim to introduce increased colour harmony and balance into clothing, lifestyle and hence mood. She noted which colours were prevalent, or missing, and replenished her wardrobe accordingly.

> "I decided to organise my wardrobe in spectrum order, I then realised what was missing… I have very colour now… I hardly ever wear black. I bought pink for getting dressed up and going out" (Mandy)

Participants perceived some colours had specific associations and desirable attributes, which could easily be added to existing décor or clothing. The colour pink was noted by one participant to have feminine qualities.

> 'I bought pink to add femininity to an outfit" (Mandy)

For others, introducing new colour, and associated attributes was not so easy, demonstrating the challenge of behavior change in everyday activities. It could be suggested that participants attending CfWB could be in the precontemplation or contemplation stages of TTM (2011:26), and not yet ready for change. The purchase of small specifically coloured items to change mood suggest a transition into the preparation stage of change. Individuals were making the decision to alter their own mood through the use of colour, however, the action required further input to implement fully.

> "I have a yellow bag, but haven't the courage to use it" (Marion)

Interestingly, yellow is the colour most drawn to by anxious and depressed individuals (Carruthers et al 2010:5). Motivation to introduce new colours was apparent. New colours were associated with new, sought after moods and behaviours. Associations with specific colours linked with aspects of identity, and ways of being. Confidence increased with the introduction of new colours into the home and wardrobe. One paper based activity revealed that colour worked alongside other aspects to act as a catalyst for changing moods. An activity to colour in pre-drawn mandalas created a sense of liberation, which in turn resulted in increased confidence and well-being.

> "Learning about colour was like a playtime…giving permission to be like children… let go of inhibitions, crayoning, going over the edge...to trust your instinct and feel more confident" (group statement).

The evaluation found that facilitating awareness of colour in a structured therapeutic group can provide meaning, affect mood and motivate healthy behaviors. Learners associated a specific colour with depression, and a serendipitous combination of colours was used to alleviate a potential panic attack.

4. CONCLUSIONS

Implications for clinical practice suggest colour related therapeutic interventions could prove beneficial for some individuals with mild to moderate mental health problems. The CfWB program introduces a potential framework that can be used reflexively by health and social care professionals. Further investigation of specific colours within context of occupation and well-being are warrented.

ACKNOWLEDGEMENTS

To all individuals who have contributed to the colour for well-being program, particularly to the participation of the 4 Learners who made this evaluation possible.

REFERENCES

Carruthers, H.R., J. Morris., N. Tarrier, and P.J. Whorwell, 2010. The Manchester Color Wheel: development of a novel way of identifying color choice and its validation in healthy, anxious and depressed individuals. *BMC Medical Research Methodology* (10) 12 1-13.

Goldstein, K., 1942. Some experimental observations concerning the influence of colours on the functioning of the organism, *Occupational Therapy and Rehabilitation*, 21: 147-151.

Mental Health Foundation (MHF), 2010. *Learning for Life: Adult Learning, Mental Health and Wellbeing*, London: MHF, 1-53.

National Institute for Health and Clinical Excellence, 2011. *Common mental health disorders. Identification and pathways to care*. Manchester: NICE

Parkes, J., and V. Volpe, 2012. Colour for well-being: Exploring adult learners' responses to utilizing colour as a therapeutic tool. *Journal of Applied Arts and Health*, 3:3, 275-293, doi: 10.1386/jaah.3.3.275_1.

Prochaska J., and J.M. Prochaska, 2011. Behaviour Change, in *Population Health*, edited by Nash, D.B., J. Reifsnyder, R. Fabius, and V.P. Pracilio. 23-41 Sudbury:MA Jones & Bartlett Learning.

World Federation of occupational therapists, 2011. *Statement on occupational therapy*. Available online, http://www.wfot.org/Portals/0/PDF/STATEMENT%20ON%20OCCUPATIONAL%20THERAPY%20300811.pdf Accessed April 30, 2013.

Address: Vanessa Volpe
Callistherapy Health Care Centre, 18 Oxford Street,
Wellingborough, Northamptonshire NN84HY
E-mail: vanessa@callistherapy.org

symposium: museum lighting

Colour Change in Old Master Paintings: How Serious is the Problem of Light?

Ashok ROY
National Gallery, London

symposium: museum lighting

ABSTRACT

In his compendium for painters written at the end of the 14th-century, Il Libro dell'Arte, Cennino Cennini alludes frequently to the colours of paintings fading through exposure to light and air. His concern was to guide young painters to eschew fugitive colours so as to produce works that would stand the test of time, and in that way 'gain great honour' for the creator and his future reputation. In the contemporary world, our responsibility has become the long-term care of works of art in collections, so as to continue to acknowledge the achievements of the original creators by passing their works on as little diminished as possible to future generations. All paintings change with time in various ways, and for this particular category of work of art, change is profoundly undesirable, particularly continuing deterioration. It is unfortunate that there is an innate contradiction between showing pictures to a large public, and the requirements of future preservation, since light, whatever its wavelength and whatever its intensity, is to some degree cumulatively damaging, even if that damage is incrementally small. It is therefore a challenge to lighting scientists and engineers, working with curators and conservators, to devise methods of lighting for picture display to meet these contradictory aims. The best solutions combine aesthetic success with conservation safety, the first requirement of which often involves an element of controllable daylight as well as artificial illumination. The second condition, by definition, must require relatively low levels of cumulative light exposure.

The fading of sensitive pigments in easel paintings and other painted surfaces and objects required for display is a well known phenomenon: it has been of concern to generations of collectors, it is well-researched for individual materials and is extensively documented both for real paintings and test samples. Quite aside from other factors that may be involved, loss of colour in pigments involves light as a key damaging factor in the great majority of cases. Considerably less attention has been given to other types of discoloration, particularly the darkening of the materials of painting, both pigments and binding media, and even less to the synergistic factors, chemical and environmental, that are also implicated in colour change in paintings. A wide range of pigments both of organic and inorganic constitutions are affected. This talk will survey some of the many types of colour change to which Old Master paintings are subject, where light alone and combinations with other factors must be considered a very serious problem in our aim of long-term preservation.

The Difficult Partnership between Energy Efficiency, Viewability and Conservation

Charles E. HUNT
University of California

ABSTRACT

In the process of preservation of historical treasures and artwork, the ideal would be an environment of darkness, unchanging temperature and humidity and absolute cleanliness. These same items for preservation, however, are typically highly desired for viewing, and this creates an immediate conflict in the Conservation effort. It is possible to maximize preservation by understanding the materials of the artifacts and omitting certain damaging spectral content from the illumination sources. This typically means filtering out all of the invisible ultraviolet and infrared content, and often includes removing narrow bands within the visible spectrum as well. This process of spectral-content filtering is typically neither energy efficient, nor convenient, especially if ordinary broad-band sources, such as halogen lamps, are used. The inefficiency problem is compounded by the wasted heat from these sources, which has to be managed as well. The new, energy-efficient artificial light sources, notably fluorescent (FL), Light-Emitting Diode (LED) and Organic LED (OLED) offer some solutions; but they introduce new difficulties in viewability. FL and LED sources have mediocre color rendering and difficulties in dimming. OLEDs suffer from poor illuminance and high maintenance due to short lifetime. The least expensive sources also undergo spectral shift during their effective lifetime. A newer solution is the "Light Engine:" an array of multi-colored monochromatic LEDs producing tunable illumination. The Light Engine offers an ideal for control of spectral content, illuminance, and lifetime, as well as other advantages. Unfortunately, at this time, the Light Engine is also a higher-cost solution upon installation, and although energy savings are immediately realized, the total cost of ownership can present a challenge except when amortized over an extended period. This presentation will overview the present options available for use in museums and facilities where conservation needs to be balanced with appearance, energy efficiency and overall costs.

*Address: Department of Electrical and Computer Engineering,
California Lighting Technology Center, University of California,
One Shields Avenue, Davis CA 95616 USA
E-mail: hunt@ieee.org*

Presenting Colour Science to Conservators and Curators: Measuring and Comparing Light Sources at the National Gallery

Joseph PADFIELD
Scientific Department, The National Gallery, London

ABSTRACT

For years specialists within museums and galleries have been relying on published CT (Colour Temperature) and CRI (Colour Rendering Index) values to select appropriate light sources to illuminate works of art and measuring Lux values to help limit their overall light exposure. However more recently it has become apparent that additional information is required to effectively compare and evaluate the growing number of alternative lights source.

In 2010 the Scientific Department of the National Gallery began developing a web-based solution to store and display SPD (Spectral Power Distribution) curves measured from a variety of light sources. This provides a platform for specialists in other museums and galleries to compare SPD curves and begin to explore how these measured curves are used to calculate CT, CRI and the newer CQS (Colour Quality Scale) value, a probable successor to the CRI value. A new Relative Exposure value is also calculated which provides an overall light energy exposure percentage for a given light source relative to daylight. This value takes into account the need to normalise the data for a fixed level of brightness and corrects for increasing energy of light with decreasing wavelength.

This talk will introduce this growing web-resource and use the data stored within it to demonstrate some of the difficulties in selecting light sources for Museum applications, showing that it is no longer a simple issue of picking a light source with a particular CT and CRI. All light sources, even those using the same basic technology, are not equal. Different examples of Tungsten, LED and or Fluorescent lamps etc. can be “appropriate” and “not appropriate” for a given application in Museums. Time just needs to be taken to select the right one for the right job. Also the basic published data for a given light source may not be enough, expected batch variations need to be considered along with control strategies, long term maintenance and technical support.

Using Light Engines in the Optimization of Illumination in Museums: the Sistine Chapel Lighting Retrofit Project

Josep CARRERAS[1], Charles E. HUNT[1], Ferenc SZABÓ[2], Janos SCHANDA[2]
[1] Catalonia Institute for Energy Research (IREC), Lighting Group, Barcelona, Spain.
[2] University of Pannonia, Dept. of Electrical Engineering and Information Systems, Veszprém, Hungary.

ABSTRACT

The mandate for transitioning to energy-efficient lighting poses conflicting challenges, particularly in developing sources which produce high-quality light for differing applications, while achieving the required efficiency.

The illumination of art certainly belongs to one of the most ambitious tasks in interior lighting regarding the strict constraints over light quality. Thus, in many museums today, the existing lighting installations lack energy efficiency as it is considered less important as compared to light quality or lighting design attributes. The EU-funded (CIP program) pilot project LED4Art, is a demonstration that both a superior light quality and high energy efficiency can be simultaneously achieved. This paper will describe, in particular, its applications to lighting design in the Sistine Chapel.

E-mail: jcarreras@irec.cat

Virtual Restoration of Faded Colours of Museums Artefacts using LED Lighting

Françoise VIÉNOT
Centre de Recherche sur la Conservation des Collections,
Muséum national d'Histoire naturelle, Paris, France

ABSTRACT

Whereas, for museum exhibition, it is recommended to illuminate artifacts with a distribution of light that covers the full spectrum to achieve fine discrimination of shades, it may be of interest to enhance the colourfulness of some faded artefacts. A procedure is presented to enhance the colourfulness of faded artefacts, based on adjusting the spectral profile of the light while maintaining a given white colour of the illumination.

The intensity of the three components of four feasible colour LED clusters was computed in order to produce white illumination metameric to a white LED light source taken as a reference. Colorimetric calculations were performed to model the colour changes undergone by target colour samples using illumination based on colour LED association with respect to the white LED reference. The model was based on CIELAB specification and allowed to optimize the choice of three colour LED associations that modify the hue and the saturation of a few target colour areas of illuminated samples while other areas are left moderately desaturated.

An experimental visual validation was practically obtained by adjusting the intensity of five calibrated colour LED, blue, cyan, green, amber and red, accommodated in a light booth. The visual validation was conducted asking twenty observers to rate the colourfulness appearance of a series of aged inkjet prints under every LED cluster with respect to the colourfulness of their original counterparts under the reference white LED source. The visual assessments agreed with the colorimetric predictions.

The demonstration could be made of the feasibility of the method by simulating in a light booth the rejuvenated appearance of a natural history specimen of which the museum possesses two differently aged items.

colour aesthetics

Units and Filters in the Human Mind: to construct a color harmony theory that can be applied to the real environment

Kiwamu MAKI
Faculty of Human Life Sciences, Jissen Women's University

ABSTRACT

The results of the experiments the auther executed, in which the impressions of color-simulated images or models of streetscapes, interiors, products were rated, couldn't be explained by a color harmony theory. The relations between the preference or harmony ratings and the variables that express the features of color compositions had a large variety. This variety indicates the necessity to introduce plural evaluation units or filters into color harmony theory to apply it into the real environment.

1. INTRODUCTION

Most substantive research that deal with color harmony discuss abstract color combinations such as that found in color chip compositions. The usefulness of such research in the real environment depends on whether the results maintain the same tendencies when they are regarding concrete items and the environment, such as products, buildings, streetscapes, and so on. However, the elements of harmony and preference sometimes show completely different tendencies, depending on the features of the objects being evaluated. Following are some examples. They are divided into two categories: units and filters.

2. UNIT EXAMPLES

2.1 Three different types of color harmony and preference

The author has reported three different types of color harmony and preference (Figure 1).

(a) Relate to the similarity of colors. *(b) Relate to the mean value of preferences of the composing colors.* *(c) Relate to the brightness difference mainly.*

Figure 1: Three types of preference or harmony of color composition.

The first relates to the similarity of colors, the second relates to the mean value of preferences of the composing colors, and the third relates to the brightness differences of composing colors (Maki 2005). These findings indicate the existence of three or more units for evaluation consideration that are mutually exclusive.

(1) One signboard. (2) Three signboards.

Figure2: The streetscape images containing color-simulated signboards.

2.2 Streetscape evaluation-type differences among the number of signboards

Streetscape images consisting of various color-modified signboards were shown to the subjects (Figure 2) . Streetscapes that display one signboard are preferred when the color is similar to the original. On the contrary, the preferences of those streetscapes displaying three signboards relate to larger streets that consist of one signboard, in which case the importance of the similarity to the original declines (Maki 2011 & the another in review).

Figure 3: A color simulated terrace image and its abstracted images.

2.3 Unity on abstract image

Concrete and abstract images of terraces, including a color-simulated image displaying four tables (Figure 3), were shown to the subjects. Those that included a gradation color pattern on the tables rated higher in the abstract image, while the image in which the light gray color was united rated higher in value for the concrete image (Maki 2002). Color unity on the same product should be important in the real environment.

2.4 Disappearing building color image

It is said that building color should be selected to fit the building's use. The questionnaire for the typical building color image showed the commonality among people; residences are beige, hospitals are white, and offices are gray. However, there was no increase in preference of these color buildings in images composed of three different streetscapes, even though an increase was observed when the color was similar to its surroundings (Figure 4 and 5; Takenouchi and Maki 2002).

These results indicate the existence of various judgment units in the mind, and some of them work exclusively with each other.

Figure 4: The combinations of a streetscape and a building in the center of it.

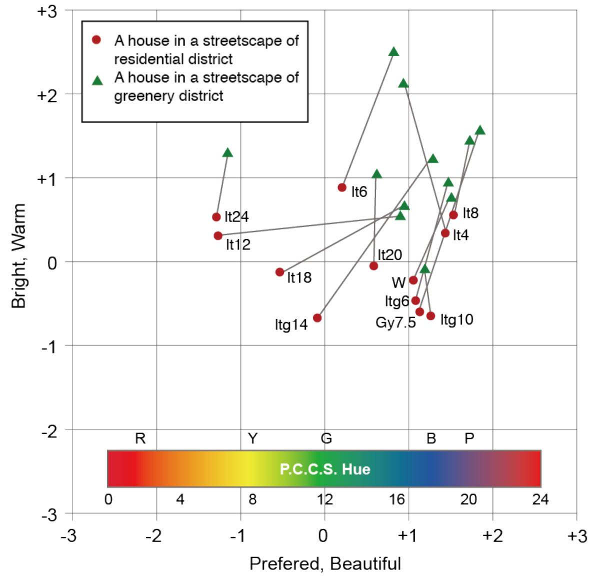


Figure 5: An example of position movement caused by the streetscape difference. (The preference scores of the scenes including a greenish house increase when a greenery streetscape is combined.)

3. FILTER EXAMPLES

3.1 Interaction between the building's shape and its color

The compositions of eight color compositions and eight streetscapes were shown to the subjects (Figure 6).

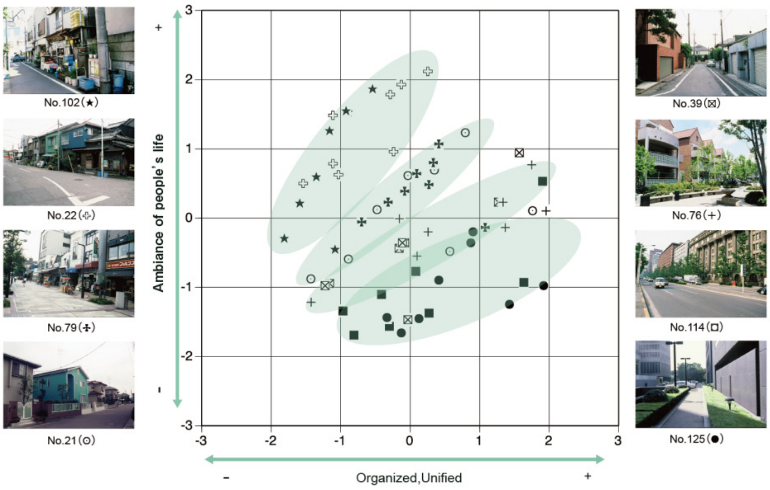


Figure 6: Impression change caused by the building color differences

Streetscapes composed of simple buildings from office areas showed a larger rating change for unity; on the other hand, streetscapes composed of buildings and commodities from commercial areas showed a larger rating change for ambience of people's life, even though the unity rating changes were lower. These results indicate that the color of buildings play a filtering role that controls how people feel about the appearance of the buildings (Maki and Sawa 1999).

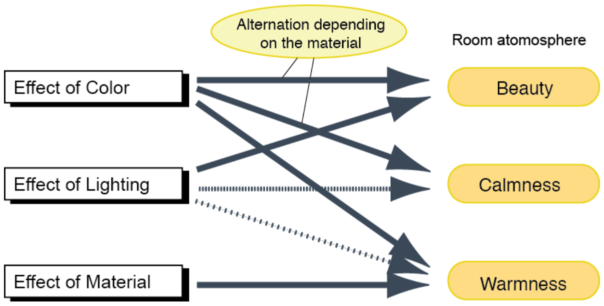


Figure7: A model of element effects to the room impressions.

3.2 Interaction between the wall color and its material

A room model that can change the lighting pattern, wall color, and wall material was shown to the subjects. The alternation of the color effect to display beauty and composure by the wall material difference was derived from a regression analysis with dummy variables (Figure 7; Maki & Sawa 1999). In this case, the material is a filter to control the color effect of the feelings.

4. CONCLUSIONS

These findings lead to the alternation of abstract color harmony theory. To increase the effectiveness in the real world, we need to incorporate these units and filters into the theory.

REFERENCES

Maki, K., 2005. Three estimation types of color scheme preference, In *AIC 2005, Proceedings of the 10th Meeting of the International Colour Association*. Granada, 1533-1536.

Maki, K., 2011. Color modification of signboard suitable for streetscapes without significant loss of visibility and logo identity, In *AIC 2011, Proceedings of the Midterm Meeting of the International Colour Association*. Zurich, 552-555.

Maki, K., 2002. Impression comparison among four color-simulated scenes, *Journal of the Color Science Association of Japan* 26(4). (In Japanese)

Takenouchi, K., and K. Maki, 2002. The Factor which Change the Impression of Building Color -The Influence of Building Type and the Background Street-, In *Summaries of Technical papers of Annual Meeting (D-1)*, Architectural Institute of Japan. (In Japanese)

Maki, K., M. Inui, and Y. Nakamura Apr., 1994. The consistency of streetscape evaluation structure, *J. of Architecture, Planning and Environmental Engineering* 458:27-33. (In Japanese)

Maki, K., and T. Sawa, 1999. The Influence of Color, Lighting and Material on the Evaluation of Interior Ambience, *J. of Architecture, Planning and Environmental Engineering* 516:15-22. (In Japanese)

Address: Prof. Kiwamu Maki, Department of Human Environmental Sciences,
Faculty of Human Life Sciences, Jissen Women's University,
191-8510 Ohsakaue 4-1-1, Hino, Tokyo, Japan
E-mail: maki-kiwamu@jissen.ac.jp

A Study of Color Harmony for Three-Dimensional Color Configuration

Shi-Min GONG[1] Wen-Yuan LEE[2]
[1] The Graduate Institute of Design Science, University of Tatung
[2] Department of Media Design, University of Tatung

ABSTRACT

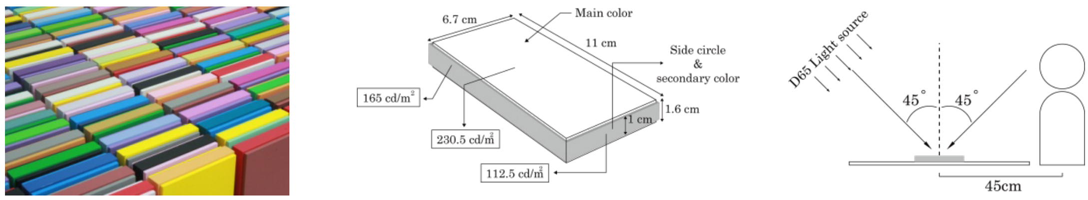
Current study aims to understand the color harmony on 3D color configuration. Thirty-two observers were invited to take part in a psychophysical experiment. Each observer was asked to assess 141 experimental samples on "harmonious-disharmonious" scale. The results showed that white color can produce harmonious feeling regardless of what color was used as secondary color. Two colors with higher lightness sum and smaller hue difference tend to be more harmonious. The phenomenon of color harmony was found to be different between 2D and 3D configurations.

1. INTRODUCTION

Many studies[1-8] have been made to see how two color combinations express harmonious feeling. However, the color configuration used in the previous studies was juxtaposition, leading the results contentious. Especially for product design, the colors applied onto product usually appear in different parts, producing 3D color configuration. In addition, how to select the harmonious colors more effectively in a large number of color combinations is important for designers. Hence, the current study carried out a psychophysical experiment using a series of color combinations applying on 3D color configuration to see the color harmony.

2. EXPERIMENTAL PLAN

To understand the color harmony on 3D color configuration, a psychophysical experiment was conducted. Thirty-two observers with an average age of 21.2 years old took part in this experiment, including 13 male and 19 female. Each observer was asked to assess two-color combinations on 3D color configuration on "harmonious-disharmonious" scale. To produce two-color combinations, 11 basic color terms according to Berlin and Kay[9] (red, orange, yellow, green, blue, brown, purple, pink, white, black and gray colors) were selected to be the main color. Each main color was produced according to their boundaries in CIELAB space proposed by Lin *et.al*[10-12]. In addition, five harmonious principles were used to produce secondary colors, including "neighboring tone with neighboring hue", "different tone with same hue", "same tone with different hue", "chromatic-achromatic combination", and "achromatic-achromatic combination". Totally, 141 color combinations were produced, as shown in Figure 1(a). To produce three-dimensional color configuration, side circle shape applied onto the cuboids was used. The main color was applied onto the cuboids shape, secondary color on side circle, as shown in Figure 1(b). Each color was measured by a GretagMacbeth® Eye-One. The CIELAB values were calculated under CIE D65 and 1964 standard colorimetric observer. This experiment was conducted in a dark room. Each experimental sample was displayed in a viewing cabinet and illuminated by a D65 simulator. The viewing distance was about 45 cm with a 45/45 illuminating/viewing geometry, as shown in Figure 1(c). In addition, the luminance levels for three observational surfaces were measured, 230.5, 165 and 112.5 cd/m^2, respectively, as shown in Figure 1(b).



(a) (b) (c)

Figure 1: *The experimental samples* and *situation.*

3. INTRA- AND INTER-OBSERVER VARIATION

In prior to analysis, intra- and inter-observer variations were examined by root mean square (RMS). The former is to see whether the observers can repeat same judgment or not. The latter is to examine how well the individual observer agrees with the mean results. For RMS of 0, it represents a perfect agreement between two data array.

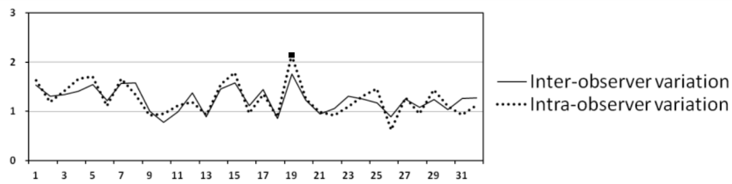


Figure 2*:* I*ntra- and inter-observer variation.*

The results are illustrated in Figure 2. It can be seen that intra-observer variation and inter-observer variation were ranged between RMS of 0.62 and 2.15. One observer was found to have RMS value exceeding 2.0 on intra-observer variation, indicating this observer can't provide consistent judgment. Therefore, the data of this observer was excluded from further analysis.

4. RESULT

In order to see the color harmony on 3D color configuration, the emotion profile was illustrated, as shown in Figure 3. In this figure, each color combination has one data point. The color combinations having same main color are grouped together. It was found that all the color combinations having white color as main color tended to be harmonious. In order to clarify the influence of secondary color on color harmony, RMS was used to calculate the variation between those samples with same main color. It was found that the color combinations with main color of white color had least RMS value, as shown in Figure 4, indicating that white color is the most influential main color. This tells us that white color can produce harmonious feeling regardless of what color was used as secondary color. On the contrary, the greatest influence of secondary color on color harmony was found on those combinations with purple color as main color.

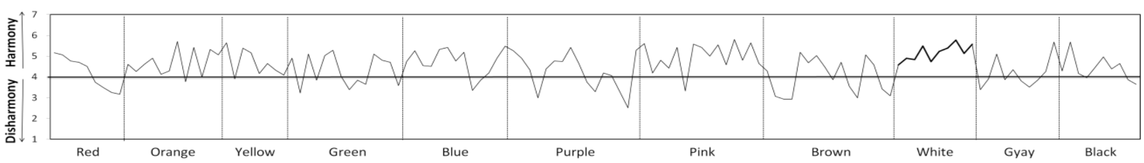


Figure 3: Emotion profile.

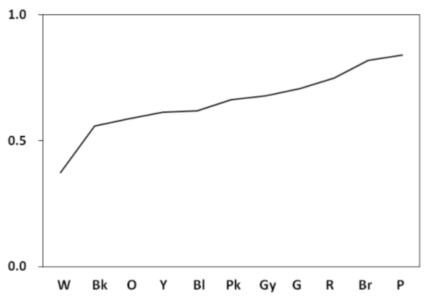


Figure 4: Variation of secondary color on each main color.

Table 1: Two-color interrelationship.

addition	subtraction
$L_{sum} = L_1^* + L_2^*$	$\Delta L^* = \lvert L_1^* - L_2^* \rvert$
$C_{sum} = C_1^* + C_2^*$	$\Delta C^* = \lvert C_1^* - C_2^* \rvert$
$a^*_{sum} = \lvert a_1^* + a_2^* \rvert$	$\Delta a^* = \lvert a_1^* - a_2^* \rvert$
$b^*_{sum} = \lvert b_1^* + b_2^* \rvert$	$\Delta b^* = \lvert b_1^* - b_2^* \rvert$
$h^*_{mid} = tan^{-1} \frac{b'}{a'}$	$\Delta h^* = \lvert h_1 - h_2 \rvert > 180°, 360 - \lvert h_1 - h_2 \rvert$ $\lvert h_1 - h_2 \rvert \leq 180°, \lvert h_1 - h_2 \rvert$
Where $a' = \frac{a_1^* + a_2^*}{2}$	
$b' = \frac{b_1^* + b_2^*}{2}$	

Furthermore, in order to understand if color attributes had any impact on the color harmony, the addition and subtraction interrelationships between two colors were calculated, including C_{sum}, L_{sum}, h_{mid}, a^*_{sum}, b^*_{sum}, ΔC, ΔL, Δh, Δa^* and Δb^*. These interrelationships are summarized in Table 1. Scatter plot and correlation coefficient were used to find out the interrelationship correlated with harmonious feeling. In these diagrams, the vertical axes means the results of harmonious, horizontal axes are two-color interrelationships. Note that the data of "chromatic-achromatic combination" and "achromatic-achromatic combination" were excluded from Figure 5(c) and Figure 5(h). The results showed that correlation coefficients were poor. Only L_{sum} and Δh had higher correlation coefficient in comparison with other attributes, 0.47 and -0.42 respectively, as shown in Figure 5(b) and Figure 5(h). From these results, it could be understood that two colors with higher lightness sum and smaller hue difference tend to be more harmonious.

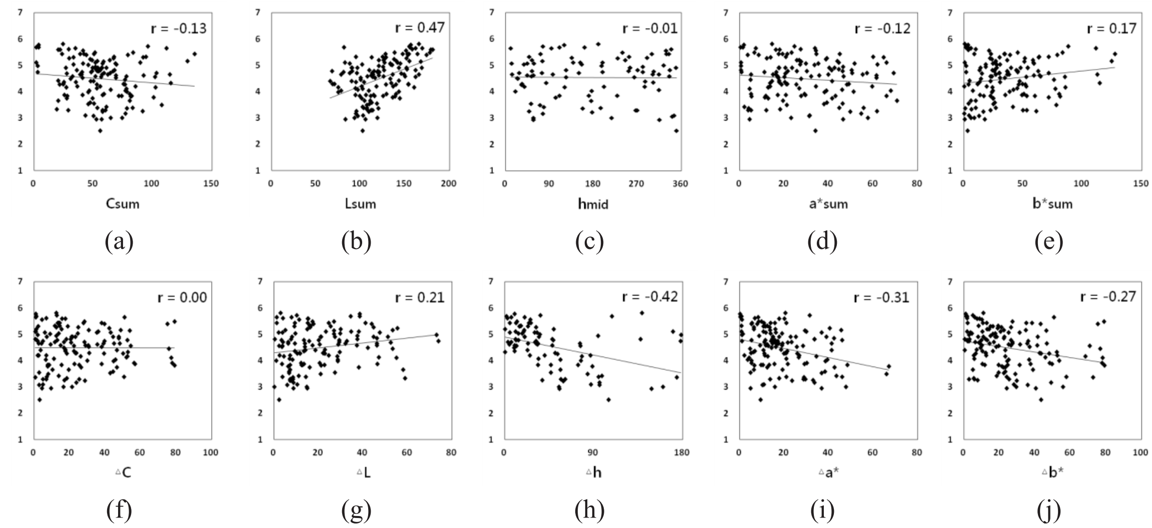


Figure 5: The relationship between harmony and two-color interrelationships.

The ΔC, ΔL, C_{sum} and L_{sum} were found to influence the color harmony on 2D color configuration in previous studies[6,8], which conducted on 2D color configuration. However, the interrelationship of ΔC, ΔL and C_{sum} were found insignificant on 3D configuration. Only the L_{sum} was found to influence the color harmony on both 2D and 3D color configurations. In addition, the Δh was found to influence the color harmony on 3D configuration, not on 2D configuration. It is reasonable to conclude that the phenomenon of color harmony was different between 2D and 3D configurations.

4. CONCLUSIONS

The current study conducted a psychophysical experiment to see the color harmony on 3D color configuration. The findings are summarized below.

1. White color can produce harmonious feeling regardless of what color was used as secondary color.
2. Two colors with higher lightness sum and smaller hue difference tend to be more harmonious.
3. The phenomenon of color harmony was different between 2D and 3D configurations.

ACKNOWLEDGEMENTS

This study is funded by the National Science Council in the Taiwan. The project number is NSC 100-2221-E-036-029-MY2.

REFERENCES

1. Chuang, M-C., and L-C. Ou, 1999. Influence of a Holistic Color Interval on Color Harmony. *Color R&A* 26:29-39.
2. Chuang, M-C., and C-L. Yeh, 1998. Influence of an Integrated Color Interval of Object Colors on Color Harmony. *Journal of Design* 3(2):113-130.
3. Hård, A., and L. Sivik, 2001. A Theory of Colors in Combination: A Descriptive Model Related to the NCS Color-Order System. *Color R&A* 26(1):4-28.
4. Kao, S-L., 2004. *A Study of the Effect of Changing Size and Shape of Colored Area on Cognition in Color Combination*. Yunlin: National Yunlin University of Science & Technology.
5. Chen, Y-F., 2008. *The Effect of Color Areas on Color Image*: National Cheng Kung University.
6. Haung, Y-H., W-Y. Lee and S-M. Gong, 2010. Area Effect on Color Harmony: Web Page as an Example. *International Conference on Color Design*. Taiwan. 21-28.
7. Haung, Y-H., and W-Y. Lee, 2010. Color Harmony for Web Design. *The 17th Annual Meeting of the Ergonomics Society of Taiwan*.
8. Ou, L-C., and M.R. Luo, 2006. A Colour Harmony Model for Two-Colour Combinations. *Color R & A*; 31(3):191-204.
9. Berlin, B., and P. Kay, 1969. *Basic Colour Terms: Their Universality and Evolution*.
10. Lin, H., M.R. Luo, L.W. MacDonald and A.W.S. Tarrant, 2001. A cross-cultural colour-naming study. Part I: Using an unconstrained method. *Color R&A*; 26(1):40-60.
11. Lin, H., M.R. Luo, L.W. MacDonald and A.W.S. Tarrant, 2001. A Cross-cultural colour-naming study. Part II: Using a Constrained Method. *Color R&A*; 26(3):193-208.
12. Lin, H., M.R. Luo, L.W. MacDonald and A.W.S. Tarrant, 2001. A cross-cultural colour-naming study. Part III: A colour-naming model. *Color R&A*; 26(4):270-277.

Address: Shi-Min Gong, The Graduate Institute of Design Science,
University of Tatung, No.40, Sec. 3,Zhongshan N. Rd., Taipei City 104, Taiwan
E-mail: ly07031985@gmail.com

Proposal for Selecting Two- and Three-color Combinations with Various Affections

Hideki SAKAI,[1] Motonori DOI[2]
[1] Graduate School of Human Life Science, Osaka City University
[2] Department of Telecommunications and Computer Networks, Osaka Electro-Communication University

colour aesthetics

ABSTRACT

A method is proposed for selecting two- and three-color combinations with various feelings. Feelings used are pleasantness, contrast, floridness, warmth, and their combinations. These feelings were extracted from 38 adjective pairs (harmonious-disharmonious, pleasant-unpleasant, unified-separate, beautiful-ugly, strong-weak, florid-sober, bright-dark, light-heavy, warm-cool, etc.) by the factor analysis. The prediction formulas are given for estimating the degree of each feeling for any two- and three-color combinations. Munsell H V/Cs of constituent colors are necessary for prediction.

1. INTRODUCTION

The purpose of this study is to propose a method for selecting two- and three-color combinations with various feelings. It was originally proposed by Nayatani et al. in 1960s based on several experiments with 628 subjects and 784 color combination samples in total, and was slightly updated for two-color combinations at 2009 (Nayatani 2009, Sakai 2009). The size and shape of samples used in the original experiments are shown in Figure 1. In this paper, we will update the prediction equations for three-color combinations.

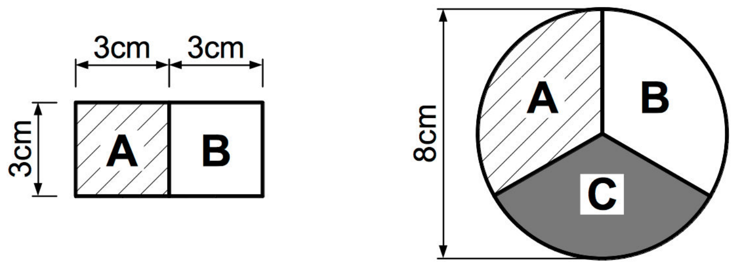


Figure 1: The sample size of two- and three-color combinations used in the experiment.

2. METHOD

The prediction formulas are given for estimating the degree of each feeling for any two- and three-color combinations.

2.1 Formulas for Feeling of Pleasantness

The feeling of pleasantness of a two-color combination, $x_p^{(2)}$, is predicted by Eq.(1).

$$x_{p,AB}^{(2)} = p_0 + \sum_{n=1}^{11} p_n \bullet x_n \ , \qquad (1)$$

where the coefficients p_n are shown in Table 1, and the variables x_n are shown in Table 2. The variables x_n consist of $Z_{1,i}$, $Z_{2,i}$, and $Z_{3,i}$, the transformed values of Munsell notation of the constituent color (i=A or B) of two-color combination under consideration. The transformation equations are given in Eq.(2).

$$Z_{1,i} = C_i \cdot \cos\theta_i ,$$
$$Z_{2,i} = C_i \cdot \sin\theta_i , \qquad \text{for } i=A, B \qquad (2)$$
$$Z_{3,i} = 8.33\, V_i ,$$

where θ_i, V_i, and C_i are the Munsell Hue, Value, and Chroma; the subscripts A and B correspond to two constituent colors of a two-color combination. Note that Munsell Hue θ_i is in angle unit; θ_i = 0 deg. for 10RP, 18 deg. for 5R, 90 deg. for 5Y, and so on.

Table 1. The coefficients p_n, f_n, and w_n used for calculations.

n	Value of p_n	Value of f_n	Value of w_n
0	- 0.741028	0.177769280 $\times 10^{1}$	0.390376570 $\times 10^{1}$
1	0.106610 $\times 10^{-1}$	- 0.222760220 $\times 10^{-1}$	0.855965000 $\times 10^{-3}$
2	- 0.251222 $\times 10^{-2}$	- 0.195147280	- 0.165580210 $\times 10^{-1}$
3	0.194627 $\times 10^{-3}$	- 0.470359449 $\times 10^{-3}$	0.154380429 $\times 10^{-3}$
4	0.212212 $\times 10^{-2}$	0.263778460 $\times 10^{-1}$	0.744526171 $\times 10^{-2}$
5	0.369588 $\times 10^{-2}$	0.163299620 $\times 10^{-1}$	- 0.172593279 $\times 10^{-2}$
6	0.596614 $\times 10^{-2}$	0.432328190 $\times 10^{-3}$	- 0.884240879 $\times 10^{-4}$
7	0.190872 $\times 10^{-5}$	0.609462090 $\times 10^{-2}$	- 0.166008430 $\times 10^{-2}$
8	- 0.213873 $\times 10^{-3}$	- 0.557301219 $\times 10^{-3}$	0.196643070 $\times 10^{-2}$
9	- 0.378737 $\times 10^{-5}$	0.285702570 $\times 10^{-2}$	0.236626819 $\times 10^{-2}$
10	- 0.585471 $\times 10^{-5}$	-	-
11	- 0.301059 $\times 10^{-5}$	-	-

Table 2. The variables x_n and y_n used for calculations.

n	Constitution of x_n	Constitution of y_n
1	$Z_{1A}^2 + Z_{1B}^2$	Z_1
2	$Z_{2A}^2 + Z_{2B}^2$	Z_2
3	$Z_{3A}^2 + Z_{3B}^2$	Z_3
4	$Z_{1A}Z_{2A} + Z_{1B}Z_{2B}$	Z_1^2
5	$Z_{1A}Z_{1B}$	Z_2^2
6	$Z_{2A}Z_{2B}$	Z_3^2
7	$Z_{3A}^3 + Z_{3B}^3$	Z_1Z_2
8	$Z_{1A}^2Z_{3A} + Z_{1B}^2Z_{3B}$	Z_1Z_3
9	$Z_{3A}^2Z_{1B} + Z_{1A}Z_{3B}^2$	Z_2Z_3
10	$Z_{3A}^2Z_{2B} + Z_{2A}Z_{3B}^2$	-
11	$Z_{3A}^2Z_{3B} + Z_{3A}Z_{3B}^2$	-

For three-color combinations, divide a three-color combination into three kinds of two-color combinations, each of which consists of neighboring two colors. Then, calculate $x_p^{(2)}$ to each of them, and take their average to predict the feeling of pleasantness, $x_p^{(3)}$. It is given by,

$$x_{p,ABC}^{(3)} = \left(x_{p,AB}^{(2)} + x_{p,BC}^{(2)} + x_{p,CA}^{(2)}\right)\Big/3 . \qquad (3)$$

where A, B, and C indicate three constituent colors (Figure 1).

2.2 Formulas for Feeling of Contrast

The feeling of contrast of a two-color combination, $x_c^{(2)}$, is predicted by Eq.(4).

$$x_{c,AB}^{(2)} = 2\,\Delta E_{AB} + 3\,C_{Max,AB}\ , \tag{4}$$

where ΔE_{AB} is the color difference between the two constituent colors (i.e., between A and B), and $C_{Max,AB}$ indicates the value of higher Munsell Chroma of A or B. The color difference ΔE_{AB} is computed by Eq.(5), the Godlove formula.

$$\Delta E_{AB} = \sqrt{(C_A - C_B)^2 + 16(V_A - V_B)^2 + 4C_A C_B\left[\sin\{(\theta_A - \theta_B)/2\}\right]^2}\ . \tag{5}$$

Equation (4) suggests that the feeling of contrast increases by increasing the color difference between the two constituent colors, and by increasing Chroma of either constituent color.

For three-color combinations, divide a three-color combination into three two-color combinations and take the average of three values of the color difference between the two-color. Take the highest Munsell Chroma of three constituent colors A, B, and C. Then, apply them to Eq.(4). That is,

$$x_{c,ABC}^{(3)} = 2\,\{(\Delta E_{AB} + \Delta E_{BC} + \Delta E_{CA})/3\} + 3\,C_{Max,ABC}\ . \tag{6}$$

This is a reasonable extension of Eq.(4).

2.3 Formulas for Feeling of Floridness

The feeling of floridness of a two-color combination, $x_f^{(2)}$, is computed by the following procedure. First, its estimation is made to each constituent color, which is given by the value of $x_{f,i}^{(1)}$, i=A, B. It is predicted by Eq.(7).

$$x_{f,i}^{(1)} = f_0 + \sum_{n=1}^{9} f_n \bullet y_n\ , \tag{7}$$

where the coefficients f_n are given in the third column of Table 1, and the variables y_n are given in the second column of Table 2. The $(Z_{1,i}, Z_{2,i}, Z_{3,i})$ in y_n are already given in Eq.(2). Then, the feeling of floridness of the two-color combination is given by Eq.(8).

$$x_{f,AB}^{(2)} = x_{f,A}^{(1)} + x_{f,B}^{(1)}\ . \tag{8}$$

This means that the feeling of floridness has an additive nature. Thus, the feeling of floridness of a three-color combination, $x_f^{(3)}$, is predicted by Eq.(9).

$$x_{f,ABC}^{(3)} = \frac{2}{3}\left(x_{f,A}^{(1)} + x_{f,B}^{(1)} + x_{f,C}^{(1)}\right). \tag{9}$$

The constant 2/3 is introduced to normalize the scale to that of two-color combinations.

2.4 Formulas for Feeling of Warmth

The feeling of warmth of a two-color combination, $x_w^{(2)}$, is computed in a similar manner to the feeling of floridness. First, its estimation is made to each of the constituent colors, $x_{w,i}^{(1)}$, i=A, B, by Eq.(10).

$$x_{w,i}^{(1)} = w_0 + \sum_{n=1}^{9} w_n \bullet y_n \ , \qquad (10)$$

where the coefficients w_n are given in the fourth column of Table 1, and the variables y_n are given in the third column of Table 2. Then, the feeling of warmth of the two-color combination is calculated by Eq.(11),

$$x_{w,AB}^{(2)} = x_{w,A}^{(1)} + x_{w,B}^{(1)} \ , \qquad (11)$$

and that of a three-color combination is calculated by Eq.(12).

$$x_{w,ABC}^{(3)} = \frac{2}{3}\left(x_{w,A}^{(1)} + x_{w,B}^{(1)} + x_{w,C}^{(1)}\right). \qquad (12)$$

3. SUMMARY

There are spreadsheet files that can calculate all four feelings available at author's web site with up-to-date information on the proposed method (Sakai 2013). We used the method to categorize images based on their impression (Doi 2011). We expect that the proposed method is a useful tool for color designers, though there is still room for improvement.

ACKNOWLEDGEMENTS

This work was partly supported by JSPS KAKENHI Grant Number 23560732.

REFERENCES

Doi, M., S. Yuguchi, and H. Sakai, 2011. Image retrieval by impression word based on feeling prediction from color combination. In *AIC 2011, Proceedings,* ed. by VM. Schindler, S. Cuber. Zurich, Switzerland, No.99, 1-4.

Nayatani, Y., and H. Sakai, 2009. Proposal for selecting two-color combinations with various affections. Part I: Introduction of the Method. *Color Research and Application.* 34 (2): 128-134.

Sakai, H., and Y. Nayatani, 2009. Proposal for selecting two-color combinations with various affections. Part II: Demonstration of the System. *Color Research and Application.* 34 (2): 135-140.

Sakai, H., 2013. *Color Selection System*. Available online, color.syuriken.jp/combi/combi-e.htm, and colorscience.sakura.ne.jp/combi/combi-e.htm. Accessed: May 1, 2013.

Address: Dr. Hideki Sakai, Graduate School of Human Life Science,
Osaka City University, Sugimoto 3, Sumiyoshi-ku, Osaka City, 558-8585 Japan
E-mails: hsakai@life.osaka-cu.ac.jp, doi@isc.osakac.ac.jp

Investigation on Various Color-Harmony Models in Predicting Color Harmony for Color-Apparel Images

Wen-Guey KUO,[1] Yuh-Chang WEI,[2] Shang-Ming LIN,[3]
Chung-Kan LEE,[2] Chi-Chu HONG[4]
[1] Department of Textile Engineering, Chinese Culture University, Taipei, Taiwan
[2] Institute of Information Communications, Chinese Culture University, Taipei, Taiwan
[3] Department of Materials and Textiles, Oriental Institute of Technology, Taipei, Taiwan
[4] Mei Cha Mei Finishing Co., Ltd., Tauyuan, Taiwan

ABSTRACT

Color harmony has been systematically investigated since 1956 at Budapest using specific pattern samples with the exception of textile specimens. And, so far, there are two known color harmony models proposed by Ou et al. (abbreviated as the Ou) and Szabó et al. (as the Szabó) separately, and these two models as well as the pilot color harmony model derived by Kuo (as the Kuo) was estimated on the performance in predicting visual color harmony for fashion apparel images using performance factor (PF/4). According to the experimental results proposed by Kuo, the color harmony might be influenced by the types of sample pattern. Therefore, the performance of those three models in predicting visual color harmony for samples of fashion apparel is discussed in this article using 162 color images of fashion apparel containing 141 and 21 ones in which the fashion apparels are with two-color and three-color combinations respectively. The results indicate that the model Szabó has the best performance in predicting the visual color harmony among the three ones tested having the mean values of 126 in the unit of PF/4.

1. INTRODUCTION

Color colorimetry has long had the purpose of measuring color or estimating or predicting color difference for more than eight decades since 1931. And, it is also able to be employed in specifying a color by color coordinate or color appearance, but not in indicating one by harmony. The latter had been further studied since 1956 at the Budapest Technical University by Nemcsics (2007), and there were advanced theories of color harmony also subsequently proposed, for example, by Szabó et al. (2009) abbreviated as the Szabó, and Kuo et al. (Kuo and Kuo 2000) as the Kuo. Furthermore, following those theories, several related researches were carried out and published during the past five years, such as Ou et al. (2011) abbreviated as the Ou. In addition, there exists a difference among those researches in which various types of samples were used respectively, and according to the experimental results proposed by Kuo et al. (2011), the color harmony might be influenced by the types of sample pattern. Therefore, the performance of those three models in predicting visual color harmony for samples of fashion apparel is discussed in this article using 162 color images of fashion apparel containing 141 and 21 ones in which the fashion apparels are with two-color and three-color combinations respectively, and estimated using the performance factor (PF) developed by Luo and Rigg (1987).

2. METHOD

Most previous studies on color harmony were typically concerned with whether the color harmony scale can be expressed with a small number of categories, or factors, by using the psychological method of category judgement proposed by Torgerson (1958). In this study, the psychophysical method of magnitude estimation was used instead of the psychological method of category judgement (Kuo 2007).

In the visual assessment experiments of scaling color harmony, 162 color specimens of apparel images having a large size of 3×3 square inch that subtends 10^0 at the observer's eye, and containing 141 and 21 ones with two-color and three-color combinations respectively accumulated in this study. Each color-image specimen shown on a flat display was assessed twice by a panel of fifteen observers in a dark room, including seven female and eight male ones being within the ages of 20 and 35 using the psychophysical method combining both magnitude estimation method and semantic differential method (Kuo and Kuo 2000).

3. RESULTS AND DISCUSSION

3.1 Stability of Visual Assessment

In this study, a series of color-harmony assessing experiments under a dark room were carried out respectively by a panel of fifteen observers using the magnitude estimation method. The coefficient of variation (CV%) proposed by Coates et al. (1981) was used to indicate the observer variation, and can be calculated used the following equation:

$$CV(\%) = 100[\text{å}(x_i - y_i)^2 / n]^{1/2} / \tilde{y},$$

where n is the number of samples in x_i and y_i sets of data, and $\tilde{y}$ is the mean value of the y_i set data. The larger the value of CV is, the worse the agreement between the two sets of data compared. For a perfect agreement, the value of CV should be zero. The results show that a general stability can be found for the visual results, i.e. the total mean value of 78 in CV unit. And, the result of assessing stability for the observers in this study is less or equal to that for those experiments of color appearance or color difference assessment (Luo et al. 1996; Kuo and Luo 1996).

3.2 The Performance Factor PF

The performance factor (PF) developed by Luo and Rigg (1987) was used to indicate the agreement between two sets of data, and defined as the following equation:

$$PF = 100 (\gamma + V_{AB} + CV/100 - r),$$

where CV and γ were proposed by Coates et al. (1981), V_{AB} derived by Schultze and Gall (1971), and r is the correlation coefficient between the two sets of data compared. The PF combines four statistical measures (suitable weighted) into one value, which eases the comparison. For perfect agreement between two sets of data, the PF should be zero. All estimations of the performance of the color difference formulae on predicting visual color differences in the following data analysis are in terms of PF/4 unit being able to indicate the percentage error between two sets of data. Meanwhile, the higher the value of PF/4, the worse the agreement between data sets is.

3.3 Comparison of the Performances of Various Color-Harmony Models in Predicting Visual Color Harmony

There are two well-known color-harmony models proposed by Szabó et al. (2009) and Ou et al. (2011) abbreviated as the Szabó and the Ou respectively, and one as a pilot color-harmony model proposed by Kuo as the Kuo, and the performances of these three color-harmony models in predicting visual color harmony were examined using the experimental visual-harmony data obtained from this study using 162 color images of fashion apparel containing 141 and 21 ones with two-color and three-color combinations respectively by means of the performance factor (PF/4). The results indicate that the model Szabó has the best performance in predicting the visual color harmony among the three ones tested having the mean values of 126 in the unit of PF/4 as shown on Table 1. However, on the whole the three models tested still cannot have good agreement between their predictions and visual results of color harmony. This finding may obviously shows that a more accurate color-harmony predicting model would be still expected for the fashion apparels with multiple-color combinations, and it is also one of the most important works of the authors in the near future.

Table 1: Estimation on the performances of the color-harmony models derived by Ou et al. and Szabó abbreviated as the Ou and the Szabó, and one as a pilot color-harmony model proposed by Kuo as the Kuo in predicting visual color-harmony data, Hv2 and Hv3 standing for the visual assessing values of the samples with two color- and three color-combinations respectively, by means of the performance factor (PF/4).

	Models		
Items	**the Ou**	**the Szabó**	**the Kuo**
$\mathbf{H_{v2}}$	191	137	197
$\mathbf{H_{v3}}$	156	115	191
Mean	174	126	194

4. CONCLUSIONS

In this study, 162 color specimens of apparel images with a visual angle of 100, and containing 141 and 21 ones with two-color and three-color combinations respectively as experimental samples. Subsequently, a series of color psychophysical experiments were carried out using those experimental specimens. And the performances of three color-harmony models in predicting visual color harmony were examined using the experimental visual-harmony data in terms of the performance factor (PF/4). The results indicate that the model Szabó has the best performance in predicting the visual color harmony among the three ones tested having the mean values of 126 in the unit of PF/4. However, on the whole the three models tested still cannot have good agreement between their predictions and visual results of color harmony. This finding may obviously shows that a more accurate color-harmony predicting model would be still expected for the fashion apparels with multiple-color combinations.

ACKNOWLEDGMENTS

Special thanks are due to the financial assistance from the National Science Council in Taiwan. And, particular thanks are also due to all observers taking part in the visual assessment experiments.

REFERENCES

Coates, E., K.Y. Fong and B. Rigg 1981. Uniform Lightness Scales, *Journal of the Society of Dyers and Colourists* 97, 179-183.

Kuo, W.G., 2007. The feasibility of establishing new color image scales using the magnitude estimation method, *Color Research and Application* 32(6) 463-468.

Kuo, W.G. and Y.C. Kuo 2000. The investigation on the relationship between DRP color image scale and CIEL*a*b* color space, *Proceedings of the Conference on the Color Application and Color Science*, 137-144.

Kuo, W.G., C.K. Lee, Y.C. Wei and Y.Y. Huang 2011. Effect of different sample patterns on color harmony, *Proceedings of 12th International Conference on Color Design, Application and Science*, 187-194.

Kuo, W.G. and M.R. Luo 1996. Methods for quantifying metamerism Part I – visual assessment, *Journal of the Society of Dyers and Colourists* 112, 312-320.

Luo, M.R., M.C. Lo and W.G. Kuo 1996. The LLAB(l:c) color model, *Color Research and Application* 21(6) 412-429.

Luo, M.R. and B. Rigg 1987. BFD (l:c) color-difference formula Part I – development of the formula, *Journal of the Society of Dyers and Colourists* 103, 86-94.

Nemcsics, A. 2007. Experimental determination of laws of color harmony Part 1: harmony content of different scales with similar hue, *Color Research and Application* 32(6) 477-488.

Ou, L.C., P. Chong and M.R. Luo 2011. Additivity of color harmony, *Color Research and Application* 36(5) 355-372.

Schultze, W. and L. Gall 1971. Application of color difference formulae to highly saturated colors differing only in lightness and saturation, *J. Color Appear.* 1(1) 17-24.

Szabó, F., P. Bodrogi, and J. Schanda 2009. Experimental modeling of color harmony, *Color Research and Application* 35(1) 34-49.

Torgerson, W.S. 1958. *Theory and Methods of Scaling*, John Wiley & Sons: New York (USA) 205-246.

Address: Prof. Wen-Guey Kuo, Department of Textile Engineering,
Chinese Culture University, No. 55 Hua Kang Road, Yang Ming Shan, Taipei 111, Taiwan
E-mails: kuow@staff.pccu.edu.tw, ycwei@faculty.pccu.edu.tw, fc013@mail.oit.edu.tw,
zenoah82000@gmail.com, mcm17@ms33.hinet.net

Color Preference Style for Twelve Basic Colors

Takashi HANARI,[1] Shin'ya TAKAHASHI [2]
[1] School of Culture–Information Studies, Sugiyama Jogakuen University
[2] Graduate School of Environmental Studies, Nagoya University

ABSTRACT

Hanari and Takahashi (2009) named individual profile of the preference for various colors 'color preference style,' that ranges from the most to the least preferred color. This study examined the color preference style for twelve basic colors presented as color names. A thousand, two hundred and twenty four undergraduates answered the degree of preference for the twelve colors by marking a slash on visual analog scales (VAS). We calculated several indices of the color preference style in each participant; the average, the standard deviation, and so on. When the high-average group and the low-average group were compared, it was found that the high-average group had less choosy color preference style. The low-average group showed choosier color preference style with larger differences among VAS scores. In addition, the large-deviation group was found to have the color preference style marked by clearer discrimination of the least preferred color than the most preferred color. Contrastingly, the small-deviation group showed the style having few disliked colors, with most colors being rated positively (above the neutral point). It was also found that the large-deviation group preferred monochromatic colors more prominently than the small-deviation group.

1. INTRODUCTION

In various color-choice occasions of daily life, we don't select the same color every time. Even when one had a certain preferred color, that color would not be always chosen for every use; rather, various colors are flexibly used according to purpose, situation, and one's feeling, thereby creating individual's comfortable color environment. If so, color preference research should pay more attention to one's 'preference profile' for many colors, as well as one's most preferred color(s) that has been studied for a century. How do we evaluate many colors to form such 'preference profile?'

Hanari and Takahashi (2005, 2009, 2012) named individual profile of the preference for various colors 'color preference style,' being contrasted with 'color preference' which is usually referred to as one's most preferred color. In other words, the color preference style is a quantitative pattern of the degree of preference for many colors, not for a certain color, that ranges from the most to the least preferred color in each individual. This study examined the color preference style for the twelve basic colors; red, orange, yellow, yellow green, green, blue, purple, pink, brown, white, gray, and black.

2. METHOD

2.1 Participants

A thousand, two hundred and twenty four undergraduates (430 males and 794 females) participated in our research. Mean age was 20.0 years old for male and 19.7 for female.

2.2 Procedure

A questionnaire was distributed to the participants to ask their preference for the twelve basic colors; red, orange, yellow, yellow green, green, blue, purple, pink, brown, white, gray, and black. These colors were given in Japanese color names. We used visual analog scales (VAS), twelve horizontal lines, to measure the degree of preference for each color. Participants answered the degree of liking of each color by marking a slash (/) on the line. The left edge of the line indicated 'do not like at all,' and the right edge indicated 'like very much.' We measured the position of each slash and converted it into value ranging from 0 (the left edge) to 100 (the right edge). In the present study, this value is called VAS score (for each color in each participant), and used as raw data for the further analyses.

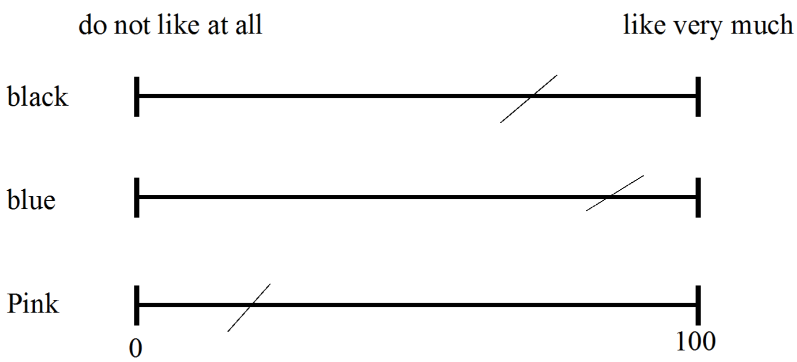


Figure 1: Samples of visual analog scales (VAS).

3. RESULTS AND DISCUSSION

We calculated six indices of the color preference style in each participant; *the average*, *the standard deviation (SD)*, *the highest* and *the lowest* of twelve VAS scores, the degree of extremity of the highest (*DEH*) and the degree of extremity of the lowest (*DEL*). The DEH (or DEL) is the mean of differences between the highest (or the lowest) score and other eleven scores, showing how extremely the most preferred (or the least preferred) color stands out from other colors in individual's preference profile.

As shown in Table 1, sex difference for each index is generally small, though it reached statistical significance for *the average* and *the DEH* probably due to large sample size. Thus, we consider there is no marked sex difference in the color preference style, and further analysis is based on the overall data.

Table 1. Indices of the color preference style.
*Asterisks indicate significant sex difference. **p< .01, *p< .05*

	Average**	Standard Deviation	The highest	The lowest	DEH*	DEL
all	61.3	23.2	93.3	24.6	34.9	40.0
male	60.2	23.1	92.9	24.4	35.8	39.0
female	62.0	23.3	93.5	24.8	34.4	40.6

We sort all data by *the average*, and picked out higher samples that scored more than mean plus 1SD (high-average group, n=191) and lower samples that scored less than mean minus 1SD (low-average group, n=178). As shown in Table 2, significant difference was found between these groups for all indices except for *the DEL*. Difference for *the SD* and *the DEH*, in which the low-average group scored higher than the high-average group, indicates that the low-average group exhibited larger fluctuation of VAS scores for twelve colors. In other words, individuals showing generally lower valuation on many colors tend to have 'choosy' color preference style; conversely, those who evaluate many colors higher are likely to have 'impartial' color preference style.

*Table 2. Indices of the color preference style for high-average and low-average groups. Asterisks indicate significant group difference. **p< .01*

	Average**	Standard Deviation**	The highest**	The lowest**	DEH**	DEL
high-average	77.5	17.9	97.3	43.8	21.5	36.8
low-average	46.1	25.4	87.2	13.0	44.8	36.2

Next we re-sorted the data by *the SD* to compare choosy/impartial color preference style. By using the same criteria as above, the large-deviation group (n=208) and the small-deviation group (n=195) were obtained. As shown in Table 3, the large-deviation group was found to have the color preference style marked by clearer discrimination of the least preferred color than the most preferred color; *the lowest* was extremely small, and *the DEL* was larger than *the DEH*. Contrastively, the small-deviation group had the color preference style showing few disliked colors. In this group, even *the lowest* was 46.2 and most colors were rated positively (scored above the neutral point=50).

*Table 3. Indices of the color preference style for large-deviation and small-deviation groups. Asterisks indicate significant group difference. **p< .01*

	Average**	Standard Deviation**	The highest**	The lowest**	DEH**	DEL**
large-deviation	55.9	34.7	98.4	5.6	46.4	54.8
small-deviation	66.1	12.1	85.1	46.2	20.7	21.7

In addition, the large-deviation group tended to prefer black and white more prominently than the small-deviation group. VAS scores of all colors excepting black and white were smaller in the large-deviation group than the small-deviation group. However, VAS scores of black was 85.7 and that of white was 83.0 in the large-deviation group, whereas 73.4 and 73.4, respectively, in the small-deviation group. Hanari and Takahashi (2008) suggested that those who prefer monochromatic colors conspicuously tend to have a particular self image such as *self concealment,* and the preference for monochromatic colors could be mediated by some top down processing. Therefore, the choosy color preference style shown in the large-deviation group may also be related to some cognitive factor. We need further consideration about the relationship between the color preference style and the cognitive factors.

4. CONCLUSIONS

In the present study, we proposed a classification of the color preference style of many people based on *the average* and *the SD*, and investigated some characteristics of each classified group. When the high-average group and the low-average group were compared, it was found that individuals in the high-average group tended to have less choosy color preference style showing smaller differences among VAS scores for liked and disliked colors. Contrastingly, the low-average group showed choosier color preference style with larger differences among VAS scores. When the large-deviation group was compared with the small-deviation group, the large-deviation group was found to have the color preference style marked by clearer discrimination of the least preferred color. On the other hand, the small-deviation group had the color preference style showing few disliked colors. We revealed that individuals had a variety of color preference styles which can be classified by its average or deviation measure, and the choosy color preference style had some unique characteristics.

ACKNOWLEDGEMENTS

This study was partly supported by a Grant-in-Aid from Sugiyama Jogakuen University (Grant-in-Aid C in the year 2012) to the first author.

REFERENCES

Hanari, T., and S. Takahashi, 2005. Relationship between cognition/attitude on colors and color preference style. In *AIC Color 2005, Proceedings*, ed. by J.L. Nieves and J.H. Hernández-Andrés. Granada: Gráficas Alhambra, S.A., 329-332.

Hanari, T., and S. Takahashi, 2008. Particular self images related to the preference for achromatic colors. In *AIC Color 2008, Proceedings*, ed. by I. Kortbawi, B. Bergstrom and K.F. Anter. Stockholm: Hotel Rival, Paper no 063.

Hanari, T., and S. Takahashi, 2009. Color preference style for multi colors and individual characteristics in color cognition. *Journal of the color science association of Japan* 33(4): 319-326 (in Japanese).

Hanari, T., and S. Takahashi, 2012. Color preference style for twelve tones in the practical color co-ordinate system (PCCS). In *AIC Color 2012 Interim Meeting of the AIC "In Color We live: Color and Environment"*, Proceedings 542-545.

Address: Prof. Takashi Hanari, Department of Media-Information,
School of Culture–Information Studies,Sugiyama Jogakuen University,
17-3 Hoshigaokamotomachi, Chikusa, Nagoya, Aichi, 464-8662 JAPAN
E-mails: hanari@sugiyama-u.ac.jp, shinya@lit.nagoya-u.ac.jp

The Usage of Color in Advertising Over Time: A Content Analytical Study Exploring Whether Economic Fluctuations are Reflected

Ellen VAN DROOGENBROECK, Malaika BRENGMAN
Vrije Universiteit Brussel

ABSTRACT

The aim of this paper is to examine whether or not economic fluctuations are reflected in the usage of color in advertising. Specifically, this study seeks to investigate whether there is a difference in the use of color in magazine advertisements between times of recession and economic growth. For this purpose the usage of color was examined carefully in a sample of 315 magazine advertisements, pertaining either to an episode of economic growth or economic downturn. The findings of this study confirm that different colors are used in magazine advertisements depending on the economic situation. Statistical comparisons of the color usage between the economic periods investigated reveal that the hues 'purple-blue', 'blue' as well as 'orange' are used more frequently during economic growth. Also more saturated colors appear to be used during economic growth than during times of recession. On the contrary, the hues 'black', 'green', 'green-yellow' and 'yellow' turn out to be applied more during an economic downturn. The colors of products displayed in the ads also appear to differ depending on the economic situation. Our findings illustrate that advertising can not only be regarded as a mirror of society, but also as a colorful mirror of the economic circumstances at the time.

1. INTRODUCTION

According to Belk & Pollay (1985), advertising can be regarded as a mirror of society. As color has a very important role in advertising (cf. Gorn et al., 1997; Litchlé, 2007; Labreque et al., 2013), the question arises whether advertising can also be regarded as a colorful mirror of one particular feature of society: the economic circumstances at the time? Whether economic fluctuations are reflected in the usage of color in marketing or advertising has, to our knowledge, not yet been explored. To begin to address this gap in the color literature, the current study attempts to answer the following research question: "is there a difference in the usage of color (hue, value and chroma) between advertisements in periods of economic growth and in periods of economic recession?" A particular domain where the impact of the economic situation on the usage of color has been studied before is the world of fashion. Helmut Gaus and his colleagues (1992) conducted a study investigating the effect of the long economic cycle or Kondratiev wave on fashion design and discerned groups of colors which appeared strongly correlated what their occurrence was concerned. It appeared that the colors of the orange-yellow cluster (including yellow, orange, red as well as highly saturated colors) were dominant just before the top of the long economic cycle, while those of the grey-black cluster (also including dark colors besides grey and black) became more dominant as the recession developed (Gaus et al. 1992, pp. 109-111). The colors of the green-blue cluster appeared to be dominant in the years prior to the top of the long economic cycle, whereas those of the brown-violet cluster (including white and pastel colors besides brown and purple) became dominant after the economic peak when the recession started to develop (Gaus et al. 1992, pp. 106-108). Based on these observations, the hypotheses for our research were developed.

H1-H10: *Warm colors* – these are the hues *yellow* (H1), *orange* (H2), *red* (H3) and *red-purple* (H4) – are anticipated to be more frequently used in advertisements during periods of economic growth than during periods of economic recession. The opposite is expected for *cool colors* – the hues *green-yellow* (H5), *green* (H6), *blue-green* (H7), *blue* (H8), *purple-blue* (H9) and *purple* (H10).

H11-H13: The *achromatic colors* - *grey* (H11) and *black* (H12) are expected to be more frequently applied in advertisements during periods of economic recession than during periods of economic growth. The opposite is anticipated for *white* (H13).

H14: *Dark colors* (colors with a low value) are more frequently used in advertisements during periods of economic recession than during periods of economic growth.

H15: *Highly saturated colors* (vibrant colors with a high chroma) are more frequently used in advertisements during periods of economic growth than during periods of economic recession.

2. METHOD

In order to answer the research questions formulated above, a content analytical study of a sample of 315 magazine advertisements was executed. The sample of ads was drawn from the Belgian magazines Knack and Knack Weekend, which were chosen as the population base for this study because of their high distribution and reading rates and their miscelaneous content coverage, targeted at the general public. Based on economical data (Eurostat, 2013) we carefully selected a period of economic growth (1999) and a period of economic downturn (2009). Considering potential color differences in advertising due to the meteorological seasons, one month was chosen per season, hereby deliberately avoiding months that could potentially bias our results.[1] In order to obtain an equal distribution of product categories advertised during both time slots, explicit quota were taken into account. The general product categories examined covered 'cars', 'beauty and care products', 'nutrition and beverages' and 'electronics and luxury products'. Sample quota for these product categories were defined based on the frequency of appearance of their ads in the magazines under investigation (see Table 1).

Table 1. Sample Quota Per Time Period

	Spring (May)	Summer (July)	Autumn (October)	Winter (January)
Cars	30 % (12)	30 % (12)	30 % (12)	30 % (12)
Beauty & Care products	25 % (10)	25 % (10)	25 % (10)	25 % (10)
Nutrition & Beverages	20 % (8)	20 % (8)	20 % (8)	20 % (8)
Electronics & Luxury products	25 % (10)	25 % (10)	25 % (10)	25 % (10)

The ads were systematically content analyzed, using a color convertor to register the colors applied to the background of the ads (dominant background color as well as backing

1 Christmas and Valentine's Day are periods wherein the color red may be excessively used. For this reason December and February were not selected. April was avoided as yellow may be particularly popular during the Easter season.

colors) and the products displayed, taking into account the three characteristics of color according to the Munsell Color System (i.e. hue, value and chroma).

Hypotheses were tested by means of Chi-square tests for independence and independent sample t-tests.

3. RESULTS AND DISCUSSION

In general no significant difference could be observed with regard to the use of warm versus cold ad background colors depending on the economic situation. Still, with regard to individual ad background colors we could discern some notable differences. Contrary to expectations, the warm color *yellow* appeared to be used more as a backing color during recession (16.5%) than during growth (9.4%); χ^2 (1; N=254; 2.821; p= .093), which means H1 should be rejected. *Orange*, on the other hand, actually appeared, as anticipated, to be more frequently used as a backing color in magazine ads during economic growth (18.1%) than during a downturn (5.5%); χ^2 (1; N=254; 9.676; p= .002), providing some support for H2. No signifcant relationship was found between the use of the hue *red* in magazine ads and the economic situation, leading to rejection of H3. H4 could not be tested as the hue *red-purple* turned out to be used very little in magazine ads. As for the cold background colors, we found as expected *green-yellow* to be used more as a backing color during recession (15.7%) than during growth (6.3%); χ^2 (1; N=254; 5.780; p= .016). Green-yellow was also used more often as most dominant background color during recession (5.9%) than during growth (1.9%); χ^2 (1; N=311; 3.325; p= .068), which means H5 can be accepted. Also the hue *green* appears to be more frequently used as most dominant background color during recession (5.9%) than during economic growth (0.6%); χ^2 (1; N=311; 6.883; p= .009), providing some support for H6. No signifcant relationship was found between the use of the hue *blue-green* in magazine ads and the economic situation, leading to rejection of H7. Contrary to our expectations, the hue *blue* appears to be more frequently used as most dominant background color during growth (13.9%) than during recession (7.8%), χ^2 (1; N=311; 2.952; p= .086), leading to rejection of H8. We also need to reject H9, as the hue *purple-blue* appears, opposed to what was anticipated, to be used more frequently during growth than during downturn: as most dominant background color ($10.8\%_{growth}$ versus $3.9\%_{recession}$); χ^2 (1; N=311; 5.307; p= .021), as well as as backing color ($18.9\%_{growth}$ versus $2.4\%_{recession}$; χ^2 (1; N=254; 18.276; p< .001). H10 could not be tested due to low occurrence of the hue *purple* in magazine advertisements.

With regard to the use of *achromatic colors*, we found no significant difference in the use of *grey* in magazine advertisements depending on the economic situation, leading to rejection of H11. The color *black,* on the other hand, did as expected to be used more frequently as most dominant background color during recession (17%) than during growth (7%); χ^2 (1; N=311; 7.462; p= .006), providing support for H12. While *white* appears, as anticipated, more frequently used as most dominant background color during growth (36.7%) than during recession (23.5%); χ^2 (1; N=311; 6.402; p= .011), we note that it is on the other hand used more as a backing color during recession (27.6%) than during growth (15%); χ^2 (1; N=254; 6.021; p= .014), providing mixed results for H13.

Mixed results are found with regard to H14. While the dominant background colors used during recession appear, as anticipated, to be darker than during growth ($M_{value} = 5.68_{recession}$ versus 6.41_{growth}; t-test t (296)= 1.706, p= .089), the opposite seems true for the backing colors ($M_{value} = 6.09_{recession}$ versus 4.96_{growth}; t-test t (384)= -3.607, p< .001).

H15, on the other hand, can be confirmed. The dominant background colors used during growth are more saturated than during recession (M_{chroma} = 6.41$_{growth}$ versus 4.03$_{recession}$; t-test t (147)= 4.185, p< .001), which is also true for the backing colors (M_{chroma} = 5.24$_{growth}$ versus 3.89$_{recession}$; t (381)= 2.946, p= .003).

We also note a significant difference in the colors of the products portrayed in the ads, which appeared to be displayed more in cold colors during economic growth than during recession (68.1%$_{growth}$ versus 53.4%$_{recession}$; χ^2 (1; N=142; 3.205; p= .073). Particularly the cold color purple-blue seemed to be more popular for products advertised during growth (9.2%) than during recession (1.3%); χ^2 (1; N=308; 9.659; p= .002). The warm color orange, on the other hand, seemed to be featured more in products advertised during recession (10.3%) than during growth (2.6%); χ^2 (1; N=308; 7.535; p= .006). We also note that during recession more black products are advertised than during growth (14.8%$_{recession}$ versus 7.8%$_{growth}$); χ^2 (1; N=308; 3.741; p= .053), as well as darker colored products (M_{value} = 4.65$_{recession}$ versus 5.56$_{growth}$; t-test t (216)= 1.974, p= .050). While we cannot discern a significant difference in the average saturation of the products advertised over both time periods, we do observe that more highly saturated products are advertised during economic growth than during a downturn (36,5%$_{growth}$ versus 25,0%$_{recession}$; χ^2 (1; N=216; 3.383; p= .066).

4. CONCLUSION

This preliminary study confirms that advertising can generally be regarded as a colorful mirror of society, in which economic fluctuations are reflected through the colors applied.

REFERENCES

Belk, R.W., and R.W. Pollay, 1985. Materialism and Magazine Advertising During the Twentieth Century. *Advances in Consumer Research* 12: 394-398.

Gaus, H., J. Van Hoe, M. Brackeleire, and P. Van der Voort, 1992. *Mensen en mode: de relatie tussen kleding en konjunktuur.* Leuven: Garant.

Gorn, G.J., A. Chattopadhyay, T. Yi, and D.W. Dahl, 1997. Effects of Color as an Executional Cue in Advertising: They're in the Shade. *Management Science* 43 (10): 1387-1400.

Labreque, L.I., V.M. Patrick, and G.R. Milne, 2013. The Marketers' Prismatic Palette: A Review of Color Research and Future Directions. *Psychology & Marketing* 30 (2): 187-202.

Lichtlé, M.-C., 2007. The effect of an advertisement's colour on emotions evoked by an ad and attitude towards the ad. *International Journal of Advertising* 26 (1): 37-62.

Address: Prof. dr. Malaika Brengman, Department of Business
Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, BELGIUM
E-mail: malaika.brengman@vub.ac.be

colour ergonomics

Age Effects on Visual Comfort for Viewing Coloured Document Layout Shown on a Tablet Computer

Hsin-Pou HUANG,[1] Yi-Ho BAI,[2] Li-Chen OU[2]
[1] Graduate Institute of Color and Illumination Technology,
National Taiwan University of Science and Technology
[2] Graduate Institute of Applied Science and Technology,
National Taiwan University of Science and Technology

ABSTRACT

Two psychophysical experiments were carried out to investigate the effect of observer age on visual comfort for reading coloured text-background combinations displayed on a tablet computer. Twenty young observers and twenty older observers participated in the study. Each observer was presented with 444 pairs of document layouts on an iPad 2, and was asked to pick one of the two layouts, of which the observer felt more comfortable to read the text. Results of Experiment 1 show that for achromatic text-background combinations, the higher lightness difference between text and background, the higher visual comfort for older observers. For young observers, on the other hand, the visual comfort values for achromatic text-background combinations remain unchanged or even start to decline for CIE lightness difference over 80. Results of Experiment 2 show that for document layouts containing achromatic text and coloured background, the higher CIELAB colour difference between text and background, the higher visual comfort for older observers. For young observers, however, the visual comfort values remain unchanged or even start to decline when CIELAB colour difference gets larger than 60.

1. INTRODUCTION

There have been extensive studies into the impacts of text-background contrast on visual comfort using desktop computer displays (Scharff and Ahumada Jr 2002; Buchner and Baumgartner 2007). Little was known, however, as to whether the findings also apply to e-reading devices, such as iPads or Kindle. The issue has become more essential in the area of aging research thanks to the increasing popularity of e-reading and web applications for older people. Our previous study (Ou et al. 2012) into visual comfort when using an LCD TV has shown that an extremely high luminance contrast for text and background could result in a decline in visual comfort, which was found to be more significant on a dark background than on a light background. The present study aims to establish whether such findings still hold true for older people reading on an e-reading device.

2. METHOD

Forty Taiwanese observers, including twenty young observers (10 male, 10 female, aged 20-30 years) and twenty older observers (6 male and 14 female, aged over 60 years), all passing Ishihara's test for colour deficiency and participating in both Experiments 1 and 2.

Both experiments were performed using an iPad 2 situated in a darkened room. The display peak white had a luminance value of 397.34 cd/m^2, with CIE chromaticity (x, y) = (0.3005, 0.3115). The viewing distance was 300 mm from the iPad 2 with a tilt angle of 15° against a desk.

Experiment 1 considered only achromatic colour combinations for text and background of a document layout. The text and background colours were based on 5 achromatic colour samples. Table 1 shows colorimetric measurement data for the 5 colours including luminance and the CIE values. Experiment 2 used both achromatic colours (as the text) and chromatic colours (as the background) for each test document layout. There were 3 achromatic and 18 chromatic colours used in Experiment 2. The 18 chromatic colours included 6 hues: red, yellow, green, cyan, blue and purple, each consisting of 3 shades (differing mainly in CIE lightness), as shown in Table 2. The 3 achromatic colour samples used in Experiment 2 were the black, medium grey and white specified in Table 1.

During Experiments 1 and 2, each observer was presented with a total of 444 paired comparisons of document layouts on the iPad 2, and was asked to pick one of the two layouts, of which the observer felt more comfortable to read the text. Each document layout presented the same text, the only difference being the luminance values (Experiment 1) and colour difference (Experiment 2) of the text and the background for the two document layouts. Figures 1 (a) and (b) show examples of screen layout of Experiments 1 and 2, respectively.

Table 1. CIE colorimetric data for colour samples used in Experiment 1 and the text colour samples used in Experiment 2 (black, medium grey and white).

Colour	Luminance	(L^*)	(x, y)
1. black	0.52 cd/m^2	1.19	(0.2638, 0.2552)
2. dark grey	12.59 cd/m^2	20.71	(0.3010, 0.3126)
3. medium grey	84.25 cd/m^2	53.17	(0.3004, 0.3114)
4. light grey	202.73 cd/m^2	76.69	(0.3010, 0.3125)
5. white	397.34 cd/m^2	100	(0.3005, 0.3115)

Table2. CIELAB values for the background colours used in Experiment 2.

Colour	L^*	C^*_{ab}	h_{ab}	Colour	L^*	C^*_{ab}	h_{ab}
1. dark red	26.9	24.9	33.2	10. dark cyan	25.6	25.4	27.3
2. red	50.8	32.5	22.3	11. cyan	49.1	31.7	258.2
3. light red	74.4	35.2	12.4	12. light cyan	76.7	33	217.4
4. dark yellow	24.8	33.3	65.3	13. dark blue	25.5	37.9	311
5. yellow	52	34.7	74.3	14. blue	51	32.1	285.3
6. light yellow	75.8	28.5	81.1	15. light blue	75.9	21.8	285.2
7. dark green	28	33.9	141.6	16. dark purple	25.2	33.7	327.1
8. green	50.8	27	141	17. purple	50.2	41.5	336.3
9. light green	76.8	31.9	141.4	18. light purple	76.6	21.3	321.4

3. RESULTS AND DISCUSSION

The scale values of visual comfort were determined using the paired comparison method (Thurstone 1927). To see whether and how CIE lightness difference between text and background might affect the observer response, the scale values obtained from Experiment 1 were plotted against the lightness difference value, as illustrated in Figure 2. It is clear from the graph that the higher the lightness difference between text and background, the higher the visual comfort for older observers. Note this tendency does not seem to be affected by the background luminance. For young observers, on the other hand, Figure 2 shows that in general, for the lightness difference over 80, the visual comfort value remains unchanged or even starts to decline, a trend different from that for older observers as described above.

Figure 3 shows results of Experiment 2. As illustrated in the graph, the higher colour difference between text and background, the higher visual comfort for older observers. Such a trend does not seem to be affected by the hue angle of the background colour, i.e. the graphs for the 6 hues appear to show similar trends. This suggests that the older observers tended to prefer large CIELAB colour difference between text and background in a document layout. For young observers, on the other hand, Figure 3 shows that in general, the larger CIELAB colour difference between text and background, the higher visual comfort value, while for the colour difference over 60 or so, the visual comfort value remains unchanged or even starts to decline.

(a) (b)

Figure 1: Examples of screen layouts for (a) Experiment 1 and (b) Experiment 2.

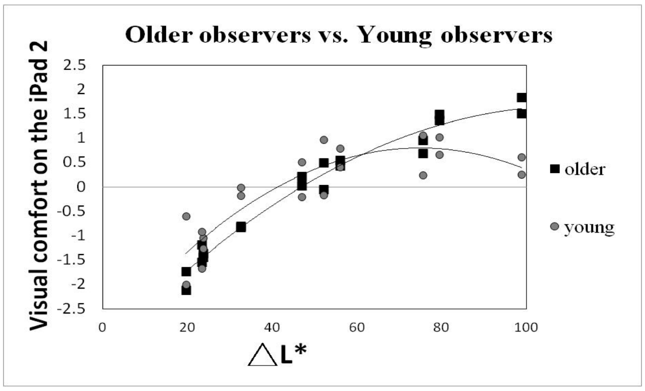


Figure 2: Young and older observer responses (visual comfort) plotted against CIE lightness difference (rL^*) between text and background as results of Experiment 1.

4. CONCLUSIONS

The visual comfort experiment using the iPad 2 shows different patterns between young and older observers. According to the experimental results, older observers tended to prefer large lightness difference (Experiment 1) or large colour difference (Experiment 2) between text and background. This suggests that older observers liked almost the biggest colour contrast in a document layout shown on the iPad 2. For young observers, on the other hand, a document layout with a medium colour contrast (lightness difference for Experiment 1 or colour difference for Experiment 2) between text and background tended to be most comfortable to read. The above tendency regarding colour difference does not seem to be affected by the hue angle of the background colour.

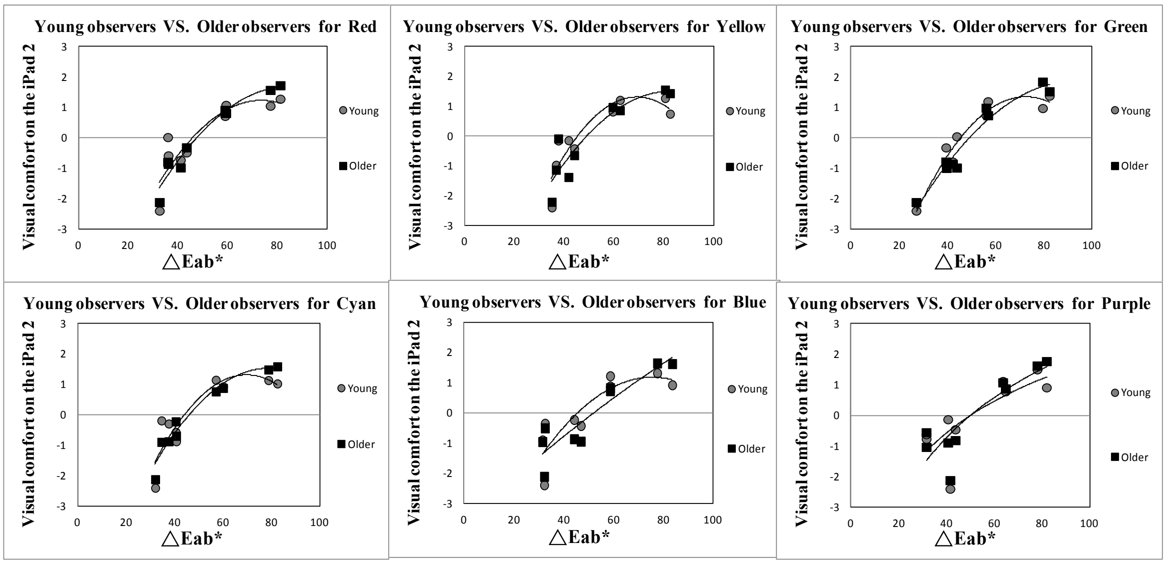


Figure 3: Young and older observer responses (visual comfort) plotted against CIELAB colour difference (rE^*_{ab}) between text and background as results of Experiment 2.

ACKNOWLEDGEMENTS

This work was supported in part by the National Science Council, Taiwan (NSC 100-2221-E-011-139-MY2 and NSC 101-2410-H-011-015-MY2).

REFERENCES

Scharff, L.F.V., and A.J. Ahumada Jr, 2002. Predicting the readability of transparent text, *Journal of Vision*, vol. 2, pp 653-666.

Buchner, A., and N. Baumgartner, 2007. Text-background polarity affects performance irrespective of ambient illumination and colour contrast, *Ergonomics*, vol. 50, pp 1036-1063.

Ou, L., P. Sun and M.R. Luo, 2012. Age effects on visual comfort as a function of lightness difference between text and background, in *Proceedings of AIC Interim Meeting 2012*, Taipei, Taiwan.

Thurstone, L.L., 1927. A law of comparative judgment, *Psychological Review*, vol. 34, pp 273-286.

Address: Hsin-Pou Huang, Graduate Institute of Color and Illumination Technology
National Taiwan University of Science and Technology
43, Section 4, Keelung Road., Taipei, Taiwan
E-mails: j133212001@gmail.com,
D10022503@mail.ntust.edu.tw, lichenou@mail.ntust.edu.tw

The Suitable Relation between Correlated Color Temperature and Illuminance for Life Activities and those Control Speeds Considering Visibility Decrease with Age

Youko INOUE, Yuki OE
Dept. of Residential Architecture and Environmental Science, Nara Women's University

ABSTRACT

This paper investigates the suitable relation between illuminance and correlated color temperature (CCT) for life activities and control speeds of illuminance or CCT considering visibility decrease with age to create a comfortable and energy-saving lighting environment by utilizing LED based on subjective experiment. The subjects are 31 young people and 26 elderly people without color blindness. Then, we clarify following relationships on the two age groups. It is clear that there is significant age difference in the noticeable, the comfortable and the acceptable in the lighting environment.

1. Relationship among the illuminance, CCT and the acceptable ratio for six fundamental indoor life activities.
2. Relationship among before and after illuminance in change, CCT, the adjustment speed of illuminance and the ratios of "Noticeable" or "Acceptable".
3. Relationship among before and after CCT in change, illuminance, the adjustment speed of CCT and the ratios of "Noticeable" or "Acceptable".

1. INTRODUCTION

In recent years, development of solid-state light sources such as LEDs and OLEDs makes it easy to propose comfortable energy-saving lighting by adjustment of lighting environment through a day with considering life activities. But today, many developed countries including Japan are confronted with an aging society. It is clear that visual function decreases with age, and elderly people need higher illuminance to obtain visibility as same as young people, and they need more time to adapt to light changing.

The purpose of this research is to propose comfortable and energy-saving light environment for both young and elderly people. First, we consider the relationship between illuminance and correlated color temperature (CCT) for six fundamental indoor life activities on the two age groups. Second, we suggest the acceptable adjustment speed of illuminance or CCT in order to provide a comfortable energy-saving lighting.

2. EXPERIMENTAL CONDITION

The interior color of the experimental room is white of reflectance 0.8, and the size of room is W2.7m × D2.9m × H2.8m as shown in Figure 1. Experiment variables are illuminance, CCT and those control speeds. An adjustable LED ceiling light is used to control the adjustment speed of illuminance and CCT. They are adjusted logarithmic with respect to time. The illuminance of the light can be adjusted from 0 to 1200 lx (0 to about 300 cd/m^2), and CCT from 3000 to 5700K which are controlled by measurement values on the center of the desk. Figure 2 shows examples of spectral distributions of the lighting.

All evaluations by subjects are performed by seeing the center of the desk. The subjects are 31 young people and 26 elderly people without color blindness. They evaluate the degree of brightness and color tone after sufficient adaptation to lighting environment. Then, they assume six fundamental indoor life activities, such as "checking steps", "reading the newspaper", "eating", "chatting with the family", "relaxing", and "sleeping", and they evaluate the acceptable level of brightness and color tone. Furthermore, they evaluate whether the light environment had changed and how comfortable or acceptable the change of the light environment is.

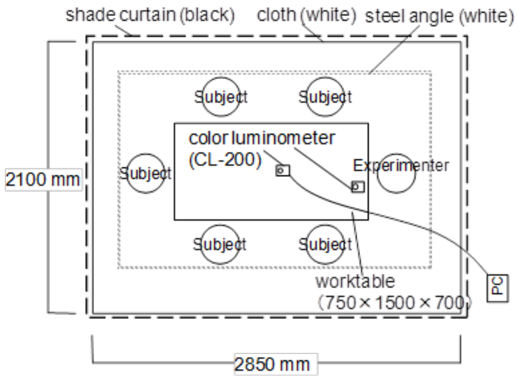


Figure 1: Experimental room.

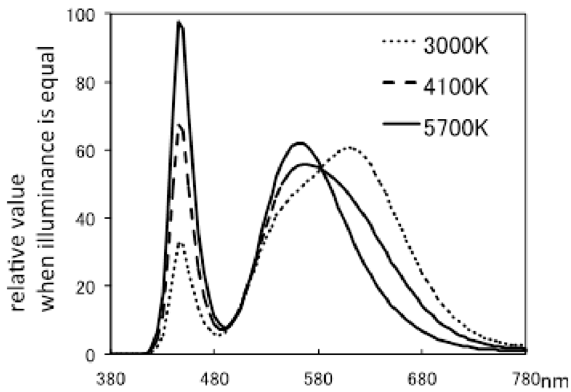


Figure 2: Spectral distribution of the lighting.

3. RESULTS AND DISCUSSION

3.1 Illuminance and CCT for Each Life Activity

Illuminance has three levels (30, 300, 1100 lx) , and CCT has three levels (3000, 4100, 5700K) . When subjects assume the indoor life activities, particularly checking steps, the range of conditions that 80% of the elderly people can accept is narrower than that of the young people except sleeping as shown in Figure 3. In brightness, the elderly people need high illuminance with low color temperature except sleeping, however, this tendency fades in color tone by lighting. Among the young people, the influence of the correlated color temperature differences with life activitie, and this tendency is clearer at a higher vote.

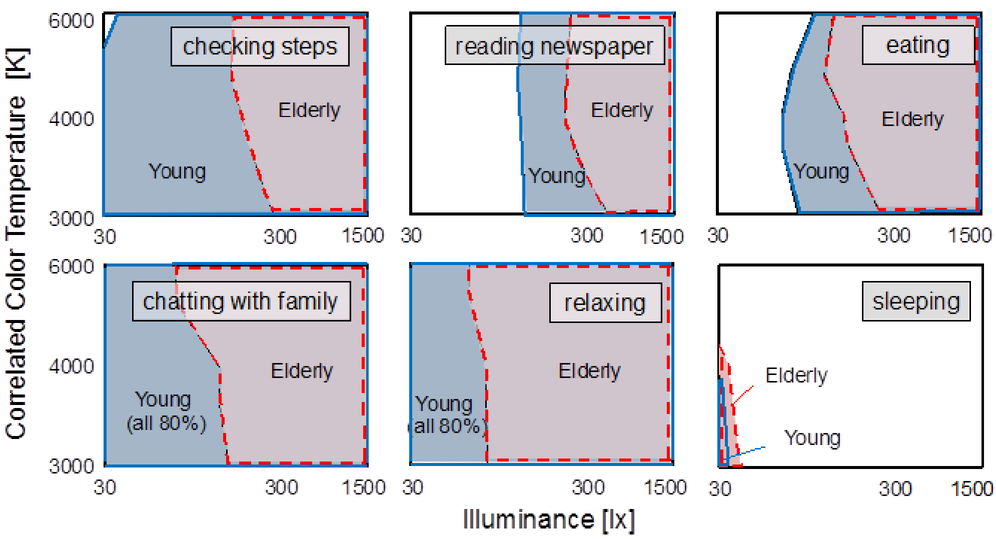


Figure 3: 80% votes of Acceptable condition for each life activity in brightness.

3.2 Adjustment Speed

The adjustment speed of illuminance has six levels (SE = 0.03~2.9, ∞:instantaneous change), that of CCT has four levels (Sc = 0.015~0.28, ∞) and they are defined as:

$$S_E = |\log E1 - \log E2| / t, \quad Sc = |\log T1 - \log T2| / t$$

E1: illuminance before the change, E2: illuminance after the change

T1: CCT before the change, T2: CCT after the change, t : the changing time [min.]

In both age groups, results for the same conditions are as the vote of "Noticeable" > "Uncomfortable" ≥ "Unacceptable" as shown in Figure 4. Therefore, although subjects notice the change of the light environment, they do not feel uncomfortable, and although they feel uncomfortable, they can accept the change.

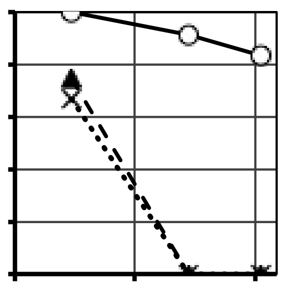


Figure 4: Relationship among evaluation contents (T1=3000K→T2=5700K, Sc=0.093).

Table 1: Evaluation contents and scale.

Noticeability	Comfortability	Acceptability
Cannot notice	Comfortable	Acceptable
Difficult to notice	Mostly comfortable	Mostly acceptable
Somewhat noticeable	Neutral	Marginally acceptable
Moderately noticeable	Mostly uncomfortable	Mostly unacceptable
Easy to notice	Uncomfortable	Unacceptable

Figure 5 shows results of 95% votes for either "Noticeable" or "Acceptable" in each S_E as adjustment speed of illuminance. In both age groups, although there is almost no influence of illuminance ratio E2/E1 between before and after change in the "Noticeable", the ratio has influenced the "Acceptable". The influence of S_E is different between the young and elderly people. For a brightening change, the young people do not accept the change of illuminance as S_E becomes faster, while the elderly people accept the momentary change of illuminance. For a darkening change, the young people can accept the change of illuminance as S_E becomes slower. However, even if the adjustment speed is slower, elderly people do not accept the change of lighting. It has a little influence of CCT on the young people at low illuminance and high speed, however, the further examination is required about this.

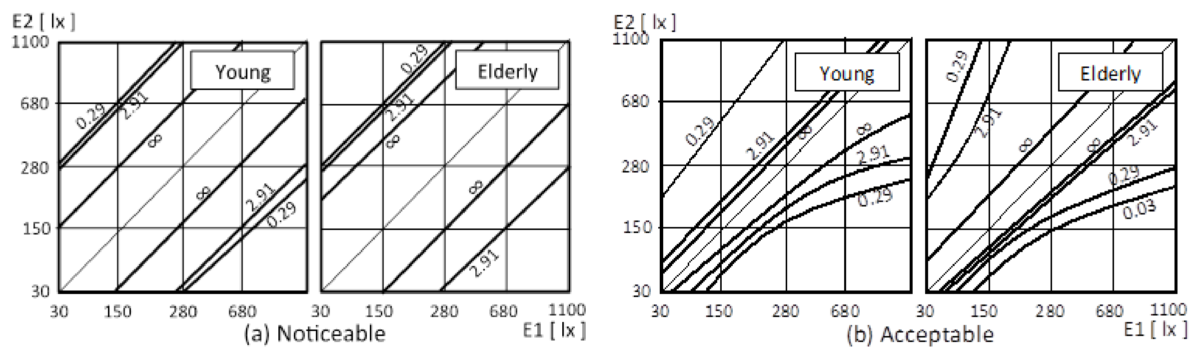


Figure 5: Adjustment speed of illuminance (95% votes, 4000K).

Figure 6 shows results of 95% votes for either "Noticeable" or "Acceptable" in each Sc as adjustment speed of CCT. As same as the case of illuminance change, although there is almost no influence of CCT ratio T2/T1 between before and after change in the “Noticeable”, the ratio has influenced the “Acceptable”, especially the elderly people. In the “Noticeable”, there is little influence of Sc on the votes within infinity to 0.093, especially the young people. For the elderly people in the change of increasing CCT, votes of “Noticeable” and “Acceptable” is almost equal. As shown in Figure 4, it has influence of illuminance only on the elderly people, and negative votes become high at 30 lx, and it becomes less than 20% above 280 lx.

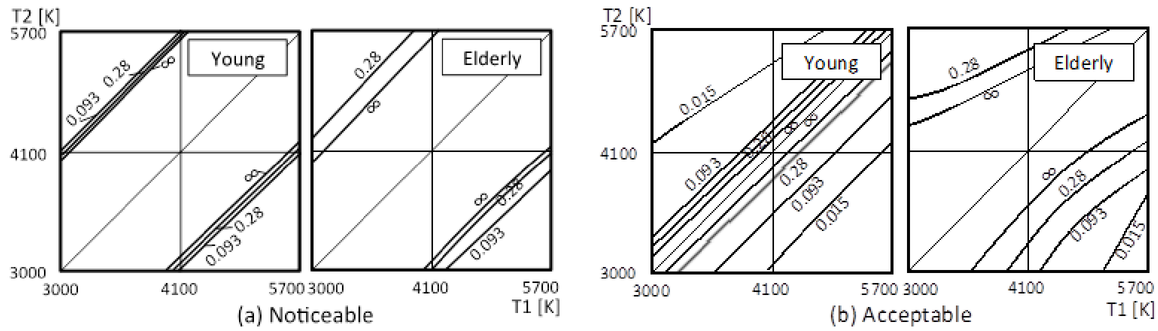


Figure 6*: A*djustment speed of Correlated color temperature *(95% votes, 280 lx).*

4. CONCLUSIONS AND FUTURE PLAN

In order to create a comfortable and energy-saving lighting environment by utilizing LED, subjective experimental results on acceptable relation between illuminance and CCT for both of the young and elderly people in six fundamental indoor life activities are presented. Moreover, acceptable adjustment speeds of illuminance or CCT are presented based on experiment results and changes by aging are discussed. In the future work, the effect of the concurrent change of illuminance and CCT has to be examined, and the proposed lighting method needs to be verified in an actual living space.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number C21560612, and the adjustment program of lighting was supported by Sharp Corporation.

REFERENCES

Inoue, Y., and M. Ishihara, 2011. The control method of lighting considering the comfortableness and the consumption energy, (part 1) Allowed adjustment speed of illuminance, and (part 2) Allowed adjustment speed of correlated color temperature. In *44th Annual Conference of the Illuminating Engineering Institute of Japan*, Proceedings, ed. by IEIJ, Ehime. 272-273 and 171-172.

Oe, Y., and Y. Inoue, 2013. Comfortable Lighting Considering Visibility Decrease with Age-The Suitable Condition of Illuminance for Life Activities and its Adjustment Speed-, In the *7th LUX PACIFICA 2013*. Proceedings, ed. by Society of LUX PACIFICA. Bangkok. 74-79.

Address: Prof. Youko Inoue, Dept. of Residential Architecture and Environmental Science, Nara Women’s University, Kitauoya-Nishimachi, Nara, 603-8506, Japan
E-mails: youkoinoue@cc.nara-wu.ac.jp, yukioe1117@gmail.com

The Impact of 'Blue' and 'Red' Lights on Alertness in the Afternoon

Mariana G. FIGUEIRO, Levent SAHIN
Lighting Research Center, Rensselaer Polytechnic Institute

ABSTRACT

Most studies to date have associated the alerting effects of light, particularly short-wavelength light, to its ability to suppress nocturnal melatonin production, which signals nighttime to the body. Recent studies, however, have shown alerting effects of long-wavelength (red) light, which does not suppress melatonin. Moreover, other studies showed that white or narrowband short-wavelength light during daytime, when melatonin levels are low increase measures of alertness. The aim of the current study was to investigate how exposures to short-wavelength (blue) light (40 lux, 40.2 $\mu W/cm^2$, $\lambda_{max} = 470$ nm) and long-wavelength (red) light (40 lux, 18.9 $\mu W/cm^2$, $\lambda_{max} = 630$ nm) close to the post-lunch dip hours affect electroencephalogram measures in participants with regular sleep schedules. Power in the alpha, alpha theta, and theta ranges was significantly lower ($p < 0.05$) after participants experienced red light than after they remained in darkness. Blue light reduced alpha and alpha theta power compared to darkness, but these differences did not reach statistical significance ($p > 0.05$). The present results extend those performed at night and demonstrate that light can be used to increase daytime alertness. These results also suggest that acute melatonin suppression is not needed to elicit an alerting effect in humans.

1. INTRODUCTION

Alertness, a construct associated with high levels of environmental awareness, is regulated by the interplay between the circadian timing system (circadian process) and the duration of time awake (homeostatic process) (Borbély 1982). The circadian process is regulated by the endogenous circadian pacemaker, which is sychronized daily with the environment by the 24-hour light/dark patterns incident on the retina. In diurnal species, the circadian process promotes alertness during the day and sleep at night. On the other hand, the homeostatic process accumulates sleep pressure as the number of waking hours increases.

In most studies to date, the alerting effects of light have been linked to its ability to suppress melatonin (Figueiro et al. 2007), which is a hormone produced at night and under conditions of darkness. It is now well accepted that the circadian system, as measured by acute melatonin supression, is maximally sensitive to short-wavelength (blue) light, but not to long-wavelength (red) light. In a recent study, however, Figueiro et al. (2009) demonstrated that, relative to darkness, exposures to both blue and red lights in the middle of the night increased beta and reduced alpha power, and exposures to high (40 lux at the cornea) but not low (10 lux at the cornea) levels of red and blue light significantly increased the heart rate. These are all measures associated with increased alertness. The findings suggest that acute melatonin suppression is not needed for light to have an effect on alertness at night, since only the blue light significantly suppressed melatonin levels compared to the dark condition. These results are consistent with studies measuring the effects of daytime light exposure on brain activity using functional magnetic resonance imaging (fMRI) (Phipps-Nelson et al. 2003, Vandewalle et al. 2006). The authors of these studies demonstrated that polychromatic (white) and short-wavelength light exposures increase measures of alertness during the daytime, when melatonin levels are low.

Since the use of light to promote alertness at night is better understood, it is important to develop lighting schemes to promote alertness during the day, especially during the post-lunch hours, when the circadian drive for alertness is not strong enough to oppose increased homeostatic sleep pressure. The aim of the current study was to extend the findings from Figueiro et al. (2009) and investigate how exposure to blue and red lights during the middle of the afternoon affects objective measures of alertness and subjective measures of sleepiness in participants with regular sleep schedules. It was hypothesized that, if light can impact alertness via pathways other than melatonin suppression, then, both blue and red lights would decrease alpha, theta, and alpha theta power relative to dim light.

2. METHOD

2.1 Participants

Thirteen healthy, paid volunteers, eight males (19-28 years, median = 20.5) and five females (18-25 years, median = 21), participated in the within-subjects study. Participants were asked to refrain from alcohol and caffeine intake 12 hours before the experimental session. Participants were also required to go to bed between 22:00 and 23:00 the night before the experiment and wake up no later than 7:30 and refrain from napping on the day of the experiment.

2.2 Lighting Condition

In addition to being in the dark (< 0.01 at cornea) condition, participants experienced 40 lux of either long-wavelength red (λ_{max} = 630 nm, 18.9 μW/cm^2) light or short-wavelength blue (λ_{max} = 470 nm, 40.2 μW/cm^2) light, administered by arrays of light emitting diodes with a full width at half maximum of 25 nm.

2.3 Electroencephalogram (EEG)

The BioSemi ActiveTwo system (BioSemi, Amsterdam, Netherlands) with active electrodes was used for EEG recordings. Electrodes were placed on the scalps of participants according to the International 10-20 system (Sharbrough et al. 1991) at Fz, Cz, Pz, and Oz. Two additional electrodes were attached to the right and left earlobes to serve as reference electrodes for those attached to the scalp.

2.4 Procedure

Upon their arrival to the lab at 14:00, participants were kept seated under dim light conditions (< 2 lux at eye level) while they were being fitted with scalp electrodes for EEG measurement. Sessions started at 14:30 and lasted for approximately 60 minutes. During the study, each participant was presented with dark (D, < 0.01 lux), red (RL, λ_{max} = 630 nm, 40 lux), and blue (BL, λ_{max} = 470 nm, 40 lux) lighting conditions in a counterbalanced manner.

3. RESULTS AND DISCUSSION

A 3 (lighting conditions) x 4 (electrode sites) x 6 (trials) repeated-measures ANOVA revealed a significant main effect of lighting conditions in the normalized alpha ($F2,24 = 5.6$; $p = 0.01$), alpha theta ($F2,24 = 6.1$; $p = 0.007$), and theta ($F2,24 = 4.6$; $p = 0.02$) ranges.

Compared to the power in the D condition, power in the alpha, alpha theta, and theta ranges was significantly lower after exposure to the RL [$t(12) = 3.860$, $p = 0.002$, $t(12) = 7.378$, $p < 0.0001$, $t(12) = 6.579$, $p < 0.0001$, respectively], but not after exposure to the BL condition.

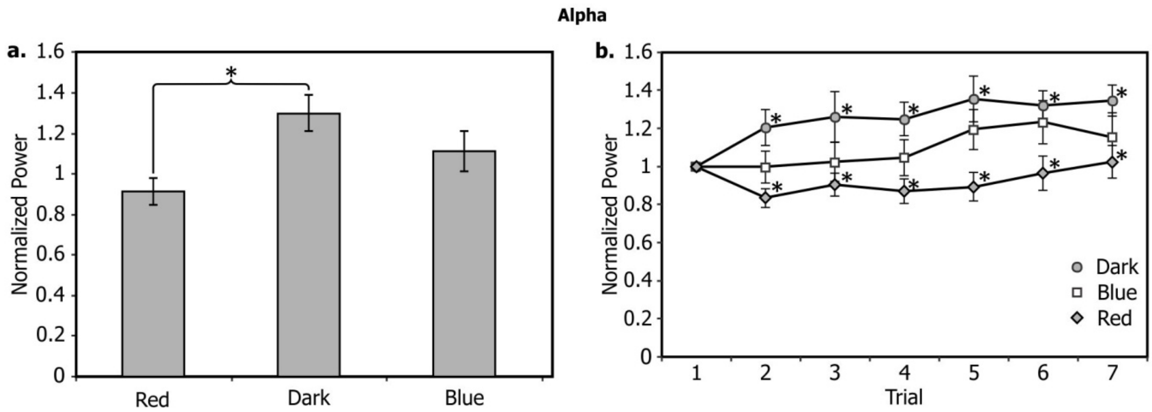


Figure 1: a) Average ± standard error of the mean normalized alpha power (8-12 Hz) for red, dark, and blue lighting conditions. Compared to remaining in darkness, alpha power was significantly reduced (*) after exposure to red but not after exposure to blue light; b) Average ± standard error of the mean of the normalized alpha power (8-12 Hz) for red, dark, and blue lighting conditions at each trial (1-7). The power at trials 2 to 7 was normalized to the power at trial 1, which was collected in darkness. Compared to remaining in darkness, alpha power was significantly (*) reduced in the red lighting condition after approximately 5 minutes of light onset and remained significantly lower throughout the 48-minute light exposure period. Similar results were obtained for power in the alpha theta and theta ranges of the EEG spectrum (not shown).

Our results show that, compared to remaining in darkness, red light exposure in the middle of the afternoon significantly reduces power in the alpha, alpha theta, and theta ranges, suggesting that red light increases alertness not only at night, but also during the afternoon hours. Moreover, our results indicate that red light is a more potent stimulus for modulating brain activities associated with daytime alertness than blue light at the same photopic light level (40 lux). Compared to darkness, power in the alpha, alpha theta, and theta ranges after short-wavelength light exposure was reduced, but this difference did not reach statistical significance.

The present work extends that from Figueiro et al. (2009), which showed that both short- and long-wavelength light exposures in the middle of the night decreased alpha power and increased beta power compared to darkness. Here, we show that the same long-wavelength light stimuli (40 lux, $\lambda_{max} = 630$ nm) can also impact objective measures of alertness in the middle of the afternoon, suggesting that light-induced melatonin suppression is not needed for light to have an impact on objective measures of alertness.

ACKNOWLEDGEMENTS

The study was funded by the Office of Naval Research and the Istanbul Transportation Co.

REFERENCES

Borbély, A. 1982. A Two Process Model of Sleep Regulation. *Human Neurobiology* 1 (3): 195-204.

Figueiro, M.G., A. Bierman, B. Plitnick and M.S. Rea, 2009. Preliminary Evidence that Both Blue and Red Light Can Induce Alertness at Night. *BMC Neuroscience* 10 (1): 105.

Figueiro, M.G., J.D. Bullough, A. Bierman, C.R. Fay and M.S. Rea, 2007. On Light as an Alerting Stimulus at Night. *Acta Neurobiologiae* 67 (2): 171-178.

Phipps-Nelson, J., J.R. Redman, D.J. Dijk and S.M. Rajaratnam, 2003. Daytime Exposure to Bright Light, as Compared to Dim Light, Decreases Sleepiness and Improves Psychomotor Vigilance Performance. *Sleep* 26 (6): 695-700.

Sharbrough, F., G.E. Chatrian, R.P. Lesser, H. Luders, M. Nuwer and T.W. Picton, 1991. Guidelines for Standard Electrode Position Nomenclature. *Journal of Clinical Neurophysiology* 8: 200-202.

Vandewalle, G., E. Balteau, C. Phillips, C. Degueldre, V. Moreau, V. Sterpenich, G. Albouy, A. Darsaud, M. Desseilles, T. Dang-Vu, P. Peigneux, A. Luxen, D.J. Dijk and P. Maquet, 2006. Daytime Light Exposure Dynamically Enhances Brain Responses. *Current Biology* 16 (16): 1616-1621.

Address: Mariana Figueiro, Lighting Research Center, Rensselaer Polytechnic Institute,
21 Union Street, Troy, New York 12180 USA
E-mail: figuem@rpi.edu

Evaluation of Visibility of Color under a Range of Spectral Illumination using Physically Based Spectral Rendering Images: Comparison of Reaction Times for Colored Handrail in the Bathroom

Taka-aki SUZUKI,[1] Keizo SHINOMORI,[2] Naoki MURAI,[3]
Yuji OZAKI,[3] Shigeki NAKAUCHI[4]
[1] Industrial Research Institute of Shizuoka Prefecture
[2] School of Information, Kochi University of Technology
[3] Aronkasei Co., Ltd.
[4] Department of Computer Science and Engineering, Toyohashi University of Technology

ABSTRACT

We measured the reaction time (RT) for subjects exposed to stimuli in the form of for colored handrail images as stimuli on a LCD display. The stimulus images were generated using physically based spectral rendering under types of lighting: a fluorescent lamp with a color temperature of 5,000 K (FL_D condition), and a LED lamp with color temperatures 3,200 K and 5,000 K (LED_A and LED_D conditions). Seventeen elderly subjects (64-84 years, mean ages: 72.2 years) participated in the experiment. The results for the three lighting sources indicated that RTs in the case of blue and orange handrails under LED_A condition were significantly longer than those under LED_D and FL_D conditions, respectively. In addition, RTs to orange handrails were not significantly longer than those for pink and red under FL_D condition, but were significantly longer for LED_A and LED_D conditions. The results indicate that this evaluation approach is effective in quantitatively evaluating the noticeability of color design under various types of lighting, e.g., fluorescent lamps and LEDs, quantitatively.

1. INTRODUCTION

The color of a bathroom handrail should be highly noticeable to allow it to be easily perceived and immediately grasped. It is also desirable that the color's visibility remains constant under a broad spectrum of lighting; e.g., filament lighting, fluorescent lighting and LED lighting. However, it is inconvenient to carry out experiments involving the use of actual colored products involving large numbers of combinations of lighting and handrail colors, due to the large amount of preparations involved and the burden placed on the test subjects (Figure 1).

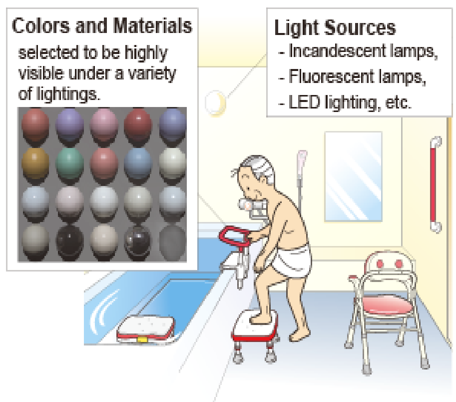


Figure 1: Bathroom handrail color design. A high level of visibility under a variety of light sources is desirable.

In the present study, in order to evaluate the visibility of handrail colors under a broad spectrum of lighting more efficiently, we propose an evaluation approach based on measuring the reaction time (RT) of subjects to stimuli comprising physically based spectral rendering images as stimuli. This evaluation technique with the rendering images allows to reduce the work for trial productions and the burden of subjects in evaluation experiments, as well as to implement the evidence-based design process.

2. METHOD

2.1 Gonio-Spectral Reflectance Measurements

We measured the gonio-spectral reflectance of six planar color bath handrail samples, along with tiles and a resin material sample for use in the intended bathroom model. The six bath handrail colors were green, blue, orange, pink and two different reds (red_1, red_2). A gonio-spectrophotometric color measurement system (Murakami Color Research Laboratory, GCMS-4) was used (Figure 2). The measuring wavelengths ranged from 390 nm to 730 nm at 10 nm intervals. The bidirectional reflectance distribution function (BRDF) was derived from the measurement data.

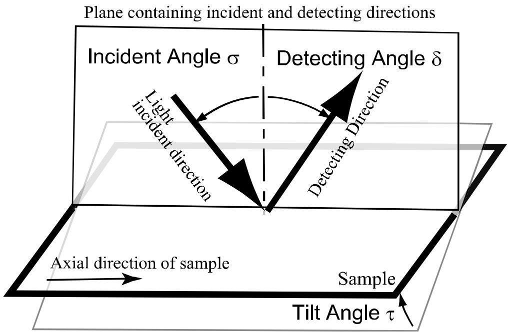


Figure 2: Angular coordinate *of the gonio-spectral* measurements. D*iffused reflectance*: σ: -30°–60°, δ*:* -25°–180°, τ*: 0°–55.7°*, *412 conditions* Specular reflectance: σ (δ): *10–70°*, *13 conditions*

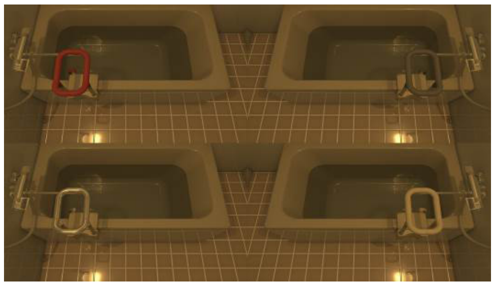


Figure 3: Stimulus images. The target is the upper left image out of these stimuli.

2.2 Physically Based Spectral Image Rendering

A handrail model was placed in a three-dimensional geometric model of a bathroom, and the BRDFs were set for each corresponding material surface as its reflection properties. Three lighting conditions were set a fluorescent lamp of color temperature 5,000 K (FL_D condition), and an LED lamp of color temperature 3,200 K and 5,000 K (LED_A and LED_D conditions). The spectral property of each light source was defined by the measured spectral distribution for the actual lamps. The total flux of the light source was set so that the minimum illuminance of the floor became 200 lx. Two-dimensional spectral light intensity distributions of the designated scene for each handrail color were rendered between 400 nm and 700 nm at intervals of 10 nm by the bi-directional ray-tracing simulation. Tristimulus values for each pixel in the designated scene pictures were calculated from the sum of the products of each pixel value of the monochromatic light intensity and CIE 1931 2-degree color-matching functions. The tristimulus values were converted to the RGB values for each pixel of the stimulus images using the ICC color profile of the display. Highlights of more than 120 cd/m^2, the maximum luminance of the display used in the experiment, were clipped. The calculated luminance of a perfect reflecting diffuser placed in the rendering scene under D65 light source was 36.7 cd/m^2 and was confirmed to be lower enough to present on the display.

2.3 Experiment Measuring Reaction Times

Four generated stimulus images, one of which was the target and the others being non-targets (Figure 3), were shown as a four-part split screen on the LCD display (EIZO, SX2462W, adjusted to Adobe RGB color Gamut, maximum luminance = 120 cd/m^2, and Gamma = 2.2). The target image included a colored handrail (green, blue, orange, pink, red_1 and red_2). The non-target images included the following: a colorless handrail whose surface was an ivory color of the original resin material, a silver color equivalent to that of a faucet, and a gray color with an equivalent luminance to the target color. Stimuli were randomly presented in a successive manner on the display. The duration of the presentation of each stimulus presentation was 1500 ms and the interval between presentations randomly varied between 4000 ms and 6000 ms. The Subjects were in a dark room and adapted to darkness for 3 minutes. Then they looked at a white screen (120cd/m^2) on the display for 3 minutes before commencing tasks. Subjects responded by immediately pressing the button corresponding to the position where the target stimulus was shown on the split screen. The positions of the one target image and the other three non-target images were changed at random. The correct/incorrect reactions and RTs were recorded (Suzuki et al., 2005, 2006). RTs regarding the target image in each color were measured 24 times and averaged. Seventeen elderly subjects (64-84 years, mean ages: 72.2years, with normal color vision) participated.

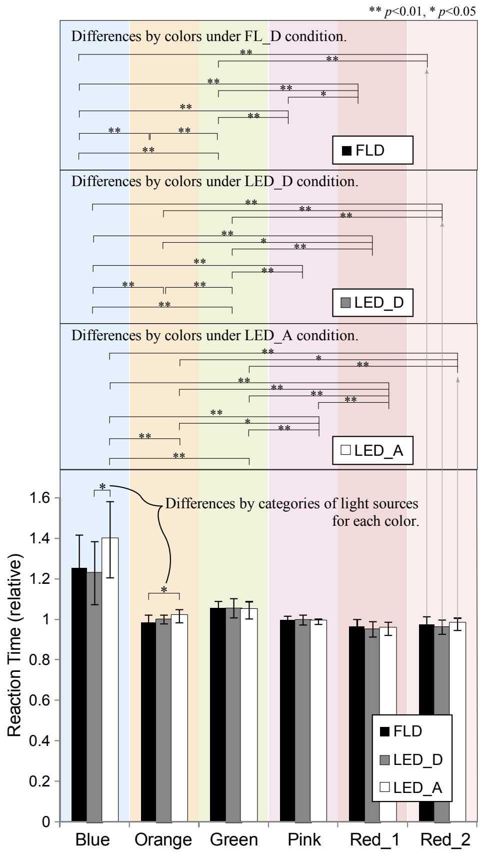


Figure 4: Experimental results.

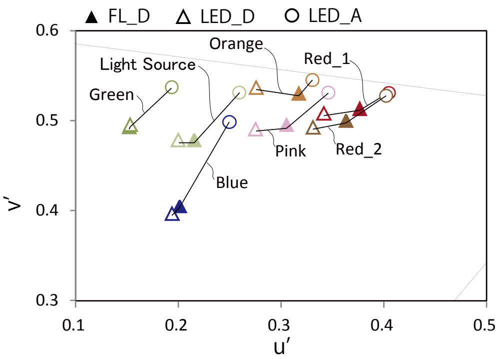


Figure 5: u'v'-chromaticity of light sources and test colors under each lighting conditions.

3. RESULTS AND DISCUSSION

RTs were normalized using the RT for pink for each subject. Figure 4 shows the mean RTs of all subjects for each handrail color under each light source. The RTs were examined using the Steel-Dwass multiple comparison among the light sources for each handrail color and among handrail colors under each light source (Figure 4). RTs for blue and orange handrails under LED_A were significantly longer than those under LED_D and FL_D, respectively. Any significant differences among lighting conditions for each color were not found. RTs for red_1 were significantly shorter than those for the other colors except for red_2 under LED_A. RTs for blue and green handrails color were significantly longer than those for the other handrails colors under all lighting conditions, excluding comparison between those of green and orange handrails under LED_A. RTs for orange handrails were not significantly longer than those for pink and red handrails under FL_D, but were significantly longer under LED_A and LED_D. These results suggested that visibility of the color orange decreases under LED illuminations. The results of the experiment indicated that RTs reflecting the visibility for some colors could vary depending on the lighting source, but did not vary in the case of others. Below, we discuss the causes of the differences among RTs. Figure 5 shows CIE1976UCS u'v'-chromaticity of light sources and test colors calculated from spectral distribution of lamps, and the spectral reflectance at 45° incidence and 0° detection. In the case of LED_A, the difference between the chromaticity coordinates of the light source and blue and orange become smaller than those of other colors. This suggests that the slow RTs in the cases of blue and orange handrails may be caused by the decreased color difference. Meanwhile, in the case of LED_D, the RTs for orange, pink, red_1 and red_2 stayed unchanged compared to those under other lighting conditions, even though the difference between the chromaticity coordinates of light source and those colors is smaller. This suggests that the variations of RTs were caused not only by the change in the chromaticity but also by something other (e.g., the complexity of the background). It means that RTs cannot be estimated using colorimetric analysis. We therefore consider that this method, which involves the measuring of the RTs of subjects responding to images generated using physically based spectral rendering images, is effective in quantitatively evaluating the noticeability of color design under various lighting conditions.

4. CONCLUSIONS

We measured subjects' RTs to images generated using physically based spectral rendering images, and showed that RTs varied according to handrail colors and type of lighting. The results indicate that this evaluation approach is effective in quantitatively evaluating the noticeability of color design under various lighting conditions. We also proposed the function-oriented color design approach using both these RT measurements and the subjective estimation (Shinomori et al., 2013).

REFERENCES

Shinomori, K., T. Suzuki, N. Murai, Y. Ozaki, and S. Nakauchi, 2013. Function-oriented color selection technique using subjective estimation (paired comparison of images) and psychophysical evaluation (reaction time measurement). *In AIC Color 2013, Proceedings,* Newcastle, *in press*.

Suzuki, T., Q. Yi, S. Sakuragawa, H. Tamura, and K. Okajima, 2006. Age-related changes of reaction time and P300 for low-contrast color stimuli. *Journal of Physiological Anthropology and Applied Human Science* 25(2): 179-178.

Suzuki, T., Q. Yi, S. Sakuragawa, H. Tamura, and K. Okajima, 2005. Comparing the visibility of low-contrast color landolt Cs. - Effect of aging human lens -. *Color Research and Application* 30(1): 5-13.

Address: Dr. Taka-aki SUZUKI, Machinery Division, Industrial Research Institute of Shizuoka Prefecture, 2078 Makigaya, Aoi-ku, Shizuoka-City,421-1298, JAPAN
E-mails: suzukita@iri.pref.shizuoka.jp, shinomori.keizo@kochi-tech.ac.jp, n-murai@aronkasei.co.jp, y-ozaki@aronkasei.co.jp, nakauchi@tut.jp

Task-Based Accessibility Measurement of Daltonization Algorithms for Information Graphics

Joschua Thomas SIMON-LIEDTKE, Jon Yngve HARDEBERG
The Norwegian Colour and Video Computing Laboratory, Gjøvik University College

ABSTRACT

Color deficient people make up about eight percent of the male population and they are often confronted with problems when retrieving information from color information graphics like transportation or geographic maps. So-called daltonization algorithms to improve images for color deficient people have been widely discussed, but it has been difficult to compare and analyze the different strategies with psycho-physical experiments due to the vast time consumption of such setups and the somewhat rarity of color deficient observers. Thus, we propose a framework that compares different algorithms based on a task-fulfilling experiment and the use of simulation algorithms in order to use normal sighted observers as "virtual" color deficient observers. We found out that both the accuracy and the variation of the reaction time can be used as an indicator for good or bad algorithms. We also related it to the color differences among the colors in the graphic and propose an objective measurement based on lightness and chroma as starting point for future measurement methods and daltonization algorithms.

1. INTRODUCTION

The nature of color deficiencies is relatively well understood (Rigden 1999), and well established models exist to simulate color deficiencies (Brettel *et al.* 1997, Kotera 2012, Viénot *et al.* 1999). Based on these models, so-called daltonization algorithms have been proposed by Anagnostopoulos *et al.* (2007), Kotera (2012) and others, which can adjust the color palette of images (and information graphics) so as to improve their quality and accessibility in terms of retrieving information content for color deficient people.

However, evaluating different daltonization algorithms is difficult due to the limited number of color deficient observers available for the researcher and due to the complexity and time consumption of traditional psycho-physical methods like rank order or pair comparison. Likewise, choosing a good color palette is becoming one important goal of making graphics more accessible in the light of universal design. The goal of this paper is to introduce a framework that can measure the effectiveness of daltonization algorithms specifically and the accessibility of information graphics generally. The paper is based on the premise that a well accessible image allows both color deficient and normal sighted observers to retrieve information quickly from the graphic. This is why we based our experiment on the reaction time needed for an observer to fulfill a certain task.

On the one hand, we decided to simulate the original and daltonized images such that normal sighted people can be used as "virtual" color deficient people assuming that the used algorithms simulate color deficiencies accurately. On the other hand, we chose a task-fulfilling experiment as setup for the framework in order to reduce experimentation time and in order to create a more life-like experience for the observer.

2. METHOD

To begin with, we compute the simulation, the daltonized version of the image and the simulated version of the daltonized image given a particular information graphic. For the original image, we identify the patches and colors of interest, i.e. the colors of the transportation lines that the observer will be asked to identify. For all of these patches we extract the RGB color values from all versions.

Secondly, we show randomly each of the different versions and the original to the observer on a gray background (c.Fig.1-lft). Each of the possible color patches associated with the particular image version are shown next to the target patch in a random order. The observer is then asked to click on the target patch in order to start the experiment, and then he/she has the task to click as quickly as possible on the right transportation line inside of the map. When the correct transportation line is clicked, the program proceeds to the next color patch. Also, the exact time needed to find the right transportation line is stored in a database, together with the exact position of the click inside the map and the information about whether or not the observer succeeds to click on the right line on the first try.

For our experimentation, we chose three different images of public transportation maps from the Norwegian cities Gjøvik, Bodø and Oslo. Also, we tested two different simulation and daltonizing algorithms based on Kotera (2012) and Viénot *et al.* (1997)/ Anagnostopoulos (2007). Thus, we get seven different versions per image - a total of 21 images for the experiment. With respect to the patches, we had five different transportation lines for the Bodø images, six for the Oslo images and seven for the Gjøvik images.

Moreover, we had a total of 23 observers, typically students between 20-30 years old; none of the observers were color deficient. The experiment was implemented as a website running on a development server on the local machine presented on a calibrated laptop screen. The website was presented in a Chrome browser window in full screen. The experiment was setup in a controlled environment with simulated D50 lighting.

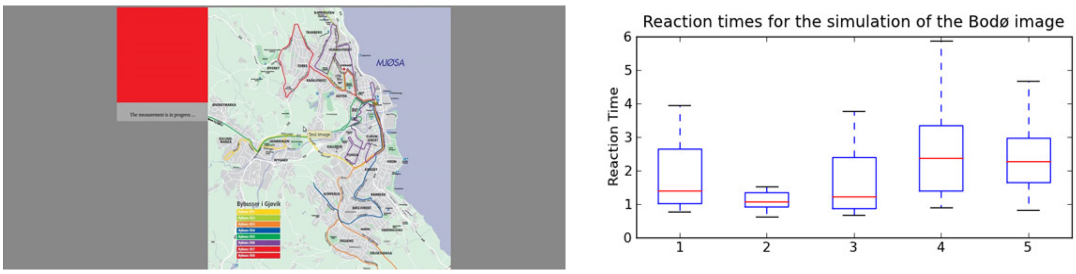


Figure 1: Website setup of our experiment (left) and reaction times (right) for the Anagnostopoulos simulation of the Bodø map

3 RESULTS AND DISCUSSION

In the following plots, we compared three different attributes of the images: To begin with, we plotted the reaction time for each version: On the one hand over all patches for each version (Fig.3-left) and on the other hand for each patch individually for each version (Fig.1-right). Secondly, we counted the number of correct clicks and divided them by the total number of clicks for all observers. Again, we plotted this accuracy rate summed up for all patches for each version (Fig.3-right) and for each patch individually for each version (Fig.2-right). Lastly, we computed the color difference between each individual patch in comparison to every other patch for each version for each image (Fig.2-left).

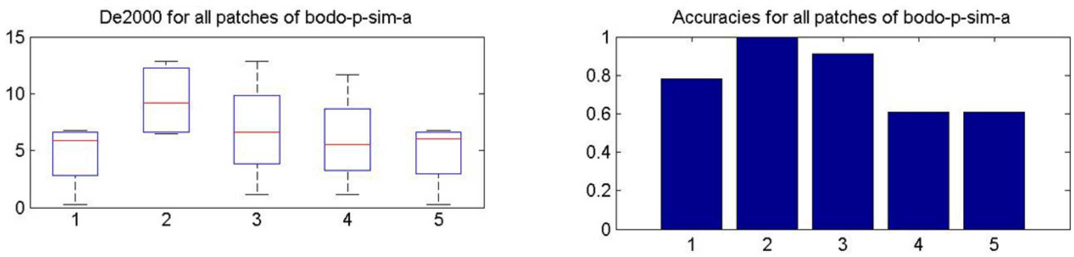


Figure 2: Color differences (left) and accuracies (right) for the Anagnostopoulos simulation of the Bodø map

First of all, we made the observation that although we cannot obtain any statistically significant difference from the reaction times, there is indeed a measurable tendency that a good daltonization reduces the reaction time of the observers and that easily accessible images have a lower variation among all observers (Fig.3-left).

Secondly, we can observe that the accuracies are high for easily accessible images and that they actually increase for the daltonized images and the simulated versions of the daltonized images (Fig.3-right). Also, it can be seen that for high accuracies, we also have fast reaction times and, more importantly, the variation among all observers is lower (Fig.2-right & Fig.1-right).

Thirdly, we can make the observation that there is no measurable correlation between average or minimum color difference and accuracy. A low minimum color difference might decrease accuracy. However, we can observe that the algorithm by Anagnostopoulos increases accuracy and decreases variation, whereas the Kotera algorithm does not seem to have a significant effect in improvement (Fig.3). The visual difference between both algorithms is that the Anagnostopoulos algorithm tries to maintain the hues of the original color and changes lightness and chroma, whereas Kotera changes colors globally, i.e. strong hue shifts exist. This observation might be a starting point for future accessibility metrics.

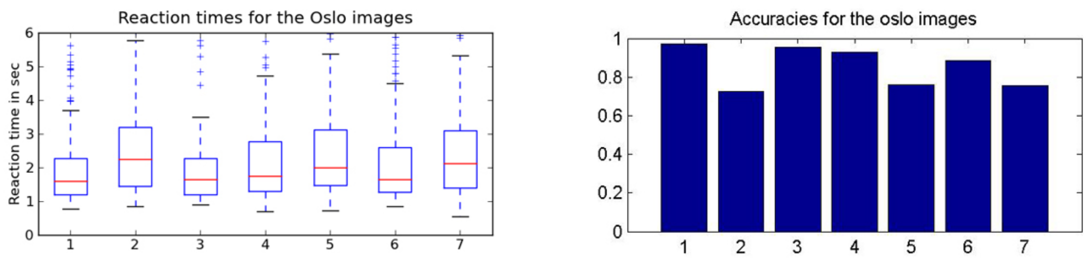


Figure 3: Overall reaction times (left) and overall accuracies (right) for all Oslo images[1]

Finally, it makes perfectly sense to use the setup in form of the task-fulfilling experiment because it saves a lot of time in comparison to psycho-physical experiments, in which observers have to compare and judge many pairs of images. In average, one observer had to spend between five and ten minutes including the explanation per experiment. The general subjective feedbacks from the observers were positive as they found the task more interesting than for example other experimentation with solely pair-wise or rank-order comparison. Also, finding the right transportation line in an image corresponds very to a real-life scenario. In future research, the experiment should additionally be repeated with color deficient observers in order to compare their behavior with the "virtual" color deficient observers.

4. CONCLUSIONS

The accuracy on the one hand appears to be a suitable indicator for a good or bad performance of a given daltonization algorithm. Thus, we suggest changing the framework to focus stronger on the accuracy aspect of the task-fulfilling experiment. Nevertheless, the reaction times should still be recorded because the variation of the reaction times among observers gives a good indicator for the quality as well and the average reaction time gives a general tendency on how the algorithm performs. Moreover, we suggest building an objective image quality metric for color deficient people based on lightness and chroma rather than a metric build on color difference generally.

ACKNOWLEDGEMENTS

We want to thank Prof. Ivar Farup for mathematical and implementation support and Dr. Peter Nussbaum and Dr. Marius Pedersen for support and feedback.

REFERENCES

Anagnostopoulos, C.-N., G. Tsekouras, I. Anagnostopoulos and C. Kalloniatis, 2007. Intelligent modification for the daltonization process of digitized paintings. *Proceedings of the 5th International Conference on Computer Vision Systems*, Bielefeld University.

Brettel, H., F. Viénot and J.D. Mollon, 1997. Computerized simulation of color appearance for dichromats. *J. Opt. Soc. Am. A*, 14 (10): 2647-2655.

Kotera, H., Nov. 2012. Optimal daltonization by spectral shift for dichromatic vision. *Twentieth Color and Imaging Conference: Color Science and Engineering Systems, Technologies, and Applications*. Los Angeles, California: 302-308.

Rigden, C., 1999. "The eye of the beholder" – designing for colour-blind users. *British Telecommunications Engineering*, 17 (4): 291-195.

Sharma, G., W. Wu & E.N. Dalal, 2005. The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. *Color Research & Application*, 30 (1): 21-30.

Viénot, F., H. Brettel and J.D. Mollon, 1999. Digital video colourmaps for checking the legibility of displays by dichromats. *Color Research & Application*, 24 (4): 243-252.

Address: Joschua Thomas Simon-Liedtke,
Gjøvik University College,
P.O.Box 191, N-2802 Gjøvik, Norway
E-mails: thomas.simon@hig.no, jon.hardeberg@hig.no

(Footnotes)

1 1-Original image, 2-Simulation (Anagnostopoulos), 3-Daltonization (Anagnostopoulos), 4-Simulation of daltonization (Anagnostopoulos), 5-Simulation (Kotera), 6-Daltonization (Kotera), 7-Simulation of daltonization (Kotera)

The Correlation between Colour Associated Thermal Perception and Human Activity Preferred: Associations Emerged via Seeing Computer Generated Projected Colour Slides

Anishka HETTIARACHCHI, Nimal DE SILVA
Department of Architecture, University of Moratuwa

ABSTRACT

Theory of colour explains the association between colour and human's thermal perception (TP), distinguishing warm colours, cools colours and neutral colours. This preliminary investigation emphasizes that every human activity demands a unique thermal milieu for its optimum performance. The current study hypothesized that colours could be potentially used to manipulate human thermal milieu as demanded by the activity intended in any built space via its unique ability to alter human TP. A group of normal sighted, healthy undergraduates (n=72, age= 20-23) were shown computer generated projected slides of an identical room in seven different hues as specified by RGB colour model within a controlled studio environment. Participants were exposed to each slide for two minutes. They spontaneously rated their thermal perception of each room on a 5-point Likert scale and selected activities they would prefer to perform in each room out of a list of activities provided to them, imagining that they were actually experiencing each coloured room shown in the slides. The study affirmed the colours' ability to alter human's thermal perception via scientific investigation. Supporting the hypotheses, the participants preferred active functions in the rooms which they rated to have a warm TP and vice versa.

1. INTRODUCTION

Colours can be described in temperature terms (Ballast, 2002). Theory of colour distinguishes a relationship between colour and perceived temperature, thus differentiating between "warm colours", "cool colours "and "neutral colours". Colours can be perceived as "warm" or "cool" related to the dominant wavelength of the colour (Ballast 2002). Similar to the entire colour associated psychological responses; thermal perception relevant to a particular colour too can be a highly subjective response which differs from person to person conditioned through ones exposure, experiences and memories. Yet, there could be certain common connotations emerging as a consequence of a fixed intrinsic, biological and primordial response, in order to perceive certain colours as warm and vice versa. Thus each colour can be generally associated in triggering a relevant thermal perception in humans. Sundstrom (1987) suggests that the colour of surroundings might have a distinct impact on changing perceptions of room temperature. Hutchison (2003) reports that walls painted "cool blue" induced more women to complain of being cold with the temperature set at 75^0F than when the colour was changed to warm yellows and restful greens at the same temperature. Stone (2001) found that individuals performing within blue partitions perceived the temperature to be cooler than those in the red partitioned workspaces.

Every human activity supposedly demands a unique state of existence for its optimum performance characterized by a unique thermal milieu which generally falls in to three basic states; stimulated state, pacified state or a neutral state. Human thermal environment as a whole is a combination of several external and personal parameters in which colours are suspected to play a unique role. Accordingly, designing spaces to facilitate the intended pace of existence is vital where colour can be an effective psychophysiological tool to support the demanded pace of existence or the level of arousal. Birren (1989) states that warm colours are related to an active behavior, while cold colours resemble a rather passive behavior. Gerard (1958 as cited in Graham 2000) suggests that psychophysiological activation increases with the wavelength from blue to red. Therefore the current study suggests that warm colours can be integrated to enhance active simulative spaces while cool colours will work well in pacifying spaces. For instance, according to the principle of colour therapy, using more of blue colour in the bed room will help insomnia or sleeplessness (Hari 2003). Equally, the right room temperature can play a crucial role for a good nights rest. Temperature regulation plays a role in many cases of chronic insomnia (O'connor 2009). The current study, while seeking evidence for colour associate thermal perception, attempts to establish a link between three variables, namely colour stimuli, thermal perception and human activity.

2. METHOD

2.1 Sample Preparation

Study was conducted with a randomly selected sample of normal sighted, healthy volunteer undergraduates (n=72, 51 females and 21 males) of an identical age group (20-23 years) and represented a cross section of the socio cultural religious, topographic and climatic contexts in Sri Lanka.

2.2 Research design

Controlling of external parameters directly pertaining to thermal perception (air temperature, radiant temperature, humidity, air velocity) was attempted via conducting the study within a controlled air conditioned studio environment ($T=26^0C$). The participants' pace of existence and the activity level were essentially the same as they were comfortably seated in the studio while involved in the given tasks. The study consisted of two main parts.

Part One: The participants were shown computer generated slides of an identical room in seven different colours (as specified in RGB colour model) projected on to a wall ;namely Red(255,0,0), orange (255,165,0), yellow (255,255,0), blue (0,0,255), green (0,128,0), purple (128,0,128), and white (255,255,255). In other words each slide demonstrated an identical room in a particular colour. The participants were shown each slide for two minutes and they were requested to spontaneously rate their TP per room on a 5 -point likert scale ;Very Cool (VC), Cool (C), Average (A), Hot (H), Very Hot(VH)).

Part Two: Using the guided imagination technique, the participants were requested to imagine as if they were experiencing the above projected coloured rooms as real and identify the activities they would prefer to perform in each room out of a list of activities given to them; sleeping, exercising, dining, reading, solving mathematical problems, having discussions with friends, meditation, sports, relaxing and drawing a picture. These responses made to a guided imagined situation were considered as equal to the real experience of the same, which is a technique used in colour therapy (Hari 2003). Participants were allowed to select the same activity for more than one colour if necessary.

3. RESULTS AND DISCUSSION

Each colour significantly was found to be associated with a certain thermal perception. Supporting the theory of colour, red, orange and yellow were perceived significantly as warm; (Red - 96%; 65% -VH, 31-% H, Orange - 91.5%; 30.5- % VH, 61% - H and Yellow 81%; 36% - VH, 45% - H,).Further green, purple and blue were dominantly perceived as cool; Green -78%; 50% - C, 28% - VC, purple - 65%; 44% - C, 21% - VC and blue - 73% ; 33% -C, 40%- VC). Aligned with theory of colour, white was identified by a majority to be a neutral colour; triggering neither a hot nor cool perception (1%-VH, 6% -H, 53% -A, 19% -C, 21%- VC). Even though only a handful of respondents rated white as warm (7%), white was also considerably marked as a cool colour (C+VC=40%). This could be a learnt association strongly molded by the Sinhalese, Buddhist religious context in Sri Lanka.

Supporting the hypotheses, the participants preferred to perform active/energetic functions in the rooms which they rated to have a warm TP and vice versa. For instance, red room was preferred for exercising and sports while orange were preferred for sports, dining and exercising. Further, yellow was marked as suitable to have in a space for friendly discussions, dining and sports. The colours identified to have a cool TP were significantly preferred for calm activities. Blue and purple respectively were decidedly preferred for sleeping and relaxing. Green room was dominantly preferred for relaxing. White, which was mostly rated to have an average TP, was chosen for calm and neutral activities, mainly drawing, reading and meditation. On the other hand, supporting the hypothesis, the study reveals a relationship between colour stimuli, thermal perception and preferred human activities. Human functions performed in an aroused, active pace were preferred to be carried out in spaces with warm colours while calm and concentrated activities were preferred for spaces with cool colours. Since rating the thermal perception and the identification of preferred activities related to each colour were done simultaneously, a relationship between thermal perception and activity was also established as given below. For instance, blue was found to associate with a very cool thermal condition and to support sleeping. Red was found to be perceived as very hot and correlated with active performances like exercising and sports.

Table 1: Conclusion - Colour, Thermal Perception vs Activity.

Colour	Thermal Perception	Activity Preferred to be performed
Red	Very Hot	Exercising, sports
Orange	Hot	Sports, exercising, dining,
Yellow	Hot	Dining, discussion
White	Average	Reading, drawing, meditation
Green	Cool	Relaxing, meditation
Purple	Cool	Sleeping
Blue	Very cool	Sleeping, relaxing

4. CONCLUSIONS

Findings of this study provide testimony for colours' ability to alter human's thermal perception and supports the distinction between warm and cool colours. Red was found to be the colour perceived as the warmest out of all colours tested while blue was found to be the coolest. Accordingly the following relationship between TP of seven colours ranging from warm end to cool end was arrived at; TP Red > TP Orange > TP Yellow > TP White > TP Purple > TP Green > TP Blue. The study further looked in to the potential of colours to support human activities in the built environment via manipulating the perceived thermal environment. The study revealed that energetic activities like sports, exercising, dining, and discussion were preferred in a warm thermal environment and thus warm colours can be integrated to enhance such performances; red and orange colours for sport and exercising , yellow for spaces where dining and warm discussions take place. In the other end the study claims that cool colours can be integrated to support spaces for calm/ pacified activities; sleeping, relaxation and meditation. It is suggested to extend this investigation more precisely via conducting the study in different rooms/work stations painted in different colours and controlling the personal variables; considering different age groups, situational groups and via increasing the sample size.

REFERENCES

Ballast, D.K., 2002. *Interior design reference manual*. Professional Pub. Inc.: Belmont, CA.

Birren, F., 1989. *Color psychology and color therapy: A factual study of the influence of color on human life*. New York: Citadel Press.

Graham, H., 2000. Healing Colour. *JSDC*, Vol 116, 257-259.

Hutchison, E., 2003. *Dimensions of human behavior; person and environment.* Thousand Oaks, CA: Sage Publications.

Hari, A.R, 2003. *The Magic Therapy of Colours: Holistic Healing through Colours*, India: Delhi, Pustak Mahal Publishers.

O'Connor, A., 2009. The Claim: Cold Temperatures Improve Sleep. The New York Times.

Stone, N., 2001. Designing effective study environments. *Journal of Environmental Psychology*, 21(2), 179190.

Sundstrom, E., 1987. Work Environments: Offices and Factories, in Stockol D & I Altman (eds), *Handbook of Environmental Psychology*, Wiley. p.751.

Address: Archt. Anishka Hettiarachchi, Department of Architecture,
University of Moratuwa, Sri Lanka.
E- mail: anishka_h@yahoo.com

colour ergonomics

Effect of Font Sizes and Colors upon Visual Perceptions of Young and Elderly People under Different Lights

Haruyo OHNO[1] and Shigeharu TAMURA[2]
[1] Faculty of Media and Arts, Otemae University
[2]AIST Kansai

ABSTRACT

Visual perception of colors used in the living environment is affected by various factors, whose psychological effects have conventionally been studied. It is difficult to predict actual color visions and the psychological and physiological effects of color targets applied to living environments based on the results of such studies[1, 2].

This paper looks at the visual perception by the young and the elderly people .The authors obtained data from evaluations of colors, and the visual ease of printed papers from the young and elderly people.

1. INTRODUCTION

An experiment on the color perception of chromatic color targets was considered, and it was concluded that the concept of the perception of gray scale obtained from previous studies can be partially applied to the evaluation of colors for the living environment[3, 4, 5].

However, the ratings of hue were widely scattered when compared with attributes, suggesting the necessity for more data to confirm the quantitative tendencies. For this reason, experiments on the visual perception of chromatic colors commonly used for living environment were conducted.

2. METHOD

Participants Experiments were conducted on 10 participants divided in two groups: a young group consisting of 10 Otemae University students with an average age of 21 (5 female and 5 male), and an elderly group consisiting of 10 people with ages ranging from 60 to 70 (10 students wore glasses to simulate the experience of having cataracts). They were not colorblind, and had visual equity over 1.0. Participants were asked to evaluate the ease of visual perception of color targets on questionnaires by means of semantic scales.

Procedure These experiments of the visual perception of color targets were conducted in a laboratory of AIST Kansai, the interior, which consisted of the ceiling, walls, floor, desk and chair, was finished in achromatic colors. Figure1shows the distributions of the light sources at 3, 30 and 300 lx under incandescent light and daylight luminescent lights(Daylight). The various sentences we used for the experiment were taken from a newspaper column. It was printed by the five kinds of color targets shown in Table 1, the 6pt, 7pt and 10.5pt Mincyo fonts that were used included the three kinds of Japanese letter styles, Kanji, Hiragana and Katakana. Two types of paper were used; one with a smooth surface and one with a rough surface. Experiment sentences were evaluated by the ease of visual perceptions from participants. Each sample was located at the center of desk covered with a cloth colored N7, at the visual distance of 30 cm, and the visual angle of targets was 35°×26.5°.

Table 1: *Color samples used for evaluation.*

	Munsell notations	Contrast
Red	7.5R 6/10	0.61
Blue	5PB 5/10	0.74
Yellow	7.5Y 8/10	0.36
Black	N2.5	0.87
Green	5G 5/6	0.65

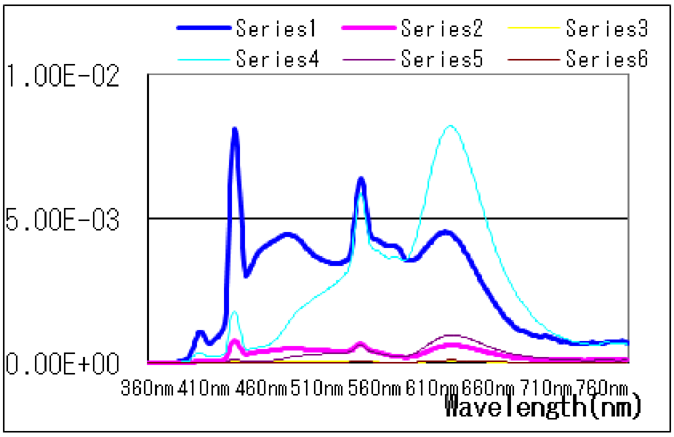


Figure 1: Spectral power distribution illuminated based on daylight and incandescent light.

1;300lx (Daylight),
2;30lx (Daylight),
3;3lx (Daylight),
4;300lx(Incandescent light),
5;30lx (Incandescent light),
6;3lx (Incandescent light),

3. RESULTS AND DISCUSSION

3.1 Letter font and illuminanyce

Figure 2 and 3 shows the percentile of the visual ease of color targets from the letter font according to the illuminances from participants under daylight. Data was obtained from the two kinds of materials of paper, and three kinds of font sizes.

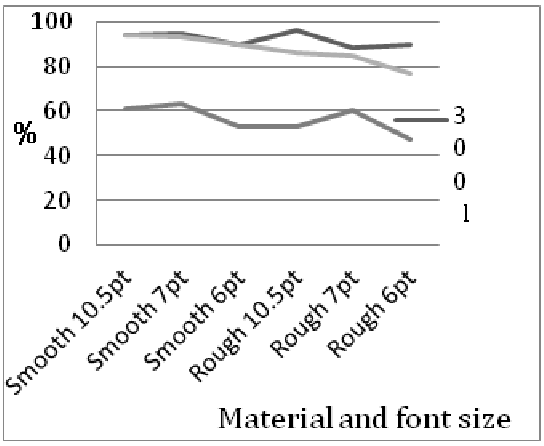


Figure 2: Elderly group (Daylight).

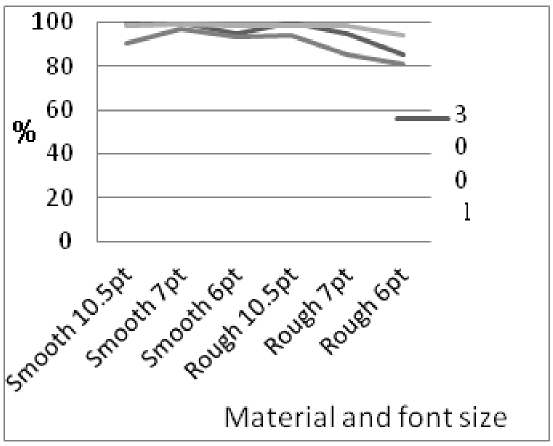


Figure 3: Young group (Daylight).

1) Elderly group

Figure 2 shows the results of the elderly, at the illuminance level 300 lx, participants read 90 - 95% of targets from 7pt and 10.5pt and 90% from 6pt (smooth surface). Participants read 90% to 95% of targets from 6pt, 7pt and 10.5pt (rough surface). At 30 lx, elder people read nearly 90% of targets from 6pt, 7pt, and 10.5pt (smooth surface) and 80% to 85% of target from 6pt, 7pt, and 10.5pt. At 3 lx, elder people read only 60% of targets from 7pt and 10.5pt 50% from 6pt (smooth surface). Participants read 50% to 60% of targets from 6pt, 7pt and 10.5pt (rough surface).

2) Young group

Figure 3 gives the result from the young. At the illuminance level 300 lx, young people read 95% to100% of targets without being influenced by the materials and fonts. At 30 lx, participants read 85% of targets from 6pt (rough surface). At 3 lx, participants read 85% to 90% of all targets.

3.2 Evaluation of colors of letters with smooth surface

At the illuminannce 3lx, many people could not distiguish colors of letters at 6pt.

1) Elderly group

For the elderly people, 80% of people could not distinguish yellow. 20% of people as black, 30% perceived as orange and 10% of the people could recognized. The blue could be distinguished by 30% of the people, and 40% of them perceived it as black, the 20% of them perceived it as green. For green, 20% of the people distinguished the green, but 50% of them perceived it as blue, and 10% perceived it as black. The black was able to be distinguished by all participants.

2) Young group

Only 10% of young people could not distinguish yellow. The red was able to distinguish 50% of the people, but the 30% of them perceived it as orange, 10% as black, and the other 10%, could not distinguish. The blue could distinguish all of them as blue. For green, 90% of them distinguished the green, and the 10% of them saw it as yellow-green. The black was able to be distinguished by 90% of participants. However, 10% participants it as dark red.

3.3 Readability of the sentences

At illuminance levels 3lx to 300lx under daylight, the ease of visual perception of sentences based on the 6pt for colors and materials of surfaces are seen in Figure 4 and 5.

1) Elderly group

Figure 4 shows the results from elder people. Using smooth surfaces, at the 3lx, sentences with red letters were read by 60% and at the 30lx to 300lx, 90%. At the 3lx, blue was read by 45%, at the 30lx to 300lx, 95% to 100%. For yellow, at the 3lx, letters were read by 35%, at the 30lx to 300lx, 75% to 80%. For green, at the 3lx, letters were read by 35%, at the 30lx to 300lx, 85% to 90%. For black, at the 3lx letters were read by 90%, at the 30lx to 300lx, 95% to 100%. Using rough surface, at the 3lx, sentences of red letters were read by 70%, at the 30lx, 90%, and at the 300lx, 100%. At the 3lx, that of blue was read 25%, at the 30lx, 70%, and at the 300lx, 95%. For yellow, at the 3lx letters were read by 35%, at the 30lx to 300lx, 55% to 70%. For green, at the 3lx letters were read by 35%, at the 30lx to 300lx, 80% to 85%. For black, at the 3lx letters were read by 70%, at the 30lx to 300lx, 90% to100%.

2) Young group

Figure 5 shows the results from younger people. Using smooth surface, at the 3lx, sentences with red letters were read by 80% and at the 30lx to 300lx, 95% to 100%, at the 3lx to 300lx, blue was read by 95% to 100%. For yellow, at the 3lx to 300lx letters were read by 95% to 100%. For green and black, at the 3lx to 300lx, 95% to 100%. Using rough surface, at the 3lx, sentences of red letters were read by 75%, at the 30lx to 300lx, 90% to 95%. At the 3lx, that of blue was read 70%, at the 30lx to 300lx, 85% to 90%. For yellow, at the 3lx letters were read by 75%, at the 30lx, 95%, and at the 300lx, 85%. For green, at the 3lx letters were read by 90%, at the 30lx, 95%, and at the 300lx, 85%. For black, at the 3lx to 30lx letters were read by 95%, and at the 300lx, 85%.

4. CONCLUSIONS

At the illuminance level 300lx, both age groups were similarly rated for each printed style, the material of paper and color, but at the 3 lx and 30 lx, obvious differences were noted. The ratings by elderly people tended to exhibit wider variation from the young. At the illuminance level 30 lx, the younger group distinguished nearly 90% of targets. However, elderly people required 10 times illuminance compared to the younger people.

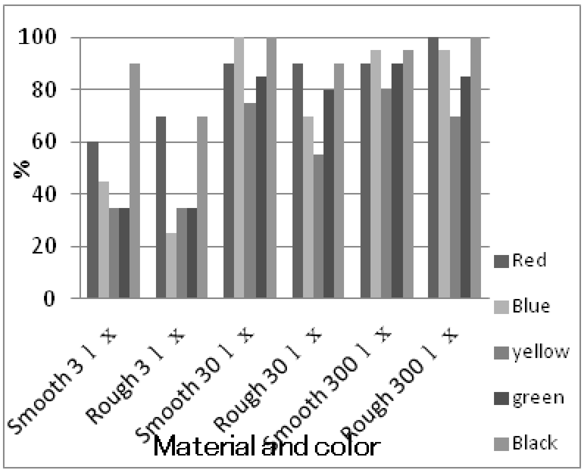


Figure 4: Elderly group (Daylight).

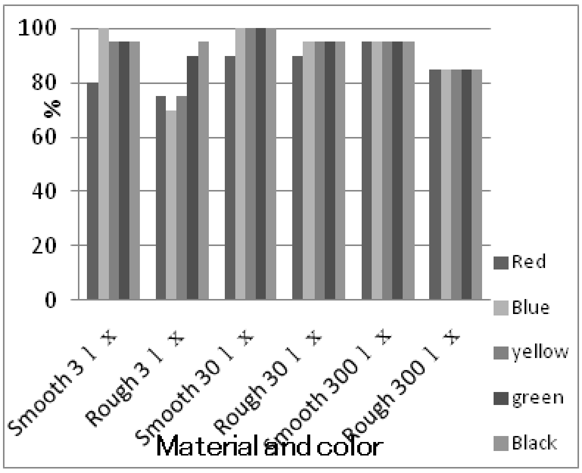


Figure 5: Young group (Daylight).

ACKNOWLEDGEMENTS

The authors would like to thank Miss Maho Watanabe, a 4th year student of Otemae University, for her help in conducting the survey during the data collection process.

REFERENCES

Shimomura, K., S. Ashizawa, and K. Sagawa, 2012. Effects of color and illuminance level on the legibility of colored letters for older people. *Journal of the color science association of Japan*, 36(1), 15-26.

Ikeda, M., P. Pungrssamee, and T. Obama, 2009. Size Effect of Patches for Their Color Appearance with Foggy Goggles Simulating Cloudy Crystalline Lens of Elderly People, *CRA*, 34(5), 351-358

Ohno, H., 1995. Evaluation of colors used for housing environment, *Journal of Japan*, 19(1), 114-115.

Ohno, H., and R. Satoh, 1987. Effect of illuminance level on apparent hue recognition, *Summaries of technical paper of annual meeting AIJ*, 441-442.

Satoh, R., H. Ohno, and M. Narasaki, 1986. Relations between visual easiness of achromatic targets and subjective contrast, *Summaries of technical paper of annual meeting Kinki Branch of AIJ*, 41-44.

Address: Prof. Faculty of Media and Arts, Otemae University,
2-2-2 Inano, Itami, Hyogo 664-0861, JAPAN
E-mails: ohnoh@otemae.ac.jp, sg-tamura@aist.go.jp

Reading from Tablet and Paper: A Study on Preference and Reading Rate

Suchitra SUEEPRASAN,[1] Tongta YUWANAKORN,[1] Tetsuya SATO[2]
[1] Department of Imaging and Printing Technology,
Faculty of Science, Chulalongkorn University
[2] Department of Design Engineering and Management, Kyoto Institute of Technology

colour ergonomics

ABSTRACT

This study compared differences in preference and reading rate between reading from tablet and paper. Participants completed a questionnaire about their familiarity with electronic media and reading media preference. Visual experiments whereby participants read one document on paper and the other one with the same type on a tablet were conducted. Three types of document were included: health information, political news and short story. Participants read all three types of document on both tablet and paper, but different contents for each type were read on different media. All documents were in Thai language and had the same level of difficulty. They were of the same appearance (text size, line and spacing) on tablet and paper. Each document contained seven misspelled words and the participants' task was to find them while reading through the content. Participants were 50 university students. After completing the visual experiments, they were asked to answer a questionnaire about visual stress symptoms that they might have experienced during the experiments. It was found that the document type did not affect the reading rate, but the type of reading media yielded significant effects. Most participants preferred reading from paper to a tablet. Reading from tablet tended to incur higher visual stress than reading from paper.

1. INTRODUCTION

The popularity of tablet as a reading device is increasing over the years. Since tablet is a self-luminous medium, when reading information on a tablet, direct light from the tablet enters a reader's eyes. In contrast, reading from paper, reflected light from a paper surface enters the eyes. Due to the differences between the two media, it is possible that reading from tablet and paper yields different effects. The study by Gould and Grinschkowsky (1984), where proofreading tasks were performed on a CRT display in comparison with paper, showed that participants proofread from paper faster than from a CRT. No change throughout the day in participants' proofreading performance (speed and accuracy) was found. Many studies reported that reading from electronic visual displays was slower, less accurate, more fatiguing, decreased comprehension and was rated inferior by readers (Dillion et al., 1988). Skimming was also found to be slower from CRTs than paper (Muter and Mauretto, 1991). Reading speed is by far the most common difference between screen and print, with reading from screen being significantly slower than reading from print (Dillon, 1992; Wright and Lickorish, 1983). Piolat et al. (1997) found that differences arose largely in human, including computer interaction, education and communication literatures. The study on memory for advertising and information content (Jones et al., 2005) showed that readers could remember more information when reading on print than on screen.

This study investigated preference for reading media by means of a questionnaire. Visual experiments were carried out to investigate reading performance. Participants' familiarity with electronic media and visual stress susceptibility were investigated to determine possible factors that could be attributed to differences in reading from tablet and paper.

2. METHOD

In this study, the reading rate (performance of readers in identifying mistake words in the document in proportion to their speed of reading) was taken as a means to determine the differences in reading performance between tablet and paper.

2.1 Sample Preparation

Two questionnaires were prepared for this study. The first questionnaire was about participants' media preference for reading, familiarity with electronic devices such as computer, mobile phone and tablet, and ease of use when reading five types of content, i.e. news, novel, journal, magazine and information. This questionnaire was given to participants before carrying out the visual experiments. The second questionnaire was a visual stress symptom questionnaire, which was given to participants after they had completed the visual experiments. It contained a list of symptoms signifying visual stress, such as boredom, sore eyes, sleepiness, etc. Participants answered from which medium (tablet or paper) these symptoms occurred or tended to occur.

The reading documents used in this study were categorised into three types according to their content. They were health information, political news and a short story about gratitude. Each type had two different contents, so that the contents presented on tablet and paper were not the same. All documents were in Thai language (native to participants) with the same length (610-620 words). They all had the same level of difficulty, which is the same type of vocabulary and the similar content. Each document contained seven words that were modified to misspell in the same way.

The documents on tablet and paper were of the same visual size, line and character spacing. The physical size of text appeared on tablet and paper was exactly the same (11.5 cm ´ 16.8 cm). The character size was 1.5 mm ´ 1.8 mm with spacing between characters of 0.5 mm and the line spacing of 3.8 mm. Image quality (sharpness and clarity) was equivalent on both media. All documents were presented on one page.

2.2 Visual Experiment

Participants read the documents in a viewing cabinet illuminated with D65 simulators in a darkened room. Illuminance in the viewing cabinet as measured at the bottom in the centre of the cabinet was 1018 lux. Luminance at the reading position of white paper was 188 cd/m^2, and of white background on tablet was 273 cd/m^2.

Participants were instructed to read through the document only one time with a task to find misspelled words. They were not told how many misspelled words there were in one document. Each participant completed the experiments on both media for all three types of document. While reading on a tablet, they were instructed not to resize the text or make any changes to the display, except to mark the misspelled words.

Fifty university students (25 males and 25 females) participated in the experiments. Twenty-five participants read the same content on a tablet, whereas the other 25 read that content on paper, so that the effect of content was eliminated. The reading time and the number of mistake words found (including the misspelled words intended in the documents and words that participants thought they were wrong for some reasons, for example, misuse of words) were recorded. The reading rate (the ratio of mistake words found to the reading time) was calculated.

3. RESULTS AND DISCUSSION

The results from the questionnaire showed that 60% of participants preferred reading on paper with 57% of them gave the reason that it was more emotional involved. Fifty-five percent of participants who preferred tablet chose tablet over paper due to ease of use. Moreover, as seen from Table 1, when reading news and information, tablet was easier to use. On the other hand, when reading a novel, journal and magazine, reading on paper was easier because readers could easily make a note and felt more familiar.

Table 1. Percentages participants regarding ease of use.

	News	Novel	Journal	Magazine	Information
Tablet	62	10	18	44	76
Paper	38	90	82	56	24

The results from paired t-test (Table 2) showed that the reading rates on paper were significantly higher for information and story documents, but not significantly different for news. The higher reading rate indicated that readers found it easier to read on paper and they could comprehend the context of the story more easily. The symptoms signifying visual stress include skipping words and frequent loss of place when reading. These symptoms lead to impaired comprehension and reduce the speed of reading. In order to comprehend the story and finding the mistake words, readers would spend more time, thus reducing the reading rate, if the media were likely to incur visual stress. The difference in luminance (tablet being higher) could be the reason why the participants tended to have more visual stress when reading from tablet.

Table 2. Reading rate and the results of paired t-test between tablet and paper.

(words/min)	Information	News	Story
Tablet	1.8 ± 0.7	1.7 ± 0.7	1.7 ± 0.6
Paper	2.3 ± 0.9	2.1 ± 0.6	2.2 ± 0.6
Sig. (2-tail)	0.001*	0.075	0.000*

Note: mean ± SD, * indicates significant difference.

The results of two-way ANOVA to determine significant differences between the reading rates from different document types revealed no significantly different between them. It is possible that since the level of difficulty and length of the documents were equivalent, the different content did not significantly affect the reading time and comprehension.

For further investigation, the participants were classified into two groups depending on the differences in reading rate between table and paper. The participants with high visual stress susceptibility were those who showed significant reading rates between the two media based on the independent t-test at 0.05 significance level. The participants in this group had a higher reading rate on paper. Based on the questionnaire, they were not familiar with tablet and none of them owned a tablet. 88% of participants in this group reported that they felt too much light coming to the eyes when reading on a tablet, and 94% experienced tiredness.

4. CONCLUSIONS

The reading rate on a tablet was significantly lower than that on paper for information and story. Nevertheless, the results showed no significant difference between document types. Reading on tablet tended to cause more visual irritation, which reduces the speed of reading. The number of mistake words found on a tablet was lower, indicating the lower degree of comprehension. Participants with high visual stress susceptibility had a higher reading rate on paper and were not familiar with a tablet. They preferred reading on paper. These indicate that familiarity and visual stress susceptibility affect reading performance.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number 23650445.

REFERENCES

Dillon, A., 1992. *Reading from paper versus screens: A critical review of the empirical literature*, Ergonomics 35: 1297-1326.

Dillon, A., C. McKnight and J. Richardson, 1988. Reading from paper versus reading from screen, *The Computer Journal* 31: 457-464.

Gould, J.D., and N. Grinschkowsky, 1984. Doing the same work with hard copy and with cathode ray tube (CRT) computer terminals, *Human Factors* 26: 323-337.

Jones, M.Y., R. Pentecost and G. Requena, 2005. Memory for advertising and information content: Comparing the printed page to the computer screen. *Psychology & Marketing* 22 (8): 623-648.

Muter, P., and P. Mauretto, 1991. Reading and skimming from computer screen and books: The paperless office revisited, *Behaviour and Information Technology* 10: 257-266.

Piolat, A., J. Roussey and O. Thunin, 1997. Effects of screen presentation of text reading and revising. *International Journal of Computer Studies* 47: 565-589.

Wright, P., and A. Lickorish, 1983. Proof reading texts on screen and paper. *Behaviour and Information Technology* 2: 227-235.

Address: Suchitra Sueeprasan, Department of Imaging and Printing Technology, Faculty of Science,Chulalongkorn University, Phyathai Road, Bangkok 10330, Thailand
E-mails: suchitra.s@chula.ac.th, yuwanakwa@hotmail.com, tsato@kit.ac.jp

keynote:
fiona jenvey

Colour Trend Forecasting Intelligence

Fiona JENVEY
CEO, Mudpie Ltd
www.mudpie.co.uk

keynote

BIOGRAPHY

Fiona Jenvey is one of the world's best known forecasters of fashion, lifestyle and business trends, Fiona established and developed one of industry's leading forecasting organisations that now operates in over 50 countries. Fiona has worked as a consultant to some of the world's largest consumer goods companies internationally.

As CEO of Mudpie, which she founded in 1992, Fiona is a respected analyst on fashion and lifestyle trends. She is also a regular speaker at conferences and exhibitions around the world, providing globally respected trend insights. Under Fiona's leadership, Mudpie has become a well known trend partner to many companies through the sale of the companies online trend service mpdclick.com, trend books and the provision of creative consultancy services. Mudpie is a pioneer in establishing collaborations and initiatives throughout the industry and has led the field in knowledge sharing and establishing community networks, including the industry's largest business to business LinkedIn group.

> "Fashion interests me, not because of the short term influence it has on the retail industry but because of its wider influence on the consumer. Cars, consumer electronics, personal care, food, entertainment, media and every other product or service should be viewed as a fashion product. A crucial element of our success is appreciating this connection and combining it with an understanding of the commercial product development processes of our clients. Mudpie is not just a trend publisher but is a strategic creative partner for businesses." – Fiona Jenvey.

'BLURRED REALITIES'– F/W 14/15

Between the digital and the real lies a new state of consciousness – a parallel world led by the vivacious Alpha Generation. Contemplating the reality of disaster in fantasy futures ignites a super-charged spirit, powering innovation and creativity. Colour and consumer trends are explored in the three trends below.

Future Tribes

In a dystopian vision of the future, a colourful warrior tribe with the 'can-do' attitude of the Alpha Generation ignites a super-charged spirit.

Parallel Worlds

Consumers look to a new state of consciousness, with parallel worlds providing intrigue, comfort and contemplation. Here, space sci-fi films and retro superheroes inspire.

Digi-Punk

A new generation of creatives are heralding nostalgia for 1990s internet kitsch, marking the return of animated gifs, memes and net art, alongside the emergence of 2.0 hashtag subcultures.

symposium: colour in fashion

The Digital Challenges Ahead for Accurate Colour Forecasting

Julie KING
De Montfort University

ABSTRACT

The trend forecasting industry was valued at $36bn in 2011, and was tipped to be a new future growth business (Barnett, 2011). The industry encompasses the important area of colour forecasting, with colour acknowledged as the initial stage in the development of any new fashion trend by many academics and practitioners (McKelvey & Munslow, 2008, Kim & Johnson, 2009). Each season companies involved in the fashion forecasting industry publish a new colour trend book suggesting a range of seasonal themes and colour palettes suitable for a diverse range of markets and demographics. The importance of colour selection in the fashion and textile industry in particular cannot be underestimated: 'Colour is usually the starting point of each season and often acts as a springboard for materials/fabric direction and trend research' (Mete, 2006:278). Mete's findings underline the importance of early, accurate colour communication, ensuring the whole supply chain is able to react to new colour trends. Research indicates the role of the increasing globalisation and homogenization of the international fashion industry, coupled with the ever increasing pace of production has created substantial pressure on the garment supply chain (Ekwall et al, 2006). The pace of electronic communications has contributed to not only the homogenization, but also the dissemination of trend information.

In recent years a new wave of trend forecasting has emerged, with established forecasters and newcomers developing a range of apps which are changing the way in which colour is communicated and used by trend forecasters, their clients and the general public. In parallel a new range of designers and creative are now working within the fashion industry; the Millenials, also known as generation Y and born between 1981 and 1999. This group now numbers over 70 million in the US alone, and they have very different priorities and working practices to previous generations (The Doneger Group, 2012).

The paper aims to investigate the use of multichannel methods of accessing information, how they impact on colour accuracy, and the implications for traditional forecasting formats, such as trend books, in the future. It will aim to suggest solutions to the potential challenges ahead.

Barnett, E., 2011. *Trend spotting is the new $36bn growth business*, http://www.telegraph.co.uk/finance/newsbysector/mediatechnologyandtelecoms/8482964/Trend-spotting-is-the-new-36bn-growth-business.html, accessed 4.5.11

Ekwall, D., T. Ottoson, and J. Peterson, J., Adding cost demand information – a method for increasing the sell through factor in fast fashion, *PLAN Annual Conference 2006, Conference Proceedings*, 84-106.

Kim, E., and K.K.P. Johnson, 2009. Forecasting the US Fashion Industry with Industry Professionals – Part 1: Materials and Design, *Journal of Fashion Marketing and Management*, 13(2), 256-267.

McKelvey, K., and J, Munslow, 2008. *Fashion Forecasting*, Wiley-Blackwell, Oxford

Mete, F. (2006) The Creative role of sources of inspiration in clothing design, *International Journal of Clothing Science and Technology*, 18(4), 278-293.

Color at Lululemon: Neons to Namaste

Andrea CILONA
Colour specialist at Lululemon athletica, Canada

ABSTRACT

In less than 14 years, Lululemon athletica has become over a billion-dollar Yoga inspired athletic apparel retailer. Our original intent is to "elevate the world from mediocrity to greatness" and in doing this we align our business around our core values of: product, quality, integrity, balance, entrepreneurship, greatness and fun. These values are directly correlated to our approach on color and overall success of our brand.

At lululemon we create key components designed by athletes for athletes. A key driver of our product is our color architecture. There is a unique art to how color merchandises in our stores and the balance of one seasonal color palette flowing into the next.

We celebrate and promote the entrepreneurial spirit by experimentation and innovation. In this, we embrace the idea of failing. At lululemon, failing is an essential part of our development process enabling us to move from mediocrity to greatness. We create the possibility of greatness in others and it makes us great as well.

As a company, we lead by being focused on product and guest facing, not just an apparel retailer. We educate and goal set in order to deliver the best quality products to our guests. We will continue to take risks and challenge the market. This is who we are. This is why our guests keep coming back.

Integrity for lululemon is hosting a one of kind Color Workshop with our entire supply base, where we are authentic in sharing ideas as a community. We champion our partnerships with our mills to align on common goals. Yoga is a metaphor for how we work. It is a union, integration or wholeness. It is not competitive. We tackle projects together and support each other in our daily practice.

Lastly, we have fun! Color surprises and delights us each and every day.

From Analogue to Digital – the future...?

Ian MORRIS
Head of Technical Services, Marks & Spencer plc

LEGACY

Colour and Marks and Spencer goes back many decades – our company archive proves that we promoted colour to our customers from as early the early 1930's. The big 'game-changer' was in the nineteen-sixties: M&S saw great opportunities to sell suits as two-part products, where you could be sure the jacket and trouser would match exactly, even if you bought them on different dates, and in different Stores and sizes – so precise colour matching systems became a necessity, and not a luxury.

Computerised colour technology took another leap forward in the 1980's with a true colour measurement system being developed with ICS, and rolled out across our mainly UK and European based suppliers – we won the Queen's Award for Technology in 1984. For the first time, colours could be accurately matched and delivered remotely without reference to a visual standard.

NOW

Colour measurement and communication has moved on massively since those early days – we have moved forward to 31-point data from the less precise 16-point data that served us well in the past – and using the 'global standard' CMC equation that all our dye houses and suppliers are familiar with. Despite this, we still have a mix of working with material samples as the 'first step', as well as existing standards from a library of many thousands. It is still very much a world dominated by physical samples to represent colour – trend analysis boards, design briefs, together with digital standards for the technical delivery of the finished product across our many dye houses.

What is the future – will it remain largely in the 'physical sample' world, or become increasingly digital?

THE FUTURE

The future is digital – at least for our customers and in the workplace!

Our customers increasingly use their computers and mobile technology to explore and shop in the digital world – how far can we go to replacing fabric standards with their 'digital' equivalent? Approving off screen – how good are today's calibrated colour screens, and can we persuade designers and buyers to substitute the light cabinet for an ultra sharp precision screen? Can the better use of digital technology provide a better and more responsive delivery of fast moving fashion colours?

Made Here, Made Possible

Keith HOOVER
VP Colour and Sourcing, UnderAmour

ABSTRACT

The late twentieth century saw the migration of the apparel manufacturing industry from developed to undeveloped nations (notably in Asia), based on preferential trade agreements, cheap labor costs, and a reduced regulatory burden. In the US, apparel and textile related jobs plummeted from approximately 2,500,000 in 1973 to 703,000 in 2004. The pain of losing these entry- and mid-level American jobs has continued over the past five years, contributing to sustained high unemployment. Although remnants of the textile industry remain in the US and Europe (for different reasons), a fundamental change has taken place impacting not only employment in the West, but garment design, development, and manufacturing processes, as well.

Prior to this shift, technical competence had been required of all players in the garment development process, due to the interlocking relationship between product design and the local supply chain. However, as manufacturing moved offshore, designers no longer had the educational benefit of direct interaction with the mills and factories to ensure that designs were feasible. "Out of sight, out of mind" added a virtual angle to a literal divide with the supply chain that created a technical as well as logistical challenge to producing garments quickly.

Novel technology – most notably in color communication – was developed to expedite meaningful communication across continents. Numerical specifications, such as spectral data, replaced more general "go-by's" thus eliminating confusion and the excess time necessary to move from inspiration to production. This same technology will serve as the foundation for "Proximity Sourcing", a new manufacturing paradigm shifting manufacturing to markets where products will be sold.

The introduction of the assembly line by Henry Ford in 1913 revolutionized manufacturing a century ago. "Made Here, Made Possible" provides a glimpse into the logic, methods, and technology behind the next manufacturing Black Swan event.

Color is Strategic: How Transparent Partnerships in Global Supply Chains Changes the Landscape of Manufacture to Deliver Ultrafast Colour

Magnus KANHOLT
CEO natific AG, Switzerland

ABSTRACT

Good design and especially colour are the reasons today why consumers buy garments. The expectation for constant newness and excitement is now an everyday requirement of the customer and must be consistently delivered by brands to drive sales.

The rapid shift in the world centres of fashion production over the past two decades has been well documented in how it has dramatically changed the way the fashion industry works and this process is still evolving. To days shoppers are educated with ever increasing access to sophisticated multi media. Complex data from around the globe is quickly transformed into simple meaningful graphics that give clear easy to understand information including the textile industry. This allows immediate insight into how every brand conducts its business as well as their latest styles on offer.

The challenges to create a profitable garment are many: complex global supply chains for materials garment construction, environmental, sustainability, health and social compliance must all be taken into consideration and actively included. These are additional to new designs, fabrics, colors and performance.

Most international brands have invested in head office inventory management and processing software and the global dyeing and finishing industry in state of the art equipment, computer driven processes and digital colour is now an established technology. Collectively the millions of dollars of investment have disappointingly not fully delivered the time and cost saving expected. These island solutions have now reached the optimum of their performance capability and are now costing many thousands of dollars to support each year.

Fashion retail brands who want to capitalise on their investment in design originality with speed to market and lower manufacturing costs are taking a lead form their customers by switching to new communication media. They now use simple and easy to use specialist color systems and tools which link everything and every one together in the manufacturing supply chain. Huge complex data flows are made simple with clear easy to understand reports and graphics providing clarity of what is happening in real time to drive good decision making.

The only way to deliver faster to market and consistently deliver the requirements of the customer and remain profitable is through a supply chain working in partnership. This need was identified by the natific team of experienced industry color specialists who worked with communication and system data specialists to develop systems that are able to create total transparency of the supply chain for maximum efficiency.

The new technology software and processes developed are now able to overcome many of the supply chain challenges including: flexibility to mange every type of color specification, manage spectral reflectance data exchange, on screen color and physical swatches, support digital and physical/visual color data management processes, include designers, gar-

ment makers and trims suppliers in the process, capability to link to existing PLM and other systems, be simple and easy to use, reduce administration for every supply chain partner, deliver capability for professional proactive decision making at the point of manufacture, increase skills, provide globally recognised reliable in depth color certification for lab/bulk production, colorist and restricted substance list compliance.

Through a textile fashion industry case study we are able to see the transition from traditional ways of communicating color through the steps to a connected transparent supply chain partnership that really manages color, moving from fast to the capability to deliver ultrafast fashion color.

E-mail: magnus.kanholt@natific.com

The Colour of Supply Chain Partnerships: Education, Manufacture in the High-tech Industry, Artisans and Brands Coming Together Making Colour Happen

Nikhil HIRDARAMANI
Director Hirdaramani, Sri Lanka / International Chair – SLDF 2013
Design for Sustainable Development Foundation – Island Craft

ABSTRACT

Sri Lanka an exotic destination and part of a region that is rich in the use of colour and a source for colour inspiration globally, situated in a tropical range with a long history of culture, diversity and an artistically rich history. The Sri Lankan colour palette is one that embraces the entire colour sphere from black to white to unusually expanded hues of colour. The Sri Lankan creative design expertise with easy access to colour sources are established as creating trends as well bringing fresh, innovative, global trend driven colour concepts easily to market.

The "Island Craft" project initially started with the use of "locally" invented colour stories for self-invented products /traditional crafts or for contemporary craft production as a value addition for a local context. These colour inspirations are drawn from natural sources, such as coral reefs, rain forests, indigenous flora and fauna, or manmade resources, such as ancient ruins, traditional or religious murals, traditional motifs, and from multinational cultural heritage. Resulting in local creative's contributing new inspirational colour stories for a variety of product ranges, such as hand crafts and textiles. This has now brought us to a turning point of creating "local trends" in the global market.

Special to the region is how the local but international mass scale export apparel companies embrace the cottage industry trends to apply in mass production to some of their textile and fashion ranges. It is still at an experimental level but becoming well established for future growth. Currently in Sri Lanka we have big apparel manufacturing companies for using experimental batik techniques and colour affects to develop largely producible digital prints for swimwear to be exported globally. Some yarn dyeing plants use their own locally sourced colour palettes. The integration goes deep with both "cottage craft" and "mass" industries using shared concepts and even raw materials to achieve innovative local colour palettes. "Natural dye" will be the most prominent part in this process since Sri Lanka has a wide range of "natural colour sources" like minerals and indigenous plants. This invention is applied by many textile based industries for their "unique" and eco friendly product ranges. The textile printing industry widely uses local based colour stories to develop innovative print patterns to bring to the world. Some textile/dye plants use the same colour concepts to develop their raw materials (yarn/ textile). "Natural dye" is taking place in a special manner and in eco friendly production and process in the country at the moment.

Sri Lanka has developed a dynamic design education sector working with leading international design universities to keep students up to date with the latest educational techniques. Uniquely young creative professionals are also encouraged to contribute to "local trends" globally, including colour stories and colour sources. Design students have access to the rich infrastructure to achieve and explore colours in many ways. Inspiration and technically well equipped workshops (domestic/in cottage industries), colour developing laboratories(in

mass industries), creative and technical expertise. The access to be purely inspired and creative combined with hands on start OF THE ART commercial industrial experience has placed Sri Lankan design students with many of the world's leading fashion retail brands.

Sri Lanka's important geographical location, investment in industry, skills, while respecting culture and the natural environment are steadily growing their contribution and influence to powerful colour trends/sources and materials to the global market. Through this case study we are able to examine a country, a culture and industry of partnerships that is an important part of the evolution that reflects the world's zeitgeist.

Colour Dyeing and Sustainability: How the Fashion Industry has Responded to Pressure to Clean Up Its Wet Processes

Allanna MCASPURN
CEO Made-By, UK

ABSTRACT

This presentation will focus on how the fashion industry has begun to focus its attention beyond the first tier of their supply chains in order to control costs and reduce their environmental impact.

This talk will look at how brands have dealt with the rising costs of raw materials, along with the pressure on them from NGO's to eliminate certain chemicals from the washing and dyeing process. It will also examine the environmental challenges brands still face, the kinds of new wet processes they are now experimenting with and an insight into what the future holds.

Address: MADE-BY, 2nd Floor, 3-4 Bywell Place, London W1T 3DN, UK
E-mail: allana.mcaspurn@made-by.org

The Life Chromatic

Ptolemy MANN
weaver, artist and architectural designer, UK

ABSTRACT

In July 2011 I began writing a blog under the title 'Significant Colour'. It has become a platform for my thoughts and feelings about all things related to colour. After 20 years of working with colour everyday in a myriad of ways I have found there are no rules or formulas where colour is concerned. Colour is intuitive, emotional, complex, intelligent, surprising, accidental and impossible to categorise; as much as we try to.

I will talk about colour in terms of scale and materials. A telescopic review of my approach to using colour from the hand dyed threads of a one-off woven artwork to the facade of a NHS hospital. I will stress the importance, for me, of Bauhaus colour theory, which underpins everything I know about colour. Wearing colour, walking on it, looking at it on a wall, feeling it; colour is everywhere and everything and there is a real art to getting it right. The significance of colour is profound, it has a far bigger impact on our everyday life than we consciously imagine. The Life Chromatic will be a quick visual gallop through architecture, art, design and craft seen through my own work and kaleidoscopic philosophy.

E-mail: fifth@ptolemymann.com

colour technology

colour technology

Testing the Performance of Whiteness Formulas using the *PF/3* and *STRESS* Indices

Manuel MELGOSA,[1] Ichiro KATAYAMA,[2] María D. HUETE,[3] Pedro A. GARCÍA[3]
[1] Department of Optics, Faculty of Sciences, University of Granada, Spain
[2] Faculty of Biology-Oriented Science and Technology, Kinki University, Japan
[3] Department of Statistic and Operational Research, Faculty of Sciences, University of Granada, Spain.

ABSTRACT

We have tested the performance of 19 whiteness formulas using 4 experimental datasets and 3 different indices: Pearson's linear correlation coefficient *r*, *PF/3* (Performance Factor divided by 3), and *STRESS* (Standardized Residual Sum of Squares). Our results indicate that the ranking of best to worst whiteness formulas was considerably different using *r* than using *PF/3* or *STRESS*. This result was confirmed from principal component analyses. Some differences were also found among results from each one of the 4 experiments. Thus, using *STRESS* there were no statistical significant differences among the 19 tested whiteness formulas for the CSMW-I experiment, but for the 3 remaining experiments, Uchida, Grum and Stenius whiteness formulas achieved statistically significant improvements with respect to other formulas. From the median of rankings of the 4 experiments together, the 3 best whiteness formulas were (in this order): Uchida, Grum and Y_{10} from *r*; Uchida, Grum, and Stenius from *PF/3*; and Grum, Stenius and Uchida from *STRESS*. Current CIE whiteness formula is ranked in positions 9, 4, and 3 using *r*, *PF/3*, and *STRESS* indices, respectively. By the moment we can conclude that testing the performance of different whiteness formulas using only the Pearson's linear correlation coefficient *r* may lead to incomplete conclusions. We would recommend the use of the *STRESS* index, mainly because of the possibility of testing whether two whiteness formulas are or not statistically significant different with respect to perceived whiteness of a set of samples in a given experiment.

1. INTRODUCTION

In a previous paper (Katayama et al. 2012) the Pearson's linear correlation coefficient *r* was employed to assess the merits of 16 whiteness formulas predicting perceived whiteness in 4 different experiments: CSMW-I (18 samples, 74 observers), CSMW-II (29 samples, 74 observers), CSMW-III (47 samples, 46 observers), and SIGW (18 samples, 69 observers). The Committee on Specification Method of Whiteness (CSMW) performed in 1987 the 3 CSMW experiments mentioned before with the aim of promoting whiteness standardization in Japan, while the Special Internet Group on Whiteness (SIGW) conducted additional experiments on whiteness at 3 different academic centers during the period 2006-2007.

Here we propose to complement these previous results using the *PF/3* -Performance Factor divided by 3- (Guan et al. 1999), and the *STRESS* -Standardized Residual Sum of Squares- (García et al. 2007) indices, which have been successfully employed in recent research testing the relative merits of color-difference formulas with respect to different visual datasets (Melgosa et al. 2008). *PF/3* is an average of 3 previous indices named *Gamma*, V_{AB} and *CV*. *STRESS* is interesting because it allows F-tests indicating whether two color-difference (or two whiteness) formulas are or not statistically significantly different. For each of the 4 experiments mentioned before, we have tested 19 whiteness formulas, which can be grouped in 5 categories (see Appendix): 1: One tristimulus value. 2: A combination of two or three tristimulus values. 3: Functions of lightness and chromaticity. 4: A color difference from a reference white point. 5: Other formulas.

2. RESULTS AND DISCUSSION

For each of the four experiments, Table 1 shows the three best whiteness formulas using *r*, *PF/3*, and *STRESS* indices (i.e. the formulas providing the highest *r* values, and the lowest *PF/3* and *STRES* values). As we can see, *PF/3* and *STRESS* provided very similar results for the 4 experiments, but the results obtained using *r* were enough different to those found from *PF/3* or *STRESS*, in particular for the CSMW-I and CSMW-III experiments.

Table 1. The 3 best whiteness formulas predicting the results in each one of the 4 visual experiments, using the r, PF/3, and STRESS indices, respectively.

	CSMW-I	CSMW-II	CSMW-III	SIGW
r	1: L^*_{10} 2: Hunter L_{10} 3: Y_{10}	1: Grum 2: Uchida 3: Z_{10}	1: X_{10} 2: Y_{10} 3: Hunter L_{10}	1: Grum 2: Uchida 3: Stenius
PF/3	1: Uchida 2: Hunter-Judd 3: Hunter 2	1: Stenius 2: Grum 3: Taube	1: Hunter-Judd 2: Uchida 3: Hunter 2	1: Stenius 2: Taube 3: Berger
STRESS	1: Hunter-Judd 2: Uchida 3: Hunter 2	1: Grum 2: Stenius 3: Uchida	1: Uchida 2: Grum 3: Stenius	1: Stenius 2: Grum 3: Taube

Principal component analyses (PCA) have been used to analyze the differences between *r*, *PF/3* (*Gamma*, V_{AB} and *CV*), and *STRESS* indices for each one of the 4 experiments, as shown in Figure 1. Numbers in the plots in Figure 1 indicate the 19 formulas tested, which in some cases are remarkably similar. Note that in most plots in Figure 1, *r* vectors pointed in different directions than vectors corresponding to *PF/3* or *STRESS*, which means that the linear correlation coefficient *r* performs differently to the *PF/3* and *STRESS* indices.

F-Tests (95% confidence level) from *STRESS* values indicated that none of the 19 whiteness formulas was statistically significantly better than the others for the CSMW-I experiment. However, for the CSMW-II, CSMW-III and SIGW experiments, some whiteness formulas were significantly better than others. Specifically, it was found that Uchida, Grum and Stenius whiteness formulas were the ones achieving main statistically significant improvements with respect to other formulas.

Beside differences between the 4 experiments, we have evaluated all together using the median values of the *r*, *PF/3*, and *STRESS* rankings of the 19 whiteness formulas. Table 2 shows the results found indicating the best to the worst whiteness formulas for each index, suggesting that Grum and Uchida whiteness formulas were the best ones for the whole set of experimental data. From Table 2 we can also see that current CIE whiteness formula is ranked in positions 9, 4, and 3 using *r*, *PF/3*, and *STRESS*, respectively. These good results using *PF/3*, and *STRESS* may be even better if some samples outside CIE range were removed in the 4 experiments we have analyzed (Katayama et al. 2012).

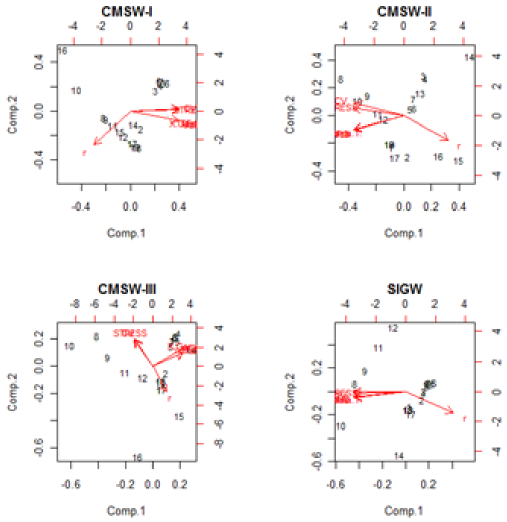


Figure 1. Principal component analyses results showing the performance of the indices tested in each one of the 4 experiments. Numbers indicate the tested whiteness formulas.

Table 2. Best (1) to worst whiteness formulas using r, PF/3, and STRESS, from the median of the rankings in the CMSW-I, CSMW-II, CSMW-III, and SIGW experiments.

r	1: Grum, Uchida. 2: Y_{10}. 3: X_{10}, Hunter L_{10}. 4: Z_{10}. 5: Stenius, L^*_{10}. 6: Stensby. 7: Taube. 8: Berger. 9: CIE. 10: Croes. 11: Hunter 1, Fukuda, Hunter 2. 12: Selling. 13: Hunter 3. 14: Hunter-Judd.
PF/3	1: Uchida. 2: Grum, Stenius. 3: Berger. 4: Y_{10}, Taube, Hunter-Judd, CIE. 5: Hunter 2, Hunter 3, Selling, X_{10}. 6: Z_{10}, Hunter 1, Fukuda, Croes. 7: Stensby, Hunter L_{10}. 8: L^*_{10}.
STRESS	1: Grum. 2: Stenius, Uchida. 3: CIE. 4: Hunter 1. 5: Y_{10}, Z_{10}, Berger, Taube, Croes. 6: Fukuda, X_{10}. 7: Stensby. 8: Hunter L_{10}. 9: L^*_{10}. 10: Selling. 11: Hunter 3. 12: Hunter 2. 13: Hunter-Judd.

3. CONCLUSIONS

The relative merit of 19 whiteness formulas has been tested from visual results found in 4 experiments using the linear correlation coefficient *r*, *PF/3*, and *STRESS* indices. The ranking of best whiteness formulas for each experiment, as well as principal component analyses, suggest that results from *r* are not in good agreement with those found using *PF/3*, and *STRESS*, which are relatively similar. *STRESS* results may be particularly useful, because F-tests can indicate if two whiteness formulas are statistically significant different or not. From values of median in rankings using *r*, *PF/3*, and *STRESS* in the 4 experiments together, we found that the best whiteness formulas were Grum, Uchida and Stenius, which showed significant improvements with respect to a number of different whiteness formulas (except for the CSMW-I experiment).

ACKNOWLEDGEMENTS

Research Project FIS2010-19839, Ministry of Economy and Competitivity (Spain), with European Research Development Found (ERDF) support.

APPENDIX

Type	Formula	Identification Name	Note
1	$W_{10} = Y_{10}$	Y_{10}	ASTM Method E97-53T(1953)
	$W_{10} = Z_{10}$	Z_{10}	TAPPI Method T425m-48(1948)
2	$W_{10} = 0.333Y_{10} + 1.060Z_{10} - 1.277X_{10}$	Berger	
	$W_{10} = 3.67Z_{10} - 3Y_{10}$	Taube	
3	$W_{10} = L_{10} - 3b_{10}$	Hunter 1	L and b are Hunter coordinates.
	$W_{10} = L_{10} + 3a_{10} - 3b_{10}$	Stensby	L, a, and b are Hunter coordinates.
	$W_{10} = \frac{100 + Y_{10}}{2} - 2000\beta_{10}$	Fukuda	β is a coordinate of Hunter UCS diagram.
4	$W_{10} = 100 - \left\{\left[\frac{220.2(Y_{10} - Z_{10})}{Y_{10} + 0.242Z_{10}}\right]^2 + \left[\frac{100 - Y_{10}}{2}\right]^2\right\}^{1/2}$	Hunter 2	
	$W_{10} = 100 - \left\{(100 - L_{10})^2 + 10b_{10}^{\ 2}\right\}^{1/2}$	Hunter 3	L and b are Hunter coordinates.
	$W_{10} = 100 - \left\{\left[3000\left((\alpha_{10} - \alpha_{n,10})^2 + (\beta_{10} - \beta_{n,10})^2\right)^{1/2}\right]^2 + \left(\frac{100 - Y_{10}}{200}\right)^2\right\}^{1/2}$	Hunter-Judd	α and β are coordinates of Hunter UCS diagram. α_n=-0.0051, β_n=0.0099.
	$W_{10} = 100 - \left\{(100 - Y_{10})^2 + 9.5\times10^4(\Delta S_{10})^2\right\}^{1/2}$	Selling	Δs is a distance on the CIE 1960 UCS diagram between the illuminant point and the test point.
	$W_{10} = Y_{10} - 13.2Y_{10}\left\{(\Delta u_{10})^2 + (\Delta v_{10})^2\right\}^{1/2}$	Croes	$\Delta u = u - u_n$, $\Delta v = v - v_n$. u and v are the chromaticity coordinates in the 1960 UCS diagram. u_n and v_n are the chromaticity coordinates of the perfect diffuser.
5	$W_{10} = Y_{10} + 800(x_{n,10} - x_{10}) + 1700(y_{n,10} - y_{10})$	CIE	x_n and y_n are the chromaticity coordinates of the perfect diffuser under the CIE illuminant D65.
	$W_{10} = 9.53\left(0.9\times\frac{\frac{1 - x_{10} - y_{10}}{1.089y_{10}}Y_{10} - 100}{100}Y_{10} + 19.19\right)$	Stenius	
	$W_{10} = 3.8Z_{10} - 1201S_{10} - 270.1$	Grum	S is a distance on the CIE xy chromaticity diagram between the illuminant point and the test point. In the original formula, saturation is determined in MacAdam's geodesic chromaticity diagram.
	$W_{10} = W_{CIE,10} - 2(T_{W,10})^2 \quad [40 < W_{CIE,10} < 5Y_{10} - 275]$ $W_{10} = P_{CIE,10} - 2(T_{W,10})^2 \quad [W_{CIE,10} > 5Y_{10} - 275]$	Uchida	T_W is the CIE tint index. $P_{W,10}$=(5Y_{10}-275)-[800[]0.2742+0.00127(100-Y_{10})-x_{10}[]$^{0.82}$+1700[]0.2762+0.00176(100-Y_{10})-y_{10}[]$^{0.82}$]
Other metrics			
	X_{10}, L^*_{10}, Hunter L_{10}		

REFERENCES

García, P.A., R. Huertas, M. Melgosa and G. Cui, 2007. Measurement of the relationship between perceived and computed color differences. *Journal Optical Society of America A* 24, 1823-1829.

Guan, S-S., and M.R. Luo, 1999. Investigation of parametric effects using small colour differences. *Color Research and Application* 24(5), 331-343.

Katayama, I., H. Uchida, H. Sobagaki and G. Baba, 2012. Comparison of various whiteness formulae based on results of whiteness evaluation experiments. *Proc. AIC 2012 Interim Meeting (Taipei)*, 610-613.

Melgosa, M., R. Huertas and R.S. Berns, 2008. Performance of recent advanced color-difference formulae using the Standardized Residual Sum of Squares index. *Journal Optical Society of America A* 25, 1828-1834.

Address: Prof. Manuel Melgosa, Department of Optics, Faculty of Sciences (Mecenas Building, Office 107), University of Granada, 18071 – Granada (Spain).
E-mails: mmelgosa@ugr.es, katayama@waka.kindai.ac.jp, mdhuete@ugr.es, pagarcia@ugr.es

3D Facial Scanner using True Colour Reproduction Technology

Soon-Young KWON, Song-Woo LEE, Jae Woo KIMM, Jin-seo KIM
Electronics and Telecommunications Research Institute (ETRI)

ABSTRACT

In this paper, we present a 3D facial model reproduction system that can represent accurate skin colour using multi-camera characterizaion. The system takes pictures using a set of three DSLR cameras and performs cameras characterization and multi-stereo reproduction. 3D facial scanner produced with continuous light source for multi camera shooting and with darkroom for exactly skin colour reproduction. We verify quality of colour of texture and geometric of 3D facial model through many actor's 3D facial models using scanner system.

1. INTRODUCTION

3D facial model construction is an important topic in computer graphics, animation, virtual reality, and computer vision research and a variety of related industries. In the process of constructing realistic 3D facial model, it is important to represent the details of skin texture such as freckles, moles, wrinkles, etc. and true color reproduction technology is essential to obtain the realistic and convincing 3D facial model.

To achieve this goal, we developed 3D facial model construction system using multi-stereo technology (T. Beeler 2011). The 3D facial scanner system consists of three DSLR cameras, three different light sources that are daylight, cross-polarized and UV lights. We used the three cameras to simultaneously capture images of a human face and construct corresponding 3D facial model. We firstly constructed two stereo matching models from three cameras by matching facial components such as right eye and left eye respectively. We then created the final facial model from the two constructed stereo matching models.

Color calibration and characterization was conducted under controlled illumination conditions to generate accurate 3D model and realistic skin color textures. As a result three different 3D facial models were constructed for each illumination condition. We also developed robust calibration and feature extraction algorithms for multi-stereo matching process that are independent of the number of cameras, camera configuration, camera brand and type, illumination condition, and distances among cameras and objects (Kim 2011).

We conducted color device characterization to guarantee color consistency among different types of devices such as cameras by transforming RGB color data into CIELAB color space and performing gamut mapping. We used polynomial regression model based on raw file images of color chart captured by the three cameras used in our experiments to extract calibration information that are used to conduct color correction.

2. 3D FACIAL SCANNER SYSTEM

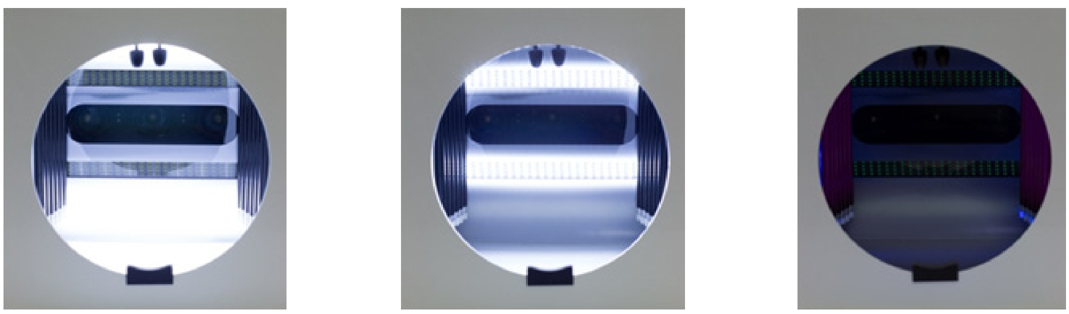
Fig. 1 shows the 3D facial scanner system which captures facial images from a set of three DSLR cameras (Canon 5D Mark II). We created left facial model usging images captured by left and middle cameras and right facial model using images from middle and right camera.

The system construct 3D facial model by matching the two 3D models. The advantage of multi-stereo reproduction is that it can cover wider range of objects and it can therefore successfully reconstruct the model including the region from eyebrows to ears of human face. The distance between two cameras is 6-7 cm so that it is identical to the distance between the human eyes. The cameras had been oriented by the optimal angles to maximize the reproduction area of the 3D facial model. The size of the texture images were set to 3744×5616 in order to gaurantee the highest possible image quality.

(a) Side (b) Back (c) Front

Figure 1: H/W Structure of the 3D Facial Scanner.

The 3D facial scanner system provides 3D model reconstruction capability using three different types of texture images that had been created under daylight, polarized light, and UV light respectively. Daylight texture images can be used to represent realistic skin texture of the human face by using texture mapping technique. Polarized light textures can be used to estimate glossiness of facial skin by detecting specular components of the face images using the difference images between the polarized light texture images and corresponding daylight texture images because polarized light textures do not include specular components of the images while the daylight textures do. UV textures enable the system to detect hyper pigmentation of the skin that is invisible to human eyes. The intensity of the UV light is in the similar level of the UV light that is detected from the sun in a sunny day and it was therefore proved to be safe to the user to be exposed to the UV light of the system for a few seconds that is enough to obtain UV textures.



(a) (b) (c)

Figure 2: Light Source in the 3D Facial Scanner: (a) daylight (white, 5500K), (b) polarized light, (c) UV-A light.

Fig. 3 shows the 3D facial models reconstructed using the facial scanner and we could confirm that the geometrical accuracy of the 3D facial model and the accuracy of the skin color values.

(a) under the Daylight *(b) under the Polarized light* *(c) under the UV-A light*

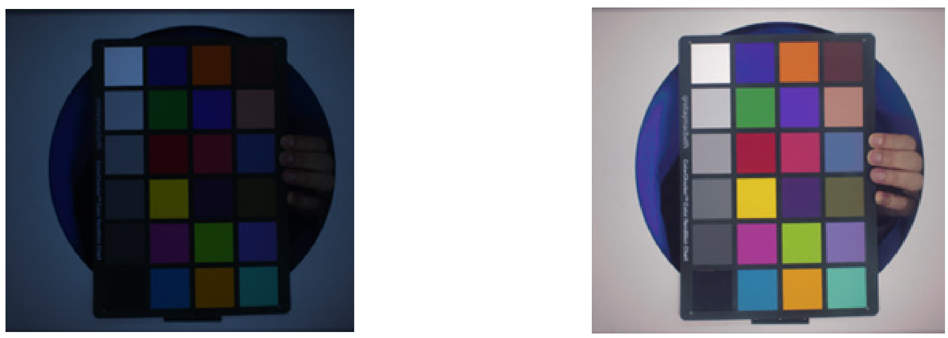
Figure3: The example of texture model each light source.

3. CHARATERIZATION OF MULTI-STEREO CAMERAS

Color device characterization technology is required to represent accurate skin color of the reconstructed 3D facial models. 3D facial reconstruction will generate errors in facial model reconstruction as well as color reproduction when color device characterization is not conducted in the pre-processing step (Jang 2012). As shown in Table 1 and Fig. 4, we have conducted camera characterization using color patches.

Table 1. Difference of color reproduction about camera (ΔE_{ab})

Type	SVD	4 Poly	7 Poly	11 Poly	14 Poly	20 Poly
Canon (5D Mark II)	**1.42**	6.61	5.46	4.53	3.96	2.51



(a) *(b)*

Figure 4: Comparison between the images with and without color device characterization

4. CONCLUSIONS

In this research, we conducted multi-stereo 3D facial model reconstruction using a set of three cameras with three different types of illumination conditions. To do this, we developed a 3D facial scanning system that could generate a satisfactory 3D facial models with realistic textures in 100 seconds. Our system also provides high quality facial textures and accurate 3D geometries that can be used for games, animation, and facial skin analysis.

Our approach has following advantages. Firstly, our approach can represent realistic human skin color by color device characterization capability. Secondly, skin textures captured under cross-polarized or UV-A light sources enable accurate skin analysis by removing specular components from the textures or providing useful information about skin pigments respectively. Lastly, our approach, by employing high resolution DSLR cameras, can generate high quality 3D geometry of human face models.

ACKNOWLEDGEMENTS

This work was supported by Ministry of Culture, Sports and Tourism and KOCCA in the CT R&D Program 2011.

REFERENCES

Kim, J-H, and B-K. Koo, 2011. Multi-camera Calibration Using Multi-view Constraints, *Korea-Japan joint workshop on Frontiers of Computer Vision*.

Beeler, T., F. Hahn, D. Bradley, B. Bickel, P. Beardsley, C. Gotsman, and M. Gross, 2011. High-quality passive facial performance capture using anchor frames, *ACM Transactions on Graphics*, 30(4), 75:1-75:10.

JANG, I-S., J-Y. You, and J-S. Kim, 2012. Makeup Color Representation Based on Spectral Characteristics, *AIC 2012 Interim Meeting*, 622-625.

Address: 218 Gajeongno, Yuseong-gu, Daejeon, 305-700, KOREA
E-mails: ksy2020@etri.re.kr, ppine97@etri.re.kr, jae_kim@etri.re.kr, kjseo@etri.re.kr

Evaluation of Color Discrimination Property for Sunglasses Based on the Color Gamut Area Ratio

Ichiro KATAYAMA,[1] Masahiko OKAMOTO,[2] Kimio MATSUMOTO,[2] Kenta NODA[2]

[1] Faculty of Biology-Oriented Science and Technology, Kinki University, Japan

[2] Technology Development Department, Yamamoto Kogaku Co. Ltd, Japan

ABSTRACT

An index for evaluation of color discrimination property for sunglass lenses was calculated by taking the ratio of the color gamut area, which was formed by the eight CIE-1974 test-color samples for the general color rendering index, on the CIECAM02 colorfulness plane under standard illuminant D65 after passing through the lens being tested, to the color gamut area, which was formed by the test-color samples on the plane under standard illuminant D65. The validity of the index for quantitative evaluation of color discrimination property for sunglass lenses was verified by the very high simple correlation coefficient between the visual evaluation results and the indices of color discrimination property. In addition, it was shown that blocking the spectral component around 565nm is effective in improving the color discrimination property of sunglass lenses.

1. INTRODUCTION

Color discrimination property is required for sports sunglasses in accordance with the particular competition, in addition to anti-glare properties and design. For example, for golf sunglasses, lenses which make it possible to see the grass grain clearly are preferred. However, a method to quantitatively evaluate the color discrimination property of sunglass lenses has not been established and, currently, trial-and-error field testing is necessary using prototypes. Therefore, the development efficiency is poor, and it is difficult to optimize the spectral transmittance distribution of sunglass lenses.

On the other hand, it is known in the field of evaluations of the color rendering property of light sources that excellent color discrimination is provided by an illuminant under which a wide color gamut is formed by the chromaticity coordinates of a set of test color samples (Thornton 1972). Since sport sunglasses are presumed to be used outdoors, by calculating the color gamut area under daylight after passing through the sunglass lens being tested, it is possible to evaluate the color discrimination property of the lens in a similar manner to the evaluation of the color rendering property of light sources. In the present study, a color discrimination evaluation index of sunglass lenses based on the color gamut area ratio is defined and, together with a study of its effectiveness, its application in the optical design of lenses is discussed.

2. CALCULATION METHOD OF THE COLOR DISCRIMINATION EVALUATION INDEX BASED ON THE COLOR GAMUT AREA RATIO

With the gamut area, $A\mathrm{r}$, which was formed by the eight CIE-1974 test-color samples for the general color rendering index (CIE 1995), on the CIECAM02 colorfulness plane (CIE 2004) under standard illuminant D65, and the gamut area, $A\mathrm{t}$, which was formed by the test-color samples on the plane under standard illuminant D65 after passing through the lens being tested, the ratio, $G\mathrm{a}$, of these gamut areas was obtained as the index for color discrimination evaluation of the lens, as shown by Equation (1),

$$Ga = \frac{At}{Ar} \times 100 = \frac{\sum_{i=1}^{8} \left(a_{\mathrm{Mt},i-1} b_{\mathrm{Mt},i} - b_{\mathrm{Mt},i-1} a_{\mathrm{Mt},i} \right)}{\sum_{i=1}^{8} \left(a_{\mathrm{Mr},i-1} b_{\mathrm{Mr},i} - b_{\mathrm{Mr},i-1} a_{\mathrm{Mr},i} \right)} \times 100 \quad \cdots\cdots(1)$$

where, $a_{\mathrm{Mr},i}$ and $b_{\mathrm{Mr},i}$ are the coordinates, under standard illuminant D65 on the CIECAM02 colorfulness plane, of the test color samples used for calculating the general color rendering index, and $a_{\mathrm{Mt},i}$ and $b_{\mathrm{Mt},i}$ are the coordinates of the same test samples under standard illuminant D65 after passing through the lens being tested. When the subscript "i" is 1, it is treated cyclically as "i -1=8".

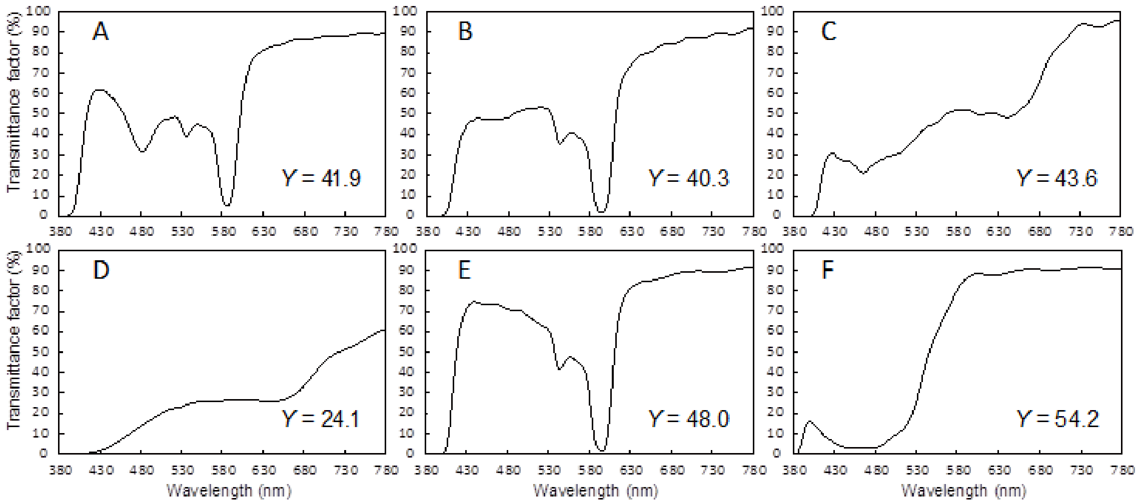


Figure 1. Spectral transmittance distributions of the sunglasses used in the experiment.

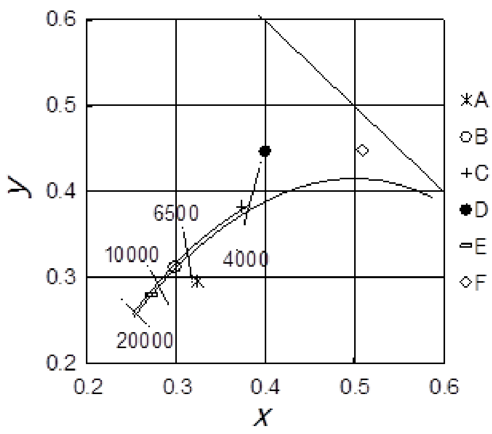


Figure 2. Chromaticities of D65 after passing through each pair of sunglasses.

3. VISUAL EVALUATION EXPERIMENTS ON THE COLOR DISCRIMINATION PROPERTY OF SUNGLASSES

The ColorChecker Classic was presented under a high intensity D55 simulator to 21 observers (13 males and 8 females) with normal color vision, who were asked to evaluate, by paired comparison, the color discrimination property of six types of sunglasses which have different spectral transmittance distributions. The illuminance on the face of the ColorChecker presented was 4600 lx. The spectral transmittance distributions of the sunglasses which were used in the experiment are shown in Figure 1. The *xy* chromaticities of D65 after passing through each pair of sunglasses are shown in Figure 2. The values of the luminous transmittances of all of the sunglasses are approximately equal except for the sunglasses D. By testing the consistency of the results of the paired comparisons made by each observer, it was confirmed that the results were statistically significant at the 5% level for two observers and the 1% level for the other 19 observers. By testing the agreement of the results among the observers, it was confirmed that the result was statistically significant at the 1% level. Since, from the foregoing results, the evaluations by the observers were considered to have been made according to a common one-dimensional scale, the interval scale of color discrimination of sunglasses was composed based on the results of the evaluations by all of the observers.

4. COMPARISON OF THE COLOR DISCRIMINATION EVALUATION INDEX WITH THE RESULTS OF VISUAL EVALUATION EXPERIMENTS

Figure 3 shows the color gamuts formed by the test color samples on the CIECAM02 colorfulness plane. The color discrimination evaluation indices, *G*a, calculated from the spectral transmittance of each type of sunglasses are also shown in Figure 3. Since the color discrimination evaluation indices, *G*a, are greater than 100 for sunglasses A, B and E, improvements in color discrimination are expected with these sunglasses. From the shapes of the gamuts, effects are expected of enhancements of the red and green color contrast.

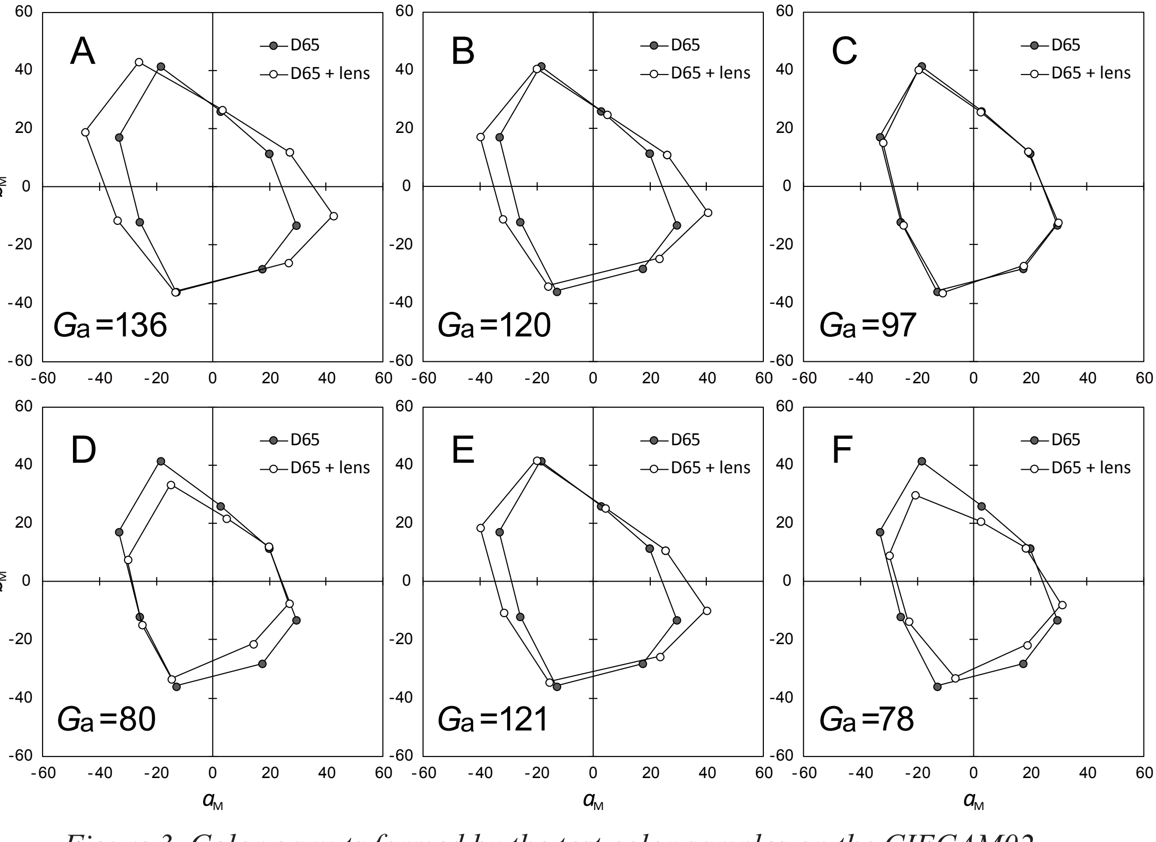


Figure 3. Color gamuts formed by the test color samples on the CIECAM02 colorfulness plane.

When we considered the relationship between the visual evaluation results and the indices of color discrimination property which were calculated from the spectral transmittance distribution of the sunglass lenses, the simple correlation coefficient was approximately 0.97 as shown in Figure 4; thus, we have confirmed that this method is effective to evaluate quantitatively the color discrimination property of sunglass lens.

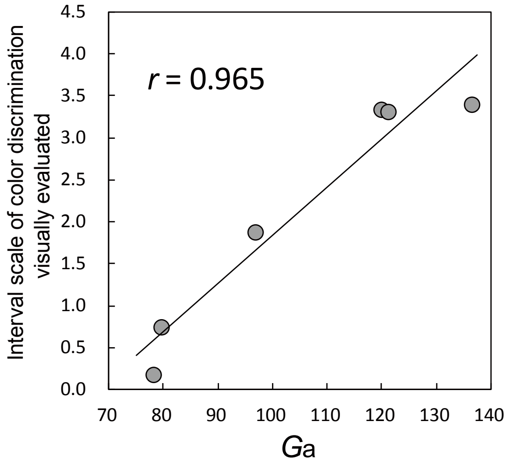


Figure 4. Relationship between the visual evaluation results and the color discrimination property indices.

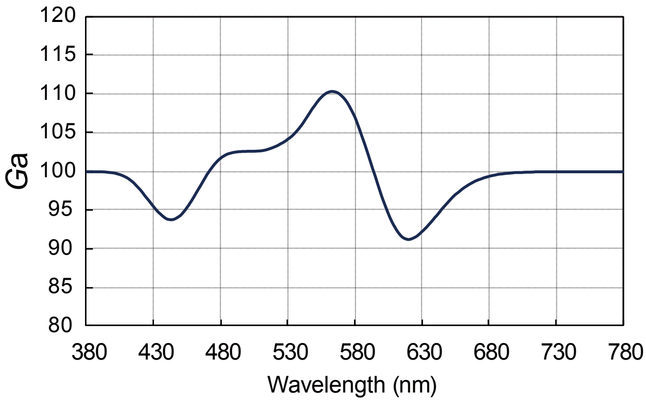


*Figure 5.Relationship between the center wavelength for the notch filter and the color discrimination property ind*ex.

5. APPLICATION OF THE COLOR DISCRIMINATION EVALUATION INDEX IN THE OPTICAL DESIGN OF LENS

The color discrimination evaluation index, *G*a, was calculated for D65 transmitted through an assumed notch filter with a FWHM of 10nm. The calculated results, as the center wavelength of the notch filter was varied from 380 to 780nm, of the indices, *G*a, are shown in Figure 5. The abscissa in Figure 5 is the center wavelength of the notch filter. Since the maximum of the index, *G*a, is close to 565nm, it is seen that the most effective improvement of the color discrimination of sunglass lenses is obtained by blocking the spectral component around 565nm.

6. SUMMARY

The color discrimination evaluation index for sunglass lenses was defined by focusing on the color gamut area formed by test color samples under daylight after passing through the lens. The validity of the index was verified by the high correlation which was found in a comparison with the results of visual evaluation experiments. In addition, it was shown that blocking the spectral component of light around 565nm with sunglass lenses is effective in improving the color discrimination.

REFERENCES

CIE Publication 13.3. 1995. Method of measuring and specifying colour rendering properties of light sources. Vienna: CIE.

CIE Publication 159. 2004. *A colour appearance model for colour management systems: CIECAM02*. Vienna: CIE.

Thornton, W.A., 1972. Color-discrimination index. *Journal of the Optical Society of America* 62(2) 191-194.

Address: Ichiro Katayama, Dept. of Biomechanical and Human Factors Engineering,
Faculty of Biology-Oriented Science and Technology, Kinki University, 930 Nishi-Mitani,
Kinokawa City, Wakayama Prefecture 649-6493, Japan
E-mails: katayama@waka.kindai.ac.jp, okamoto@yamamoto-kogaku.co.jp,
matsumoto.k@ yamamoto-kogaku.co.jp, noda@ yamamoto-kogaku.co.jp

Modeling the Effects of Vat Dyes and Aloe Vera on the UV Protective properties on Cotton Fabric

Neha SINGH[1]*, Suman PANT[2], Pankaj GILL[3] and M.S. PARMAR[4]
[1]Textile Design Dept., National Institute of Fashion Technology, New Delhi.;
[2] Faculty of Home Science, Banasthali University, Rajasthan;
[3] Govt. College Karnal, Haryana;
[4] NITRA, Ghaziabad (U.P.)

ABSTRACT

The incidence of skin cancer has been rising worldwide due to excessive exposure to sun light. Elevated exposure to ultraviolet radiation component of sunlight results in skin damages; such as sunburn, premature skin aging, allergies and skin cancer. Medical experts suggest several means of protection of human skin against ultraviolet radiation; use of sunscreens, avoidance of the sun at its highest intensities, wearing clothing that covers as much of the skin surface. However, this paper gives an insight about how textile material specially cotton can be efficiently utilized for protecting human skin from the harmful ultraviolet radiations by combining vat dyes with aloe Vera.

Key Words: Fabric construction, Vat dyes, Aloe vera, UV protection, Protective clothing, sustainability.

1. INTRODUCTION

In the recent years, a new type of peril related to the excess exposures to sun light which causes human skin damage have been noticed that is UV radiation through sun light. Approximately 10% of sun's energy is in the form of ultraviolet radiations. Atmosphere absorbs most of the lethal radiations emitted by the sun, only 5% of the harmful radiations reach to the surface of the earth. UV radiation can pilot the acute and chronic reactions and damage, such as acceleration of skin ageing and sunburn. The approaches to prevent the UV exposure by reducing exposure to sunlight include: avoiding outdoors specially during noon hours, using sunscreen creams or lotions and wearing protective clothing. Another mode of protection is the application of sunscreen creams and lotions. But a sunscreen's effectiveness depends upon its ability to withstand heat, humidity and sweat.

Today consumers are demanding more and more charge addition in the products. In the past few years, there has been great interest in textiles and garments that offer enhanced reassure as well as protection to the wearer. So the concept of UV protection clothing is also attracting attention of consumers. In the present work an attempt has been made to provide UV resist properties to protect the human skin from harmful effect of UV radiation. To impart UV resist properties to cotton fabric basic finishing treatments like mercerization and bleaching, UV absorbers such as natural Aloe Vera finish, vat dyes were selected. To estimate the performance of each treatment on the fabric, these treatments were applied separately with different concentrations and some treatments were applied in combination also.

2. EXPERIMENT

2.1 Materials

Selection of the fabric was based on their utility and suitability as per the climate condition of the country for the upper and lower garment. Two different type of fabric in two different weave, plain and twill with different thickness, were chosen thus total four fabrics were selected. All fabrics were in grey state with off white color.

Table 1. Fabric code given to the fabrics used in the study.

Name of the fabrics	Weave	Fabric Code
Cotton (loosely woven)	Plain	CPL
Cotton (compactly woven)	Plain	CPC
Cotton (loosely woven)	Twill	CTL
Cotton (compactly woven)	Twill	CTC

2.2 Dyeing Studies Vat Dyes in two colors were selected; Coravat Brown G A/C and Coravat Yellow 5G MD. The dyes used were commercial sample supplied by colourtex Ltd. Fabrics were prepared for dyeing by scouring them in a 1g/L solution of non-ionic detergent (Lissapol N) for 45 min at 80°C and at a liquor-to-fabric ration of 50:1. This was followed by repeated washing, rinsing in hot and cold water and then drying the fabrics. The fabric was dyed with two different colors (yellow and brown) of vat dyes in three different percent shades (0.5%, 1% and 2%).

2.3 The color yield (K/S) values of the dyed samples were then measured spectrophotometrically using the Kubelka- Munk equation.

2.4 Finishing with natural Aloe Vera: Aloe Vera is known to possess UV protective properties it is added in sun screen lotions and creams to protect skin from UV rays. Therefore it was used as UV absorber to find out its effect on UPF of cotton fabrics by micro encapsulation technique. Cotton fabrics were dipped with 2%, 4% and 6% of commercial UV absorber. The finish was applied on the fabric with the help of padding mangle. Padded materials were cured at 130°C for 3 minutes. All the fabrics were given hot and cold rinse thereafter and then air-dried.

2.5 Evaluation of physical properties of fabric was conducted by testing the fiber content, fabric count, yarn number, cloth cover, thickness and weight/unit area.

2.6 Determination of ultraviolet transmission The Labsphere UV-1000F Ultraviolet Transmittance Analyzer is designed for measuring the UV transmission of dry textiles as a means of determining their ultraviolet protection factor. The UV-1000F satisfies all the requirements of Australian/New Zealand Standard AS/NZ 4399:19961.

3. RESULTS AND DISSCUSSION

3.1 Effect of physical properties on UPF

Percent UVR transmission, UPF values and the fabric constructional parameters viz. fibers type, thread count, cloth cover, thickness and weight per unit area of unfinished fabrics (prior to finishing) have been examined. In terms of fibers composition it is known that cellulose is very transparent to UV radiation, hence untreated cotton transmits large amount of UV radiation. It was seen that cotton fabric woven with twill weave showed good protection from UV rays as compared to the plain weaved fabrics. UPF of compactly woven fabrics was higher than loosely woven fabric.

3.2 Effect of vat dyes on the UV transmission of cotton fabrics

The fabrics given basic finishing treatment were dyed with vat dyes in two different colors (yellow and brown) in three different percent shades (0.5%, 1% and 2%). All the dyed samples were tested for K/S and UPF. It is evident from results that as concentration of dyes is increasing the UPF is also increasing in all the fabrics. The reason is that with increase in dye concentration, color strength (K/S value) also increased which shows presence of more amount of dye in fiber. As compared to the undyed samples, UVR transmission of dyed fabrics reduced considerably which in turn enhanced UPF of dyed fabrics. However, impact of fabric type i.e. weight/ thickness/ cover factor was observed on UPF of vat dyed fabrics. Fabrics with more thickness / weight / cover factor were showing better UV protective properties. Increase in UPF of vat dyed loosely woven plain weave cotton fabric (CPL) is less where as drastic increase in UPF of other fabrics is found after dyeing. Best results were shown by compactly woven twill weave fabric.

ANOVA results shows that the effect of Coravat Brown G A/C color on UPF are significant ($p < 0.05$) Also fabrics are highly significant ($p < 0.05$) i.e. effects of fabrics are not homogeneous. It can be seen that effect of Coravat Yellow 5G M/D color are significant ($p < 0.05$) Also fabrics are highly significant ($p < 0.05$) i.e. effects are fabrics are not homogeneous. Thus both the factors concentration of dye as well as fabric type significantly affected UPF of cotton fabric.

3.3 Influence of aloe vera on the vat dyed samples of cotton fabric

An endeavor was made in this study to find out cumulative effect of dye and UV absorber on UV protective property of cotton. Fabric was first dyed with vat dye in 2% shade and then finished with Aloe Vera in 3gm, 6gm and 9gm/m^2 concentrations.

As is evident from data in comparison to individual treatments with dye and with UV absorber, UPF of cotton fabric given both the treatments is higher. Thus a kind of cumulative effect was observed. This trend was found in all the fabrics and in both the dyes, brown and yellow. Thus it can be said that dyeing as well as UV absorber finishing provide excellent protection in the comparison to only dyeing and only UV absorber finishing samples.

ANOVA results shows that the effect of vat brown dye and Aloe Vera are insignificant ($p >.05$) fabrics are significant ($p >.05$) i.e. effects are fabrics are not homogeneous. Effect of vat yellow dye and Aloe Vera are insignificants ($p >.05$) fabrics are significant ($p >.05$) i.e. effects are fabrics are not homogeneous.

4. CONCLUSION

It can be concluded that as the color strength of vat dyed fabrics was increasing, the UPF was also increasing. Except the CPLSMB fabric all the fabrics exhibited the excellent protection, from UV rays after dyeing with vat dyes. Almost similar results were obtained with brown and yellow vat dyes with little variation. After combining vat dyes with aloe vera excellent UPF was observed. There is a significant change in the UPF of vat dyed cotton fabric after treatment with aloe vera.

ACKNOWLEDGMENTS

The author wish to thank National Institute of Fashion Technology, New Delhi, India for providing necessary and timely help in completion of this study.

REFERENCES

ASTM D6603 – 00: *Standard Guide for Labeling of UV Protective Textiles*, 1194-1198

Australian/New Zealand Standard AS/NZ 4399:1996, "Sun protective clothing Evaluation and classification," Published jointly by Standards Australia and Standards, New Zealand.

*Address: *Dr. Neha Singh, Assistant Professor, Department of Textile Design,*
National Institute of Fashion Technology, Hauz Khas, New Delhi -110016, INDIA
www.nift.ac.in
Email: nehasinghtd@gmail.com

Mobile Phone Camera Characterization for Soil Colour Measurements under Controlled Illumination Conditions

Luis GOMEZ-ROBLEDO,[1] Nuria LOPEZ-RUIZ,[2] Manuel MELGOSA[1]
Alberto J. PALMA,[2] Luis F. CAPITAN-VALLVEY[3]
Manuel SANCHEZ-MARAÑON[4]
[1] Department of Optics. University of Granada
[2] ECsens, Department of Electronics and Computer Technology. University of Granada
[3] Department of Analytical Chemistry, University of Granad[a]
[4] Department of Soil Science and Agriculture Chemistry. University of Granada

ABSTRACT

The general purpose of this work is to investigate the potential of a mobile phone to capture soil colour images and process them, returning the corresponding Munsell colour coordinates from the digital RGB captured images, and also estimate the tristimulus values from the same images. A mobile phone HTC Desire HD, which runs Android 2.2, has been used to take and process images of a Munsell Soil Colour Chart under fixed illumination conditions. To obtain tristimulus values of each sample a Konica Minolta CS2000d spectroradiometer has been used under the same conditions. Penrose's pseudoinverse method has been used to compute relationship between RGB coordinates from digital images and tristimulus values. Once the model has been computed it was implemented in the mobile phone. Results of this calibration show that more than 90% of the samples used in the calibration (238 chips) were measured by our mobile phone application with accuracy below 2.03 CIELAB units and a mean correlation coefficient equal to 0.9972. In case of Munsell models mean correlation coefficient is equal to 0.9407. This points to the idea that a conventional mobile device can be used to determine the colour of a soil under controlled illumination conditions.

1. INTRODUCTION

Soil colours are usually determined by visual comparison, seeking the closest match between the soil sample and one of the standard chips contained in the so-called Munsell Soil Colour Charts. This subjective method gives some problems that have been described previously (Sanchez-Marañon et al. 2011) in relation to identifying the colour of soil specimens using Munsell Soil Colour Charts. The problem of subjectivity can be removed if we replace the visual comparison by the use of the built-in camera of present smartphones. It is interesting to study the potential of these devices to quantify the colour of a soil sample.

It is already known that there are mathematicals models that can relate RGB and many colour coordinates useful for soil science (Viscarra Rossel et al. 2006), by using simple equations (Wyszecki and Stiles 1982) or look up tables (Viscarra Rossel et al. 2006). First method starts from the hypothesis that all the RGB sensors have the same spectral sensitivity missing that these coordinates are strongly device-dependent (Pascale 2003). Second method has good results, but for a mobile phone, a look up table requires much memory and high computational cost.

Our specific objective is to find two models for obtaining Munsell notations and tristimulus values from RGB measurements. These models must be simple, because they should work together as an implemented software in the mobile phone (Figure 1).

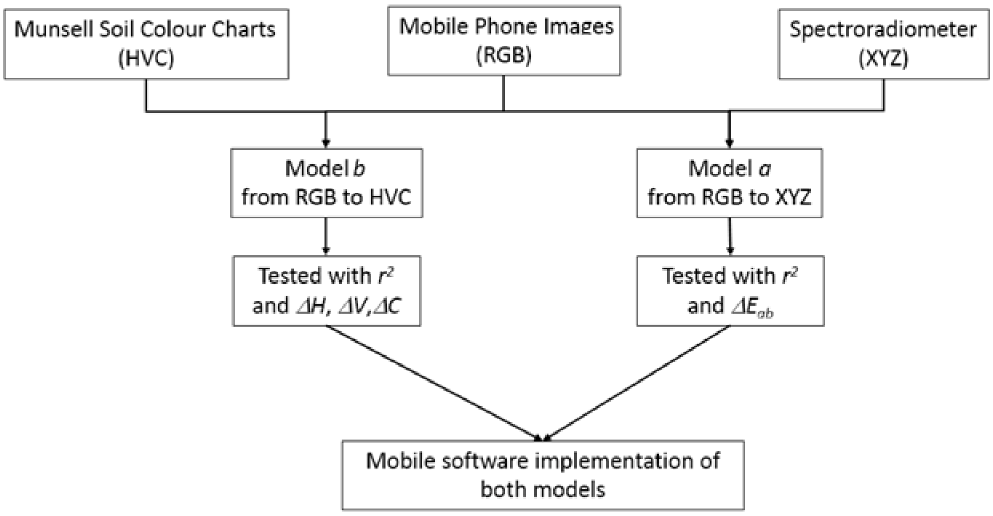


Figure 1: Flowchart illustrating the process of software implementation.

2. METHOD

2.1 Samples

For calibration we used a recent edition of the Munsell Soil Colour Charts (Munsell-Color, 2000) to build models from digital images. These charts include 238 standard colour chips with their corresponding Munsell notations, placed on seven Hue charts from red to yellow: 10R, 2.5YR, 5YR, 7.5YR, 10YR, 2.5Y, and 5Y (H = 10, 12.5, 15, 17.5, 20, 22.5, and 25, respectively). In each Hue chart, the chips are arranged by visual steps of Value (2/ to 8/) and Chroma (/1 to /8). It can be assumed that any natural soil colour is represented in these standard charts, considering the possibility of intermediate colours between neighbour chips.

2.2 Measurements

To achieve mentioned objectives we followed the methodological approach shown in Figure 1. RGB sensor was calibrated and then, tested in two different ways. Samples were measured by two different devices: an HTC Desire HD (HTC Corporation, Taiwan) mobile phone and a Konica Minolta CS2000 (Tokyo, Japan) spectroradiometer. With the aim of normalizing all the measurements, it was used a Konica Minolta PTFE reference white (Tokyo, Japan), allowing white balances in each image. First device gives us the RGB colour coordinates and second device tristimulus values. All the measurements were made in a GretagMacbeth Spectralight III lighting booth (X-Rite, Switzerland) equipped with a D65 simulator. For each image the mode of the RGB values has been taken to minimize theeffect of noise in the images.

2.3 Models

Relationship between XYZ and RGB is usually assumed as a linear. Johnson (Johnson 1996) noted that it is better to use a non-linear transformation and consider a polynomial transform between colour spaces. Accordingly, we have computed the pseudo-inverse matrix proposed by Penrose (Penrose 1955), which is a 3xn matrix, providing the nearest relationship between vectors XYZ and RGB (model *b*). The same relationship between HVC and RGB has been assumed in model *a*. Performance of each model has been tested computing Pearson' correlation coefficient between results from each model and spectroradiometric (model *b*) or colour charts Munsell notation (model *a*). Equation 1 summarizes the polynomial dependence between each variable, $\varphi(RGB)$ represents *H, V, C* and *X, Y, Z* for models *a* and *b* respectively.

$$\varphi(RGB) = a + bG + cB + dRG + eR^2 + fG^2 + gRGB + hB^2 \qquad (1)$$

3. RESULTS AND DISCUSSION

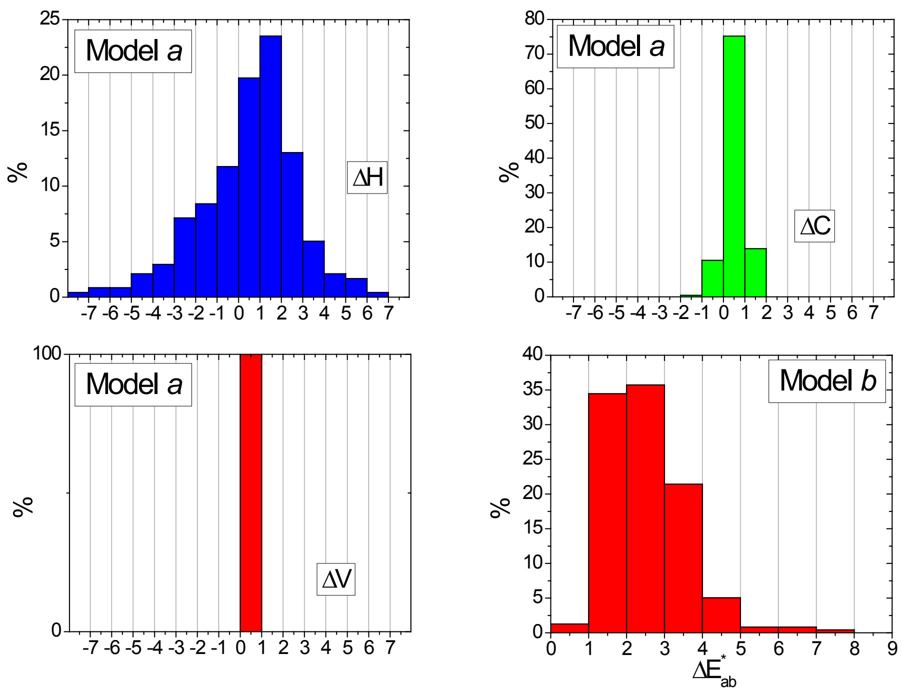


Figure 2: Histogram of colour differences for each model.
H, V, C are Munsell Hue, Value and Chroma coordinates.

Figure 2 shows the percentages of samples that have a Δ*H*, D*V* and Δ*C* between fixed values. It also shows CIELAB colour differences between fixed values. Table 1summarizes mean values of the histograms and corresponding standard deviations. Pearson's correlation coefficient of each model is shown in first column of Table 1.

From model *a*, Munsell Hue differences are in the range 0-8, with a 70% of the samples inside the [0–2] interval. For Munsell Value and Chroma the range of differences is dramatically lower than for Munsell Hue. For model *b,* most CIELAB colour differences are below 3 CIELAB units.

Table 1. Performance of models a and b, mean values and standard deviations (sd).

Model	r^2	ΔE^*_{ab}	$sd(\Delta E^*_{ab})$	ΔH	$sd(\Delta H)$	ΔV	$sd(\Delta V)$	ΔC	$sd(\Delta C)$
a	0.9407	-	-	<0.01	2.23	<0.01	0.52	<0.001	0.38
b	0.9972	2.03	1.04	-	-	-	-	-	-

4. CONCLUSIONS

The results for the calibration process were good, since we found CIELAB colour differences with a low average value of 2.03 CIELAB units. We found almost no differences in terms of Munsell Value and Chroma, but Munsell Hue differences are higher (although still lower than the steps in the Munsell colour charts).

Although a mobile phone built-in camera is an automatic device (it cannot be properly calibrated) and we think that it is necessary to measure real soil samples, all these results suggest that a device to measure soil colour under controlled lighting conditions can be used. Current proposed models can be easily implemented in other mobile phones.

ACKNOWLEDGEMENTS

This work has been partially funded by Ministry of Education (Spain) under project FIS2010-19839 Research Project, and the Junta de Andalucía (Spain) under project PE10-TIC5997, with European Regional Development Fund (ERDF) support.

REFERENCES

Pascale, D., 2003. *A review of rgb color spaces*... from xyy to r'g'b'. Babel Color.

Penrose, R., 1955. A generalized inverse for matrices. *Mathematical Proceedings of the Cambridge Philosophical Society* 51(3).

Sanchez-Marañon, M., P.A. Garcia, R. Huertas, J. Hernandez-Andres, and M. Melgosa, 2011. Influence of Natural Daylight on Soil Color Description: Assessment Using a Color-Appearance Model. *Soil Science Society of America Journal* 75 (3):984-993. doi: DOI 10.2136/sssaj2010.0336.

Viscarra Rossel, R.A., B. Minasny, P. Roudier, and A.B. McBratney, 2006. Colour space models for soil science. *Geoderma* no. 133 (3-4):320-337. doi: http://dx.doi.org/10.1016/j.geoderma.2005.07.017.

Wyszecki, G., and W.S. Stiles, 1982. *Color Science: Concepts and Methods, Quantitative Data and Formulae*. Wiley New York.

Address: Prof. Luis Gómez-Robledo, Departamento de Optica, Facultad de Ciencias,
Universidad de Granada, c/Severo Ochoa s/n, Granada (Spain), 18071
E-mails: luisgrobledo@ugr.es, nurilr@ugr.es, mmelgosa@ugr.es,
ajpalma@ugr.es, lcapitan@ugr.es, msm@ugr.es

Thermochromic Dyes and Sunlight Activating Systems: an Alternative Means to Induce Colour Change

Marie LEDENDAL,[1] Robert CHRISTIE,[1] Samantha VETTESE FORSTER[2]
[1] School of Textiles and Design, Heriot-Watt University
[2] School of Art and Creative Industries, Edinburgh Napier University

ABSTRACT

Thermochromic leuco dyes may be applied to textiles substrates to provide colour change when the temperature is raised. These materials have been used previously by designers in interesting ways, activated with a variety of heat sources. This paper presents the outcome of research developing a set of 'design variables' appropriate for textile designers, for use with thermochromic textiles when activated by sunlight. Sunlight has the potential to provide a sustainable alternative means to induce colour change compared with the variety of electrical heating mechanisms that have previously been explored which are more controllable but energy intensive. The use of sunlight as the direct heat source was investigated for sun-screening textiles, for use either externally in an urban environment or in indoor window applications. Observations of sunlight-activated textiles led to identification of the significant colour change design variables as: amount of sunlight, time interval, rhythm, contact surfaces, ambient temperature and distribution of sunlight.

1. INTRODUCTION

Thermochromic leuco dyes change from coloured to colourless when the temperature is raised. This dye type consists of three components: colour former, acid activator and low melting solvent, microencapsulated so that the chromic system is protected by a walled structure. Mixing the chromic dyes with permanent pigments provides colour change between two colours (Christie, Robertson and Taylor 2007, p.2-3). Thermochromic dyes are characterised by an activation temperature at which most of the colour change takes place, although in reality the change is observed over a range of temperatures (LCR Hallcrest accessed 2010). A number of notable designers have experimented with the use of thermochromic materials, aiming to exploit the dynamic colour change properties. Most commonly, they have used electrical heating mechanisms to activate the dyes for fashion and interior textile design applications (Seymour 2008). These designers include Orth and International Fashion Machines (Seymour 2008, p.75), XS Labs (Berzowska and Bromley 2007, p.2), Worbin (Worbin 2010, p.146) and Berzina (Seymour 2008, p.183). This paper describes preliminary research using a novel approach to thermochromic dye activation in which natural sunlight is used to induce the colour change. The research has investigated the effects observed when the sun is the direct activating heat source, aimed at the design of sun-screening textiles that contain printed thermochromic elements. Carefully conducted observations have led to the formulation of a set of design variables for use in designing with thermochromic dyes and sunlight. Comparisons are made, from the perspective of the textile printmaker practitioner, between the principles involved in printed thermochromic textiles that are sunlight-activated and those activated by electrically-powered heaters.

2. METHOD

The research described in this paper involved systematic observations to investigate the colour change of thermochromic textiles activated by the sun in relation to the prevailing weather conditions. Thermochromic dyes with activation temperatures in the range 20-47ºC were screen printed as single colours, in some cases combined with permanent pigments, on to a range of textile substrates with different thicknesses. In order to describe the sun conditions during the observations, two conditions were selected from the 'Lighting Design Glossary' (Lighting Design and Simulation Knowledgebase accessed 2011). To simplify the analysis, these two descriptions were re-defined as: 'sunny sky' containing 0-15% clouds, and 'cloudy sky' containing 25-80% clouds.

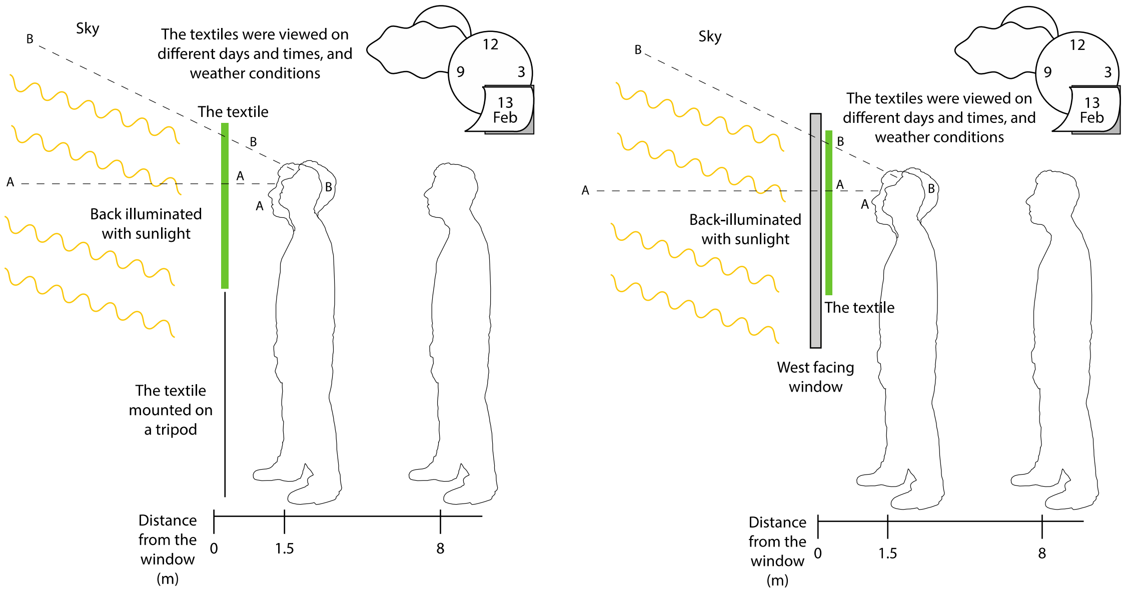


Figure 1: Set-ups used A and B for textile sample observations, indoors as well as outdoors.

Standard viewing methods, as illustrated in Figure 1, were devised for visual observation of the printed fabrics carried out to develop an understanding of the influence of the sunlight on the colour outcome for two different scenarios: indoor and outdoor situations. The observations were aimed at establishing relationships between the perceived colour of the fabric samples and the two sky conditions, when sunlight passed through the samples (referred to as back-illuminated). The observations were carried out in two geographic locations: Scottish Borders, UK and Scania region (Skåne), Sweden. For the indoor observations, the samples were mounted on a windowpane, whereas for outdoor observations the samples were mounted on a tripod (Figure 1). The ambient temperature indoors was mainly in the range 20-22ºC. Most observations outdoors were carried out during summer, with ambient temperatures in the range 13-18ºC. The results were assessed in terms of the impact of sunlight on the appearance of the printed textiles. A comparison was made of features involved in using sunlight and electrical heating sources to activate the thermochromic textiles in terms of their effectiveness and their limitations based on literature review and the author's previous experience with chromic materials.

3. RESULTS AND DISCUSSION

The investigation led to the development of a set of design variables for use with thermochromic dyes activated by sunlight, presented in the context of textile design practice. The design variable 'amount of sunlight' illustrates the importance of the presence of sunlight and its random nature arising from weather variations. Observations demonstrated that the dynamic colour change behaviour of the printed samples depended on their placement (free-hanging or towards a contact surface), the level of sunlight and the weather including the sky conditions and the ambient temperature. The design variable 'ambient temperature' is determined by the environment in which the sun-screening textile is located, including time of day and geographical location. The design variable 'time interval' was addressed by devising two specific definitions, illustrated schematically in Figure 2: (a) the time taken for the chromic dye to achieve colour change (t_1), and (b) the time during which the chromic dye remains either in its active (t_2^a) or inactive (t_2^i) state, in each case as the sun comes and goes. The definition of t_1 is the time it takes for the dye to change colour either from being inactive (colour state 1) to being active (colour state 2) or vice-versa. The time taken for the printed samples to reach a state of all-over colour change differed depending on the relationship between the thermochromic activation temperature and the 'internal heat coefficient' (h_i) of the window surface (Karlsson 2001, p.5). The time for colour change due to heating by the sun, which varied from minutes to more than one hour, also depended on the environment, in turn influenced by the solar energy transmission through the window (Karlsson 2001, p.14).

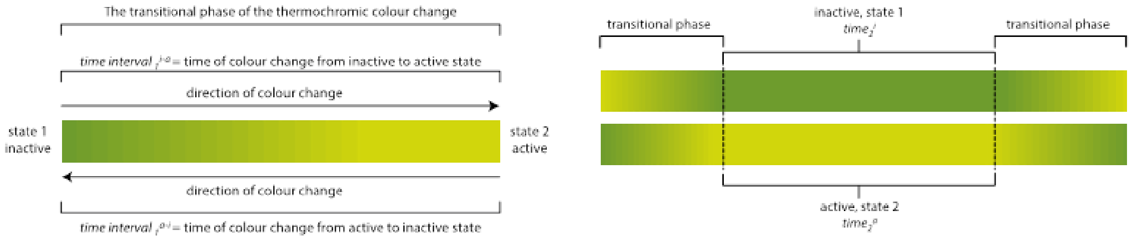


Figure 2: Visualisation of the definitions of the design variables t_1 and t_2.

The variable 'rhythm' involves a combination of the length of time between successive activations and deactivations and the time in the active and inactive states. The rhythm of the colour change is weather dependent; a constant sky creates a slower tempo while alternating weather conditions leads to a quicker tempo. The design variable 'contact surface' defines the impact of close-touching surfaces on the activation of colour change. Contact surfaces, both indoors and outdoors, facilitate activation the dyes, as well as increasing the rate of colour change. The variable 'distribution of sunlight' determines the illuminated activated areas of the textile, as well as the heat spread through the samples. The pattern of colour change demonstrated that this process started mainly at the centre of the fabric spreading towards the edges. When sufficient heat was generated by the sunlight, all of the illuminated areas printed with the thermochromic dyes displayed colour change.

A comparison of sunlight and electrical heating solutions, based on theoretical and experiential considerations, identified that the sun provides certain technical advantages, as well as the obvious energy-related environmental and sustainability advantages. Direct sunlight will more readily change the colour of larger printed areas with no need for additional application features. Complex heating circuitry with high energy demand would be required to produce sufficient heat over the surface (Robertson et al. 2008, p.27). There are design limitations, but also potential advantages, due to the random, unpredictable nature of sunlight activation in terms of the time and level of available sunlight, and its dependence on weather conditions. In contrast, electrical circuitry integrated into textile applications may be optimised to regulate the heating, with the potential to use computer-based methods to control energy flow, and thus the temperature profile, in order to provide control of the colour change (Robertson et al. 2008, p.30).

4. CONCLUSIONS

A series of design variables have been identified to provide a tool for use by textile printmaker practitioners in design applications, for example in sun-screening textiles that incorporate printed thermochromic dyes and use sunlight as an activator.

ACKNOWLEDGEMENTS

We thank the Worshipful Company of Dyers of the City of London for financial support, in the award of a PhD studentship (to ML).

REFERENCES

Christie, R., S. Robertson, and S. Taylor, 2007. Design Concepts for a Temperature-sensitive Environment Using Thermochromic *Colour Change, Colour Design & Creativity*, 1(1): 5,1-11. Available online: www.jaic.jsitservices.co.uk/index.php /JAIC/article/viewFile/80/74. Accessed: February 13, 2010

Berzowska, J., and M. Bromley, 2007. Soft computation through conductive textiles. Available online: www.xslabs.net/papers/iffti07-berzowska-AQ.pdf. Accessed: February 25, 2010.

Karlsson, J., 2001. *Windows: Optical Performance and Energy Efficiency.* PhD diss. Uppsala University.

LCR Hallcrest, Thermochromic Leuco Dyes. Available online: www.colorchange.com/leuco-dyes. Accessed: April 4, 2010.

Lighting Design and Simulation Knowledgebase, Light Design Glossery. Available online: www.schorsch.com/en/kbase/glossary/skies.html. Accessed: March 28, 2011.

Robertson, S., S. Taylor, R. Christie, J. Fletcher and L. Rossini, 2008. Design with responsive colour palette: The development of colour and pattern changing products. *Advances in Science and Technology* 60: 26-31. Available online: http://www.scientific.net/AST.60.26. Accessed: April 16, 2013.

Seymour, S., 2008. *Fashionable Technology, the intersection of design, fashion, science, and technology,* Wien & New York: Springer-Verlag.

Worbin, L., 2010. *Designing Dynamic Textile Patterns.* PhD diss. Chalmers University of Technology.

Address: MA. Marie Ledendal, School of Textiles and Design,
Heriot-Watt University, Scottish Borders Campus, Galashiels, TD1 3HF, UK
E-mail: mkl4@hw.ac.uk

Dimensional Property of Textile Dyestuffs

Mina ABDOLSAMADI,[1] Seyed Hossein AMIRSHAHI,[1] Shahram PEYVANDI[1,2]
[1] Department of Textile Engineering, Amirkabir University of Technology
[2] Department of Psychology, Rutgers, The State University of New Jersey

ABSTRACT

The spectral dimensionality of a set of 4827 colored textiles including of 1050 individual textile dyestuffs and their combinations on different fibers is investigated. The principal component analysis technique is employed to determine the significance importance of different principal directions of spectral data of desired dataset. The accumulated energies known as percentage cumulative variance (CV%) of the first 3 to 18 eigenvectors are firstly calculated and considered a criterion for the evaluation of the reduced spaces. Samples are then presented in compressed spectral spaces with different sizes (3 to 18 dimensions) and the efficiencies of compacted spaces are evaluated by the spectral and colorimetric differences between the actual and the reconstructed spectra. The dimensional property of desired dataset is compared to the Munsell spectral data and it is found that both datasets converge to identical results when 14 eigenvectors are employed.

1. INTRODUCTION

There are 27,000 individual dye products under 13,000 generic names that have been indexed in Color Index. Within such great number of individual dyes, the textile dyestuffs have distinctive situation. In fact, more than 80% of such colorants are specially designed for textile applications and several dyes with close spectral and colorimetric performances are presented that could be alternatively used in color formulation of colored textile materials. Hence, the selection of suitable candidates in a color matching trial has been always a serious issue for colorists. Although some scientific ideas have been presented to get rid of different dye classes by designing a universal dye class for textile industry, the spectral property of the existing package of textile dyestuffs that nearly allows unlimited degree of freedom has not been reported yet.

Different methods have been investigated to describe and/or extract the spectral patterns of certain primaries. Some approaches like delta functions, box functions, Fourier functions and Gaussian functions were used to introduce the primaries for reconstruction of different spectral dataset. Obviously such methods presented the predefined fixed spectra that would be generally suitable for estimation of reflectance spectra form colorimetric information (Glassner 1989, Attarchi and Amirshahi 2009, Sun *et al.* 1999). On the other hand, some learning-based methods have been developed which extract the primaries based on desired learning dataset. The principal component analysis method, abbreviated by PCA, is the most important technique of this group that extracts the hidden pattern of spectral data and shows the principal directions of dataset based on statistical properties of samples. PCA is the most widely used method which applied in many issues in color science and reporting the primaries of different datasets (Tzeng and Berns 2005, Fairman and Brill 2004, Ohta 1973).

In this study, the spectral dimensionality of a huge spectral dataset including the reflectance spectra of 4827 colored textiles is investigated. Samples of different fibers were dyed with different classes of dyestuffs and the PCA technique was employed to extract the principal directions of dataset. The extracted statistical primaries were used for spectral reconstruction of samples and the suitability of primaries is discussed.

2. METHOD

A pallet including of 4827 colored textiles was prepared. Samples were dyed by 1050 individual primaries and their mixtures. The reflectance spectra of samples were then measured in the range of 380 to 730 nm with 10 nm interval. The reflectance spectra of 1269 Munsell chips were downloaded from http://spectral.joensuu.fi/ and were fixed between 380 to 760 nm with 10 nm interval.

Several criteria were used to determine the spectral dimensionality of spectral reflectances of textile dyestuffs $R(\mathbf{R})$. Firstly the accumulated energy of reduced different spaces was determined as shown by Equation (1).

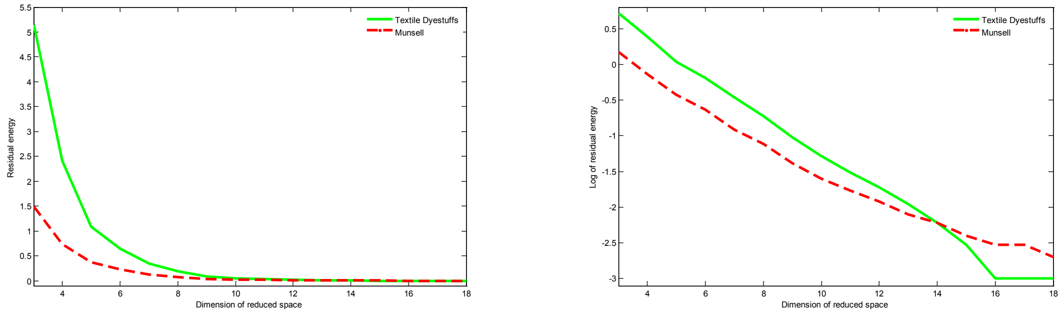
$$CV\% = \frac{\sum_{i=1}^{k} w_i}{\sum_{i=1}^{p} w_i} \times 100 \qquad (1)$$

where $CV\%$ shows the accumulated energy or the percentage of cumulative variance and defines by the ratio of the variances that represent by the first k eigenvectors to the total variance of matrix $R(\mathbf{R})$ with dimension p. In fact, Equation (1) shows the energy represented that are taken into account by the first k principal components.

The effective dimension of the reflectance spectra of colored textiles was also studied by the reconstruction of spectral reflectances of samples in different reduced spaces and the root mean square errors between the original and the reconstructed spectra were calculated. The goodness of fit coefficient (GFC) between the corresponding reflectances was also considered as another criterion for the effectiveness of different dimensional spaces. Finally, the color difference values between the original and reconstructed spectra were computed under illuminants D65 and A while the 1964 standard observer was used and reported as colorimetric suitability of different spectrally reduced spaces. Results of spectral compression of reflectance spectra of Munsell dataset were also reported for better evaluation of results obtained for the textile dyestuffs.

3. RESULTS AND DISCUSSION

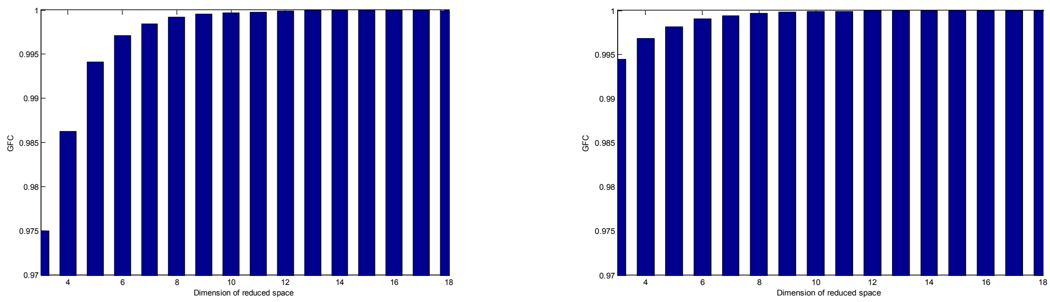
The percentages of the residual accumulated energy of different reduced spaces are computed for textile dyestuffs and Munsell datasets and are shown in Figure 1a. Figure 1b shows the logarithmic scale of Figure 1a. As the plots show, the accumulated energies for textile version of dataset are smaller in the low dimensional spaces while the situation changes by the increasing of dimensions of reduced spaces to 14.



(a) *(b)*

Figure 1: Plot (a) shows the percentage of residual energy of the first 3 to 18 eigenvectors for textile dyestuffs and the Munsell samples. Plot (b) shows the semi-log plot of figure (a).

Figure 2 shows the GFC values for both textile dyestuffs and the Munsell datasets. Again, the GFC values of the Munsell dataset are higher in the low dimensional spaces and condition changes with the increasing of number of components.



Textile dyestuffs *Munsell*

Figure 2: The GFC values of textile dyestuffs and Munsell datasets in reduced spaces.

Finally, the mean of the root mean square error between the actual and the reconstructed spectra for two datasets are shown in Figure 3.

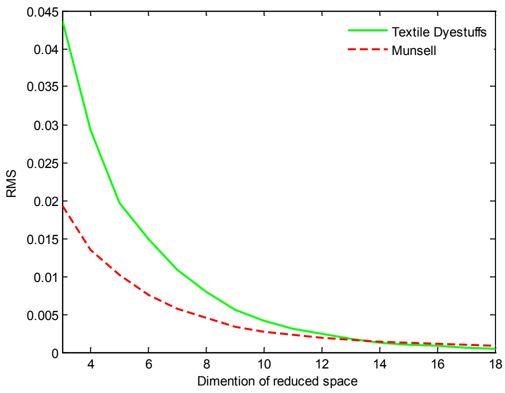


Figure 3: The mean of RMS between the actual and the reconstructed spectra for textile dyestuffs and Munsell datasets.

The CIELAB color difference values between the original and the reconstructed spectra under D65 and A illuminants and 1964 standard observer were calculated for both datasets and the results are shown in Figure 4.

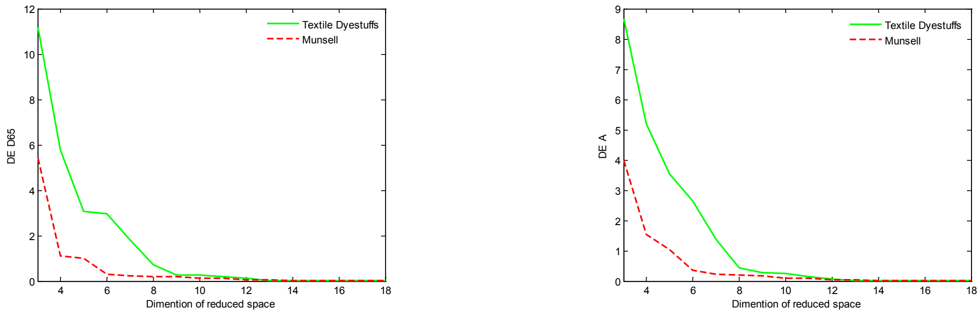


Figure 4: The mean of ΔE values between the actual and the reconstructed spectra under D65 and A illuminants for textile dyestuffs and Munsell specimens.

Figure 4 shows that the colorimetric errors are smaller for the Munsell samples up to first 13 eigenvectors and after this point the colorimetric errors of reconstruction become smaller for textile dyestuffs.

4. CONCLUSIONS

The principal component analysis technique was employed to determine the spectral dimensionality of a set of 4827 reflectance spectra of textile dyestuffs. Different criteria, i.e. the percentage of accumulated energy, the GFC and mean of RMS errors and the color difference values under D65 and A illuminant were employed to determine the dimension of desired dataset. According to results, the effective dimension of textile dyestuffs dataset would be about 10 that led to small spectrophotometric and colorimetric errors.

REFERENCES

Glassner, A.S., 1989. How to Drive a Spectrum from an RGB Triplet, *IEEE Comput. Graph*. 9(4) 95-99.

Attarchi, N., and S.H. Amirshahi, 2009. Reconstruction of Reflectance Data by Modification of Berns' Gaussian Method, *Color Res. Appl*. 34(1) 26-32.

Sun, Y., F.D. Fracchia, T.W. Calvert and M.S. Drew, 1999. Deriving Spectra from Colors and Rendering Light Interference, *IEEE Comput. Graph*. 19(4) 61-66.

Tzeng, D.Y., and R.S. Berns, 2005. A Review of Principal Component Analysis and Its Applications to Color Technology, *Color Res. Appl*. 30(2) 84-98.

Fairman, H.S., and M.H. Brill, 2004. The Principal Component of Reflectances, *Color Res. Appl*. 29(2) 104-110.

Ohta, N., 1973. Estimating Absorption Bands of Component Dyes by Means of Principal Component Analysis, *J. Anal. Chem*. 45(3) 553-557.

Address: Prof. Seyed Hossein Amirshahi, Department of Textile Enginering, Amirkabir University of Technology, Tehran 15914, Iran
E-mails: mina_abdossamadi@yahoo.com, *hamirsha@aut.ac.ir, peyvandi@gmail.com*

Simulation of Blue Skin Color caused by Melanin Concentration

Motonori DOI [1], Akira KIMACHI [2], Shogo NISHI [2] and Shoji TOMINAGA [3]
[1] Department of Telecommunications and Computer Networks,
Osaka Electro-Communication University
[2] Department of Engineering Informatics, Osaka Electro-Communication University
[3] Graduate School of Advanced Integration Science, Chiba University

ABSTRACT

Color simulation of human skin is one of the most important topics in many research areas. Skin color appearance is changed by the concentration of pigments in the skin. In some cases, melanin concentrations make pale blue spots, such as Mongolian spots. Blue skin color is caused by melanin contained in the dermis. The present paper proposes a method for color simulation of blue melanin spots as well as brown spots on skin by considering melanin concentrations in either the epidermis or dermis. We present an algorithm to estimate skin colors by using a skin model and the Kubelka-Munk theory. In experiments, the $L^*a^*b^*$ coordinates of skin colors with the increase of melanin density are estimated for evaluating the relationship between skin color and the layer melanin contained. Moreover, a skin image with blue spots is synthesized based on the estimates to confirm the visual effect of color contrast on skin. The experimental results show that the synthesized color image with melanin spots in the dermis appears pale blue as expected.

1. INTRODUCTION

Color simulation of human skin in various conditions is one of the most important topics in many research areas including computer graphics, medical imaging and cosmetics development. Skin color appearance is changed by the concentration of pigments in the skin. Generally, concentration of melanin makes brown spots on skin surface. In some cases, concentration of melanin makes pale blue spots, such as Mongolian spots as shown in Figure 1. The brown skin color is caused by melanin concentrated in the epidermis, the outer layer of skin, while the blue skin color is caused by melanin contained in the dermis the layer underlying the epidermis. Skin color simulation in such an unusual case is important. This paper describes the simulation of the blue skin color.

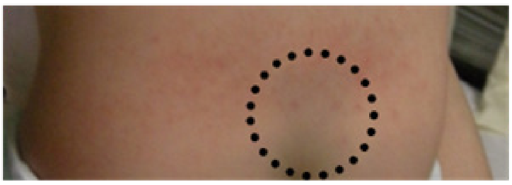


Figure 1: A Mongolian spot at a lumbosacral region of a baby (in a dashed circle).

2. SKIN COLOR SIMULATION FOR DIFFERENT MELANIN CONCENTRATION

We show two methods to simulate skin color for different melanin concentration. One is based on estimating skin color in $L^*a^*b^*$ coordinates for evaluating the relationship between skin color and the layer melanin contained. The other is based on image synthesis using the estimates to confirm the visual effect of color contrast on skin.

2.1 Skin Color Estimation

In a previous work (Doi 2005), we estimated spectral reflectance of melanin increased brownish skin by using the Kubelka-Munk theory (Kubelka 1948,1954) (KMT) and a skin model with two layers of the epidermis including melanin and the dermis including hemoglobin. The KMT is convenient for calculating the optical values of reflectance and transmittance within a layer consisting of turbid materials. In the work, the spectral reflectance was estimated by a function with parameters of spectral scattering of skin tissues, spectral absorption of pigments, and thickness values of the layers. The method estimated not the RGB values for skin because of its device dependence, but the surface spectral reflectance which is inherent in skin.

In this paper, we simulate the skin color with a modified function for blue melanin spots by specifying melanin concentration in either the epidermis or dermis. Our skin model for melanin spot is shown in Figure 2. The incident light penetrating the skin surface is absorbed and scattered in epidermis and dermis. In normal skin, melanin is included in the epidermis only. In the model for melanin spot in the dermis, melanin is included in both of the epidermis and dermis. The dermis includes oxy-hemoglobin and deoxy-hemoglobin, too. The body reflectance of the skin surface is described as a function of wavelength,

$$R_b(\lambda) = R_e(\lambda) + \frac{T_e(\lambda)^2 R_{dt}(\lambda)}{1 - R_e(\lambda) R_{dt}(\lambda)}, \qquad R_{dt}(\lambda) = R_d(\lambda) + \frac{T_d(\lambda)^2}{1 - R_d(\lambda)} \tag{1}$$

where $R_e(\lambda)$ and $T_e(\lambda)$ are, respectively, the spectral reflectance and transmittance of the epidermis. $R_d(\lambda)$ and $T_d(\lambda)$ are the spectral reflectance and transmittance of the dermis, respectively. The reflectance of tissues under dermis is regarded as unity.

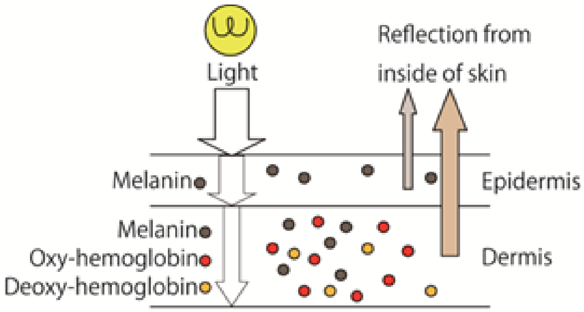


Figure 2: Skin optics model for a melanin spot in the dermis.

The skin color simulation consists of three steps. The first step is pigment density estimation from the measured spectral reflectance of skin. The second is spectral reflectance estimation from modified pigment densities. The third is conversion of spectral reflectance to L*a*b* coordinates. In the first step, the skin reflectance function without melanin in the dermis is used. Densities of melanin in the epidermis, hemoglobin in the dermis are estimated by fitting the function to the measured reflectance. In the second step, we use a function based on the new skin model. In the modified function, melanin absorption is added to the absorption in the dermis. Coefficients for tissue scattering and pigment absorption published in Refs (Anderson 1981, Gemert 1989) are used in this paper. In the final step, the estimated spectral reflectance is converted to L*a*b* coordinates under the standard illumination D65.

2.2 Synthesis of Skin Image based on Spectral Reflectance Estimation

Image synthesis uses multiband skin images, which consist of spectral reflectance data at each pixel. First of all, we extract the pigment distributions from the multiband skin images by our method based on multi-resolution analysis (MRA) and skin reflectance estimation (Doi 2012). The multiband skin images are decomposed into texture components of shade, sulcus cutis and pigment color by MRA. Sulcus cutis refers to fine wrinkles on skin surface. The pigment density at each pixel is estimated from the pigment color texture components by using the skin reflectance estimation function. Pigment distribution images are obtained from the estimation results. For the synthesis of a Mongolian spot, a melanin distribution with high melanin concentration areas is added to the dermis layer. Then, the pigment color texture components are generated from the pigment distributions by the function. Next, all texture components are composed into multiband skin images by MRA. Finally, an RGB color image of skin is produced from the modified multiband skin images.

3. EXPERIMENTS

Skin colors with melanin concentration in either the epidermis or dermis were estimated. The results are shown in Figure 3. Estimation results were obtained as $L^*a^*b^*$ color coordinates. The a^* and b^* values of the skin with a melanin spot in the epidermis were larger than those of a normal skin, meaning that the skin color became reddish. In contrast, when the melanin concentration was high in the dermis, the a^* and b^* values were smaller than those of a normal skin, suggesting less saturated color than the normal skin color. The color difference was caused by the differences in the scattering property and the depth order of layers, according to Equation 1.

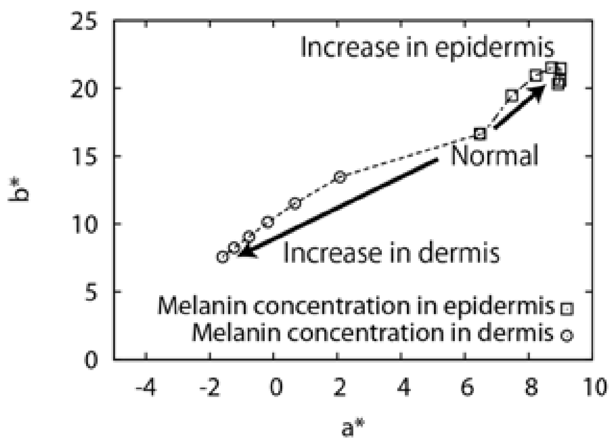


Figure 3. a^* and b^* coordinates of simulated skin color for increased melanin concentration in the dermis and epidermis.

However, the color of a melanin spot in the dermis is generally observed as pale blue. This discrepancy in color appearance is caused by the visual effect of color contrast of a melanin spot with the surrounding normal skin color. In order to confirm this visual effect, we synthesized a skin image with melanin spot. We captured the multiband (17 bands) images of skin surface of a Japanese person. We synthesized nine melanin spots of different melanin concention in the dermis into the skin image as shown in Figure4. The color of the skin image with melanin spots in the dermis appears pale blue as expected.

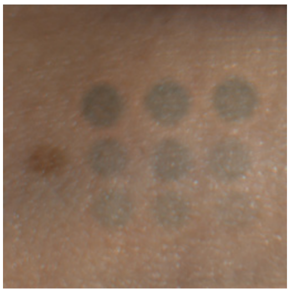


Figure 4. Synthesized skin image with melanin spots in the dermis.

4. CONCLUSIONS

This paper has proposed a method for skin color simulation in an unusual case of melanin concentration in the dermis. We introduced a skin model that includes melanin in the dermis. The color of melanin spot was estimated by the modified spectral skin reflectance function based on the skin model. Experimental results of skin color simulation showed that the simulated melanin spot in the dermis appears pale blue as expected

ACKNOWLEDGEMENTS

This work was supported by Grant-in-Aid for Scientific Research on Innovative Areas “Shitsukan” (No. 23135529) from MEXT, Japan.

REFERENCES

Anderson, R.R., J.A. Parrish, 1981. The Optics of Human Skin, *Journal of Investigative Dermatology*, 77(1) 13-19.

Doi, M., N. Tanaka, and S. Tominaga, 2005. Spectral Reflectance Estimation of Human Skin and Its Application to Image Rendering, *Journal of Image Science and Technology* 49(6) 574-582.

Doi, M., M. Konishi, A. Kimachi, S. Nishi and S. Tominaga, 2012. Robust Estimation of Pigment Distributions from Multiband Skin Images and its Application to Realistic Skin Image Synthesis, *Computer Vision – ECCV 2012 Workshops and Demonstrations*, 2, 421-430.

Gemert, M. J.C.V., S.L .Jacques, H.J.C.M. Sterenborg, W.M. Star, 1989. Skin Optics, *IEEE Transactions on Biomedical Engineering*, 36(12) 1146-1154.

Kubelka, P., 1948. New Contributions to the Optics of Intensely Light-Scattering Materials. Part I. *Journal of Optical Society of America*, 38(5) 448-457.

Kubelka, P., 1954. New Contributions to the Optics of Intensely Light-Scattering Materials. Part II. *Journal of Optical Society of America*, 44(4) 330-335.

Address: Motonori Doi, Department of Tele-Communication and Computer Networks,
Osaka Electro-Communication University,
18-8 Hatsu-cho, Neyagawa, Osaka 572-8530, Japan
E-mails: doi@isc.osakac.ac.jp, kima@oecu.jp,
s-nishi@isc.osakac.ac.jp, shoji@faculty.chiba-u.jp

Photonic Textiles for SMART Mood Changing Garments; MoodWear

Danying YANG,[1] George K STYLIOS[2]
[1, 2] School of Textiles and Design, Heriot-Watt University, UK

ABSTRACT

Wearable electronics, textile photonics and mood changing technologies are integrated to explore the concept of smart ambience in this paper. Stimulated by the wearer's voice, a responsive colour changing fabric has been designed and developed for SMART garments by integrating aesthetics and functionality. By establishing the ability of expressing the mood states of the wearer, colour changing reacts sound changing characteristics of the wearer, to create a mood changing smart clothing system.

Keywords: Photonic Fabric, Physiological/Psychological Changes, MoodWear Clothing

1. INTRODUCTION

Referencing the past and predicting the future, a variety of technologies are being used and developed to create fashion. Textiles and clothing are no longer fulfilling conventional needs of comfort and protection. Colour and shape changing are contextually beyond established usages. Design thinking needs to look forward to encompass new materials and technologies. In a truly smart or intelligent manner, textiles/clothing can sense, react even adapt to environmental stimuli (Tao 2001). Lately advances have been made to developing such wearable technology and smart clothing further in physiological and psychological areas.

As far as colour is concerned, the knowledge of optical mixing brings us to another way of understanding and designing colours that differs from subtractive colour mixing. Extraordinarily, more than a mere physically visual effect, colour plays a vital role for personal preferences and psychology. As visual perception, optical colour seems to have no connection with hearing, but with the psychology of mood states, they can be correlated for example with various characteristics of our voice. How can colour behave intelligently with hearing, understanding and presenting back the information to the wearer?

This is adapted in this research by building a system in which a built-in microphone and a programmable microcontroller are integrated in a purposely designed and made wearable PCB. Programmable data processing is used to convert the sound signal to a corresponding colour change, triggered to represent a change of mood visually. RGB LEDs and special fibre optics are designed as an array fabric matrix capable of displaying this colour change, as photonic fabrics. As a smart interface, this photonic fabric of the MoodWear clothing can intelligently respond to both visual and functional changes, as the result of physiological/psychological changes.

2. METHOD

In a world of complex interconnected systems and dynamically changing environments, the methodology of this project is based on a systems approach (Bäumer, Bischofberger et al. 1996), in which technology and design are marrying each other to realise an integrated smart clothing system with aesthetic as well as functional attributes.

2.1 The SMART Garment System; Clothing Design and Information Technology

Information exists in our physical environment that can flow from this environment into a computational system via sensory transduction. We take the primary sensation, voice in this case, as physical events in our nervous system to signal, store and process the information in our mind; and perception as physiological information coded in our brain nerves. Therefore, mind and brain are like software and hardware of our smart computational system (Gregory and Colman 1995). Creativity starts with the processing of a human's sensation and perception, and in turn being feed back to the human as information or an action. These are essential elements in intelligent technology. Our smart garment system is built under this working concept with three activities, as shown in Figure 1. According to the physiological and psychological human cognition, the basic idea of sensation and perception are investigated as mood changing theories and further combined with information technology to form a smart garment system.

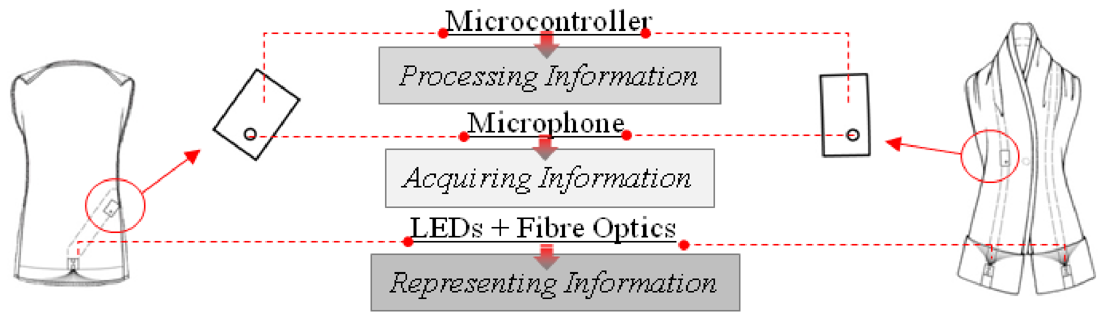


Figure 1: Smart information systems; The photonic fabric/garment.

2.2 Colour Changing Design with Mood Changing Technology

Mood, as a state of mind or emotion, is often thought as a psychological reaction to external stimuli. As the general index of both physiological functions and psychological experiences (Thayer 1996), recent scientific findings define the everyday mood as biopsychological in nature. Unlike the case of acute and emotional feelings as in fear or surprise, generally speaking, mood can be classified in two main types; positive or negative, or being in a good mood (happy) or in a bad mood (sad). Like a clinical thermometer, mood is changeable and it reflects on all the internal and external events that affect us. Because of complexity and limitations, the profound psychological cause and effect of mood are still being researched. Nevertheless, on the level of consciousness, we can recognise mood from basic physiological implications and psychological experiences.

In our system, which is made of photonic fabrics, auditory sensation and visual perception are applied, as shown in Figures 2 and 3. When the hearing signal is produced by our voice, we cannot only perceive different qualities of voice, but also infer human moods such as happiness or sadness, anger or calmness by analyzing its characteristics such as tone and intensity. Visually, colours play a vital role in projecting an image and creating a mood, such as blue or purple colour is cool and related to a calm or bad mood; but the exciting or happy mood is indicated by warm red or orange colour, according to psychometric charts. Is there any connection with what you hear and what you see? Hearing and vision seem to be different senses and are perceived in different parts of our brain, but our sensations are interlinked in the interactivity of mood states. A good clue to different mood expression is by considering a voice or music that is not only auditory but also visual. It is somewhat like a "joined sensation" (Gregory and Colman 1995). For example, sound often changes the perceived hue and brightness with the description that loud tones are brighter than soft tones, or lower tones are darker than higher tones.

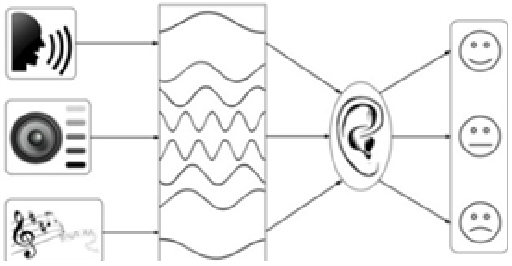


Figure 2: Hearing sensation and perception through a human's ear.

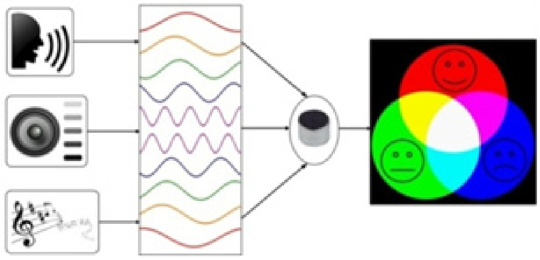
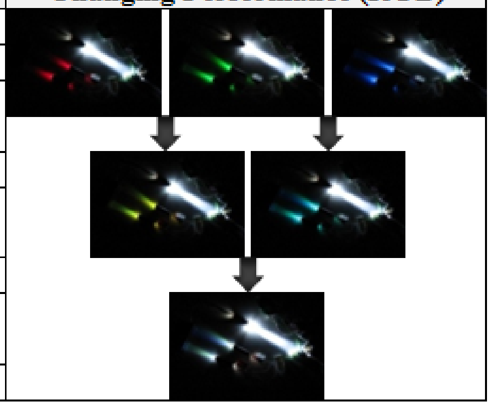


Figure 3: Hearing sensation and colour perception through a microphone.

The transducer applied in the sensory part of our SMART garment system is a miniature microphone shown in Figure 3, which converts a sound pressure wave to an electrical signal by means of electrostatics. As the sound wave strikes the microphone's diaphragm, it vibrates and induces a voltage change. This is similar to how a human's ear works. Obviously, the structure and function of a human ear are technically more difficult and complex, with the ability to sense the sound by multiplexing of loudness, pitch and timbre. In this research, sound loudness is taken as a measure of someone's mood.

As a visual interface, the wearable photonics can be as either liquid crystal displays (LCDs) or LEDs and fibre optic displays (FODs). Since wearable LCD panel or film used on clothing is still considered neither flexible with poor angle of visibility, nor lightweight with bulky characteristics (Kirstein, Grzyb et al. 2005), LEDs and FODs were chosen for the mood changing aim of this project. At the foremost, the energy conversion is based on the intensities of sound signals which are graded to several levels of volume (sound loudness) and converted to different range of voltages (sound pressure). Here RGB LEDs are being used as effective devices to display this sound pressure variation. After the converted voltage is supplied to the LEDs, the colour changing performance can be dynamically and automatically presented, by the voice control circuit and according to the colour changing design shown in Table 1.

Table 1: RGB LED colour changing design – 8 Colours Plan.

Sound Volume	Voltage (mV)	Colour Changing		LED Lighting and Colour Changing Performance (RGB)
Halt	0	Black	0 0 0	
Low	7.14	Blue	0 0 255	
Low to Moderate	14.28	Cyan	0 255 255	
Moderate	21.42	Green	0 255 0	
Moderate to High	28.56	Yellow	255 255 0	
High	35.7	Red	255 0 0	
High to Low	42.84	Magenta	255 0 255	
Tutti	50	White	255 255 255	

3. RESULTS AND DISCUSSION

Lady's and a man's MoodWear garments are carefully designed and prototyped by photonic fabrics connected to RGB LEDs and fibre optics, which through wearable electronics can detect the mood of the wearer, with dynamic colour lighting presentation, as shown in Figure 5. According to the lighting colour plan established, sound signals are picked up by the microphone and programmed to induce the voltage change from 0-50mV. The voltage signals are amplified by the microprocessor and the circuit activates the LEDs corresponding to the programmed colours. For example, high sound volume triggers the red colour to represent positive mood, and low sound volume triggers the blue colour for negative mood, while between high and low volume, the output is green. This clothing system has high levels of functionality and intelligence. Smart textile-based connections and clothing fasteners are created and packaged for serving the circuitry of the data system. New properties like flexibility and miniaturization are infused in the clothing design aesthetics.

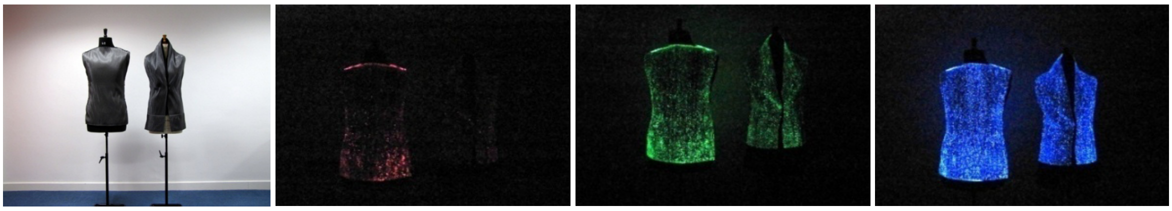


Figure 5 Presentation of MoodWear collection - RGB colours.

4. CONCLUSIONS

Fibre optics and LEDs have previously been applied for illuminating applications on clothing, but their colour dynamic change according to the human's physiological and psychological state in real time has never been considered before, rendering this work original. For the first time a responsive photonic fabric system with colour changing ability has been designed and developed by responding to a sound stimulus via wearable electronic control integrated in the garment and hence fastening an intimate communication between human and clothing. Thereupon, the new concept of SMART clothing ambience has been realised by research and implementation of design/technology aspects, transcending disciplinary boundaries to enrich human life by marrying Art and Science.

ACKNOWLEDGEMENTS

We acknowledge the sincere and professional contribution of Mr. Jin Zhou, Wuhan Polytechnic University.

REFERENCES

Bäumer, D., W.R. Bischofberger, et al., 1996. User Interface Prototyping – Concepts, Tools, and Experience. *the 18th International Conference on Software Engineering* (ICSE), Berlin.

Gregory, R.L. and A.M. Colman, 1995. *Sensation and Perception*. London and New York, Longman Pub Group.

Kirstein, T., D.C.J. Grzyb, et al., 2005. *Wearable computing systems - electronic textiles. Wearable electronics and photonics*. X. Tao. New York, Woodhead Publishing Ltd. and CRC Press LLC: 177-179.

Tao, X., 2001. Smart technology for textiles and clothing. Smart Fibres, Fabrics and Clothing. X. Tao, Woodhead Publishing Ltd. and CRC Press LLC: 1-6.

Thayer, R. E. 1996. The Origin of Everyday Moods: Manging Energy, Tension, and Stress, Oxford University Press, Inc.

Address: Dr. Danying Yang, Research Institute for Flexible Materials, RIFleX,
Heriot Watt University, TD1 3HF, Scotland, UK
E-mails: yangdanying2007@yahoo.co.uk, g.stylios@hw.ac.uk

New Measurement System for Characterizing the Total Color Impression of Effect Coatings

Gabriele KIGLE-BÖCKLER, Sandra WEIXEL
BYK-Gardner GmbH, Geretsried, Germany

ABSTRACT

Color harmony, is an important quality criterion and essential to achieve the impression of a high quality finish. Effect finishes can change their total color impression not only with viewing angle but also with lighting conditions. Dependent on the pigment type an additional sparkling effect can be created under direct illumination. These new generations of special effect pigments can no longer sufficiently be described with traditional multi-angle color spectrophotometers quantifying the diffused light reflection at 3 or 5 angles. This paper presents a new technology which was developed to objectively describe the total impression of effect coatings focusing on flake characterization by measuring with a camera the visual impression of "sparkling" and "graininess" simulating the effect changes under direct and diffused lighting conditions.

1. INTRODUCTION

"The first impression counts" and "Color sells" are statements everybody can relate to. The visual impression of the vehicle exterior during the first ten seconds establishes lasting perceptual quality opinion extending beyond design and paint appearance. This explains why color consistency is one of the most important quality criteria of an automotive finish and why designers are continuously looking for new colors.

Over the past decades, metallic and special effect colors have taken a dominant role in the color palette of all automotive makers and many other applications ranging from electronic devices to appliances to cosmetic products. Designers are looking for new colors which not only make the product look pretty and distinct, but actually underline its styling. Pigment manufacturers are developing new types of aluminum flakes to create fine or coarse looking metallics with more or less accentuated light-dark flops. Thus, the colour impression of the coating depends on illumination and viewing angle. New artifically produced interference pigments are broadening the range of effects which one can see under direct or diffused lighting conditions. The color changes under sun light and cloudy sky to make the product appear alive and exciting.

As color harmony is a customer relevant quality criteria the question is whether all these effects can be objectively controlled in daily production quality control and communicated among the entire supply chain of coating manufacturer, OEM maker and part suppliers. Since the '80s color specifications for metallic colors have been a challenging task resulting in multi-angle color spectrophotometers as defined in DIN 6175, Part 2, tolerances for different viewing angles and development of new color equations based on visual correlation studies using automotive metallic and effect colors: ΔE94 with lightness travel (Rodrigues, 2004), ΔE_{eff} (DIN 6175-2, 2001), ΔEAudi2000 (Dauser, 2012).

In the last 15 years, more pearl colors containing special interference pigments which create color shifts and/or special sparkling effects were introduced. More than multi-angle color measurement is needed to capture these effects. In the following paper the measurement of optical texture i.e. appearance change under different lighting conditions will be discussed in detail.

2. SPARKLE AND GRAININESS

In contrast to solid colors, effect finishes change their color and appearance with viewing and lighting conditions. Practice has shown that two samples with effect pigments could be measured as a perfect match with a 5-angle spectrophotometer, but visually be not acceptable due to differences in sparkle and/or graininess. This effect cannot be captured with conventional multi-angle color instruments, because they measure the integral of the spectral reflection over the detected area and can not distinguish between the basecoat color and the reflection of the effect pigments.

2.1 Visual Evaluation of Sparkle and Graininess

Under diffused illumination whereas the light intensity is equal from all directions (cloudy sky, typical spray booth for a car) a metallic finish can create a light/dark pattern depending on the aluminum flake size from very fine to very coarse (Figure 1). Commonly used terms to describe the phenomenon are graininess, coarseness, texture or salt & pepper. The effect is only obvious at a close distance and does not change with viewing angle. Graininess can vary with the flake size, the orientation of the flakes in the coating, and with agglomeration of flakes during the application process.

Under direct illumination i.e. the light intensity comes from mainly one dircetion (sunny sky, inspection with an intense spot light) the same metallic or effect finish can look completely different (Figure 2). Small light flashes can be seen with low to high intensity. This effect is also referred to as sparkle, micro-brightness, glint or diamonds. Sparkle is caused by the reflectivity of the flakes and therefore is influenced by the flake type (aluminum flake, mica, Xirallic®), the concentration level of the effect pigments, flake size or application method (bell / bell versus bell / pneumatic). In contrast to graininess, the sparkle effect is depending on the illumination angle.

Figure 1: Graininess under diffused light.

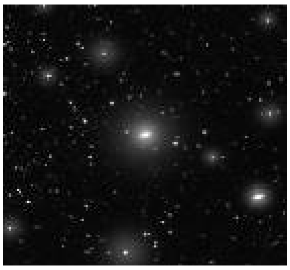


Figure 2: Sparkle under direct light.

Investigations on optical texture properties of effect coatings were done by visual studies under two different illumination conditions using comparison tests to well defined anchor panels. (E.J.J. Kirchner, G.J. van den Kieboom, S.L. Njo, R. Supèr, R. Gottenbos, 2006). The studies showed good results in terms of observer-repeatability and observer-reproducibility. As an outlook sub-parameters were discussed such as number and intensity of sparkle points. These additional parameters could be of help when evaluating different pigment types such as natural mica based interference pigments versus artificially produced Xirallic® pigments.

2.1 Instrumental Measurement of Sparkle and Graininess

To measure sparkle and graininess, a multi-angle spectrophotometer with additional direct and diffused illumination and a digital camera for detection was developed by BYK-Gardner. The resolution of the black & white camera correlates with the spatial resolution of the human eye. The camera takes pictures under various lighting conditions. Diffused illumination by a white coated hemisphere is used to simulate cloudy sky condition for measuring graininess. Direct illumination at three angles is used to measure the sparkle impression under direct sun light (Figure 3).

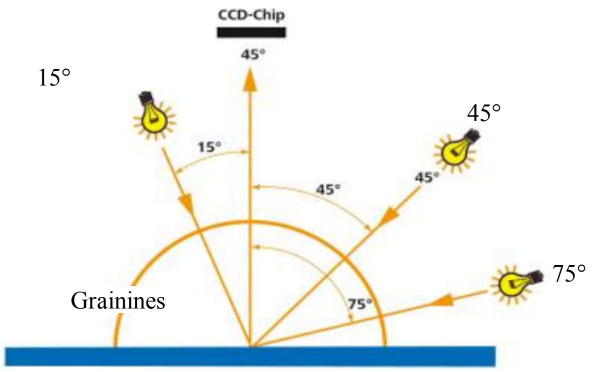


Figure 3: Schematic for effect measurement.

In order to obtain numerical values that can be used for daily process control and QC purposes, the camera pictures are analyzed with algorithms that were established based on visual evaluations of a variety of automotive finishes together with several partners from the automotive, pigment and paint industry.

2.1.1 Sparkle Measurement under Direct Illumination

The sparkle impression is changing with the angle of illumination. Therefore, the instrument illuminates the sample under three different angles 15°/45°/75° and takes a picture with the CCD camera located at the perpendicular (Figure 3). The camera is equipped with a dynamic exposure time dependent on the lightness of the sample. The pictures are analyzed by image analyzing algorithms using the histogram of lightness levels of the individual pixels as the basis for calculating sparkle parameter values. A threshold is set and only the very bright pixels above the threshold are evaulated for sparkle. To allow a better differentiation, the impression of sparkle is described by a two-dimensional system: sparkle area and sparkle intensity for each angle (Figure 4).

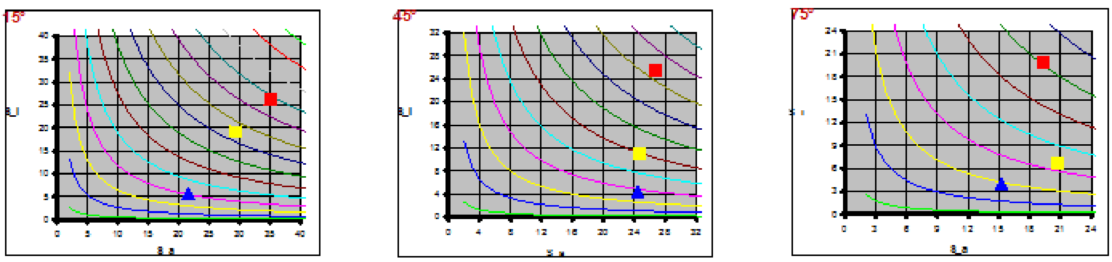
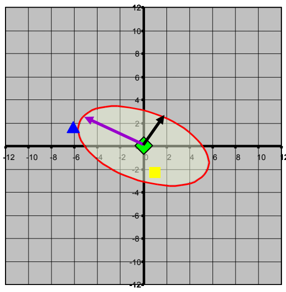


Figure 4: Sparkle measurement under three illumination angles.

The sparkle data, sparkle area and intensity, give information on different flake types and concentration levels. Additionally, the comparison of sparkle area at 15° and 75° illumination gives information about flake orientation. The colored hyperbola in figure 4 relate to a combined value namely sparkle grade. Sparkle grade is a function of sparkle area and sparkle intensity and can be seen as a measure how strong the sparkling effect of a coating is perceived by a human observer. Based on various visual studies it was proven that sparkle grade cannot be used as a significant acceptance criterion for pass/fail decisions: a sample with a low sparkle area but high sparkle intensity can have the same sparkle grade as a sample with high sparkle area and low sparkle intensity, thus appearing visually completely different.

Therefore, a sparkle tolerance model was developed which allows setting a "Delta Sparkle" value for paint batch or part QC. The calculation of the "delta Sparkle" is a weighted value and includes both an acceptance limit for sparkle grade as well as for a change within the same sparkle grade. The sparkle tolerance space has the form of an ellipse with the long axis being tangential to the sparkle grade hyperbola of the standard (Figure 5).



$$dS = \sqrt{\left(\frac{f_1(Sa_{Std}, dSa, Si_{Std}, dSi)}{Tol\_Gr}\right)^2 + \left(\frac{f_2(Sa_{Std}, dSa, Si_{Std}, dSi)}{Tol\_Gr * Tol\_GF}\right)^2}$$

Figure 5: Delta Sparkle describes the total sparkle difference between sample and standard.

2.1.2 Graininess Measurement under diffused illumination

Graininess is evaluated by taking a picture with the CCD camera under diffused lighting conditions. The picture is analyzed using the histogram of lightness levels of the individual pixels whereby the uniformity of light and dark areas is summarized in one graininess value. A graininess value of zero would indicate a solid color, the higher the value the grainier or coarser the sample will look under diffused light.

3. CONCLUSIONS

The introduction of more and more new effect pigments requires new innovative measurement technologies to capture the total color impression. It is no longer sufficient to measure the color impression only under different viewing angles. The color perception is also changing under different lighting conditions (direct and diffused illumination) and therefore, so-called sparkle and graininess effects can be objectively described.

REFERENCES

Dauser, T., 2102. *Audi Colour Tolerance Formulas*. Private Communication.

DIN6175-2, 2001. *Tolerances for Automotive Paints – Part 2: Goniochromatic paints*.

Kirchner, E.J.J, G.J. van den Kieboom, S.L. Njo, R. Supèr, R. Gottenbos 2006. The Appearance of Metallic and Pearlescent Materials, *Color research and application* 4,31.

Melgosa, M., 2013. *Testing the AUDI2000 colour-difference formula for solid colours using some visual datasets with specific connections to the automotive industry*, Poster Session CIE-Meeting, Paris, 2013.

Rodrigues, A., 2004. Color technology and paint. In *AIC Proceedings of the Interim Meeting of the International Color Association*, Porto Allegre, 103-108.

Address: Gabi Kigle-Böckler, Global Business Manager Automotive
BYK-Gardner GmbH, Lausitzerstr. 8, 82538 Geretsried, Germany
E-mails: gabi.kigleboeckler@altana.com, sandra.weixel@altana.com

architectural colour

Cultural Influence on Psychological Impact of Colour in Interior Design – Preliminary Results

Zoran MARKOVIC[1], Slobodanka RADANOVIC[2]
[1] University of Botswana, Dep. of Industrial Design and Technology, Gaborone, Botswana
[2] RS Studio, Zrenjanin, Serbia

ABSTRACT

Colour has the biggest impact on final users in design, including architectural and interior design. This impact is sometimes even greater then impacts of all others tools and techniques combined together (shape, form, dimension, balance, symmetry, scale, accent, focus, etc.). This impact depends on many factors - cultural background of final users is one of them. The main research questions are whether colours affect final users and how strong cultural influence affects the impact which colours make on final users.

The paper presents preliminary results of the research regarding influence of cultural background on psychological impact of colour in interior design. The Research started in 2012 and has been conducted on numerous locations worldwide. Preliminary results (obtained from the first three countries) support the research hypothesis.

The Research intends to describe and present current situation regarding cultural influence on colour impact in interior design, and aims to revisit previous works in this area, but including a multi-cultural background (e.g. Kaya/Epps, etc.). It conducts analyses both on psychological (personal) and sociological (group) level.

Key words**:** Colour Psychology, Psychological impact, Culture, Cultural Background.

1. INTRODUCTION

Conducted analysis of all tools and techniques used by designers in interior design indicate that colour has the biggest impact on final users. The paper presents preliminary results of the research regarding cultural background and its influence on psychological impact of colour in interior design. The Research started at the beginning of 2012 and it is still conducted on various locations worldwide. The Research has been fully finalised in Botswana and Serbia, and it is in its final stage in Kenya; it has started in Slovenia and India, and it is in the preparation phase in Brazil, Singapore and Malaysia. The plan is to finalise all data collections by June 2013, prepare the results matrixes for each country before October 2013 and finalise a comprehensive comparison study during the period from November 2013 to January 2014. The preliminary results obtained from the first three countries support the research hypothesis and they are presented hereto, together with the research methodology, research tools, forms, matrix and plan of the final comparison. Explanations and details how and why these countries were selected, together with analysis of cultural circles are also given in the research report hereto.

2. RESEARCH PROJECT

2.1 Research Question, Hypothesis and Expected Results

The main research questions are whether colours affect final users and how strong the cultural influence affects the impact which colours make on interior design. The Research starts with a hypothesis that such influence is profound and colour impact differs in each and every cultural circle that we have analysed. When we go into details, our hypothesis could be developed for the prevailing gamma in these areas – sandy/earthy colours prevailing in Botswana; strong and vibrant colours prevailing in Kenya; white and grey/light blue colours prevailing in Serbia, etc. Through experiments we will proof our hypothesis to be right or wrong. If it proofs right, it will be a great breakthrough; interior designers, even paint manufacturers would use these results in everyday practice. Furthermore, it will open new research fields regarding colour vs. cultural background. The results would be empiric and exact, showing psychological interference of particular colours with cultural backgrounds presented in numbers (percentage, etc.). Before we start analysing cultural influence, we have to proof the existence as well as the level of power of impact of colours on users/visitors of a particular interior design. And, as usually, answers to these main questions will be given at the end. Only upon finishing the analyses of all collected data, we will be able to list and describe these impacts and influences. During the work on this project, we have to keep in mind that we are taking the road less travelled as this area of research is still not fully established.

2.2 The Main Goals of the Research

The Research is intended to establish, describe, proof and present the current situation regarding cultural influences on colour impact in interior design and to analyse psychological (personal) and sociological (group) impacts. The planned experiments will proof or disproof the preliminary research hypothesis and redo known experiments, but with a multi-cultural background. They will find, proof, describe and present contemporary cultural influence on colour impact – from psychological to sociological, revisit and renew previous research in this area (Kaya/Epps research at University of Georgia, USA, etc.).

2. 3 Research Teams (Scientific Disciplines) and Informants Involved in the Research

This research was planned as a multi-disciplinary and inter-disciplinary method from the beginning. The Research team involves several specialists from different areas: Design, Interior Design, Psychology, Sociology, Coloristic, Architecture, History of Interiors, Design and Architecture, etc. Due to the fact that so many people are involved in the research, the main team was divided per countries, not per disciplines. In every country-team (sub-team) there are some different specialists. For example, a research team from Serbia has the same core members as all other teams but it also incorporates a very strong sociology group. A team from India incorporates a medical physiologist, a specialist in humans' physical reactions on different impacts, including colour impacts. A team from Slovenia has some members who are very strong in technological mode of thinking, etc.

To maintain similar target groups, all sub-teams would work with volunteers/informants students. Groups of students should include approximately equal number of males and females between 20 and 30 years of age, and they should come either from technical or design schools. This will create similar experimenting groups and lead to minimum influences of other elements in final results. Comparing these results, the research team could be able to concentrate on a cultural component in differences within the matrix.

3. METHODOLOGY

3.1 Project Methodology

For this research we are planning to use a Mixed Method (combined Qualitative and Quantitative methods, both emerging and predetermined approaches, both open and closed-ended questions, and both quantitative and qualitative data and analysis). Research Sub-teams would collect both quantitative and qualitative data and use them for the best understanding of the research problem. Data collection would involve gathering both numeric information, as well as text information so that the final database represents both qualitative and quantitative information. Numbers of the same type of emotional impact will go parallel with analysing particular type/colour, together with recording all details.

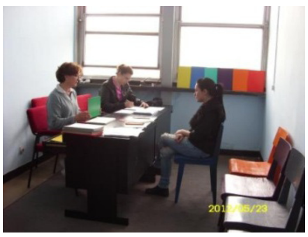
3.2 Tools and Procedures

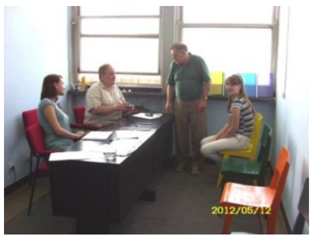
Main sources of data collecting are interviews with volunteers/informants. To collect good and useful data, the informants have to be from the similar group. But, even more important is that research tools have to be similar in every country. We have divided all research tools into two groups – for preliminary interview and for final interview.

Figure 1-4. Interview room and interview tools.

During the preliminary research, we collect data regarding general prevailing colours for each country/cultural circle. In this group there are 30cm rulers, brushes, crayons and folders, all of them assorted in six basic colours. At interviews, informants are expected to choose colours as per their own priority, from each of the tools. These results could be used later as a preliminary and rough estimation. It is important to highlight that a waiting area is also full of colours. It psychologically prepares an informant for the discussion on colours.

The main part of interview is comparing associations, emotions and intensity of colours according to informants' feelings and understanding. During the interview, the research team uses cartons with 6 basic colours (3 primary and 3 secondary), 6 light tinted basic colours, 3 gray scale colours (white, gray and black), and 5 colour combinations. The most critical element of this part is that all research teams will have available the very same colours ("My blue has to be everyone's blue").





Figures 5 and 6. Interview – interviewer, informant and the secretary taking notes of informant's answers.

During it, interviewer shows cartons with different colours to informant who responds how he/she reacts to this colour, and what emotions are present. Teams fill in two types of forms. One form is for basic information on the informant (gender, age, school and department, national and cultural background etc.) with preliminary research information (preferred colours of a pencil, brush, ruler, etc.). The second form concerns each colour-carton.

4. PRELIMINARY RESULTS AND CONCLUSION

4.1 Preliminary Results

Preliminary results have been finalized for the first group of countries – Botswana, Serbia and Kenya. Preliminary results show similarities, but they still vary in all three countries. The most prevailing colours are blue and red. For Serbia the blue colour leads with 26% and red 24%. For Botswana the red is similar to green, violet and orange, but the blue is leading with 33%. In Kenya the blue colour is also prevailing with 35%, followed with red 27%. This opens a new question regarding the blue and its prevailing through different cultural circles. On the other hand, percentage, balance of other colours and even the most prevailing colour vary in all three countries.

4.2 Preliminary Conclusion

The paper introduces this research, presenting its methodology, tools, procedures and preliminary results. The final research will be prepared and the comparison matrix done when all involved teams finalise their data collecting. Looking only at preliminary results we could conclude that the research hypothesis is proved. Even preliminary results show some similarities, but differences between countries exist and they show influences of cultural circles. Due to lack of space the full matrixes with preliminary and full results could not be presented hereto (results obtained so far for Serbia only contain more than one hundred pages). The Research continues and we expect full and final research results before the end of 2013.

5. REFERENCES

Adams, F.M., and C.E. Osgood, 1999. A cross-cultural study of the affective meaning of color. *Journal of Cross-Cultural Psychology*, 7, 135-157.

Nemcsics, A., 1993. *Colour dynamics: environmental colour design*. Akadémiai Kiadó (Budapest).

Rompilla, E., 2005. *Color for interior design*. The New York School of Interior Design.

Kaya, N., and H.H. Epps, 2004. Color-emotion associations: Past experience and personal preferences, *AIC 2004, Interim Meeting, Proceedings*, 31-34.

Boyatzis, C.J., and R. Varghese, 1994. Children's emotional associations with colors. *Journal of Genetic Psychology*, 155, 77-85.

Choungourian, A., 1968. Color preference and cultural variation. *Perceptual & Motor Skills*, 26, 1203-1206.

Address: Zoran Markovic, University of Botswana
E-mail: <markovicz@mopipi.ub.bw>
Address: Slobodanka Radanovic, RS Studio, Zrenjanin, Serbia
E-mail: <slobodanka@beotel.net>

The City Colour Planning, between Instances of Conservation and Needs for Renewal

Cristina BOERI
Colour Lab, Design Department, Politecnico di Milano

ABSTRACT

The colour plans since their appearance, in Italy at the end of the Seventies, were a response to the need to protect and regulate, but also to enhance the colour identity of the historic city. The colour plans, then, have been assuming diversified objectives and intervention methods, which partly reflect and partly fuel the issue of the city chromatic identity poised between past, present and future. Starting from a reading of the various approaches and methods, objectives and results, characterising the colour plans, especially in Italy and in Europe, the aim of this paper is to present a summary of the main orientations the urban colour planning and design have been assuming.

1. INTRODUCTION

Colour represents, now as in the past, an important element of the image and imagination of the city. But, whereas in the past urban dimension was mostly related to local materials and pigments in one virtually inevitable solution of continuity, the advent of new building materials with new construction techniques marked the start of a homologation process of urban characteristics. If from one side, then, cities appear increasingly declined in a shade of greys, result of the diffusion of construction materials, such as the concrete and asphalt, on the other, synthetic colours and products ready for use have generated a globalization of the colour offer and colour charts.

To the progressive loss of chromatic identity of the architectural scale, often, new forms of identity have been substituting, especially in that micro-fabric of urban signs that, in fact, today represents the new chromatic image of the city.

In this context it is interesting to note that it is the colour to assume a relevant role in the debate on the need to preserve the identity of the city, but also to initiate processes of urban and social re-qualification. Colour, in fact, in many examples of colour planning interventions, has worked as the driver of a deeper and more enduring process of social transformation and re-appropriation of urban spaces.

Colour plans since their appearance, in Italy at the end of the Seventies, were a response to the need to protect and regulate, but also to enhance the colour identity of the historic city. The colour plans, then, have been assuming diversified objectives and intervention methods, which partly reflect and partly fuel the issue of the city chromatic identity poised between past, present and future. On the one hand the need to preserve the historical identity of the built environment through its original and traditional colours, on the other the need to re-signify, bringing a sense of belonging and perceptual qualities to the urban context. On the one hand the need to impose unambiguous rules to protect the historical heritage colours, on the other the need to involve the citizen, proposing criteria or indications that guide individual choices or create active participation.

2. A SUMMARY OF THE VARIOUS TYPOLOGIES OF PLANS

Starting from a reading of the various approaches and methods, objectives and results, characterising the colour plans, especially in Italy and in Europe, it has been attempted to provide a summary of the main orientations the urban colour planning and design have been assuming[1]. A summary in which the emphasis is not so much on the value of the single method, or contribution, but on the abundance and diversification of the views and, consequently, of the actions prepared. In the belief that it is above all in the debate, which has always accompanied them, that the colour plans have proved their vitality, and need.

2.1 Colour plans of historical matrix

The first experience of colour regulation of the historic city is the colour plan of Turin, by Giovanni Brino, which started in 1978 and was legitimized on the basis of the rich historical record that was found (Brino and Rosso, 1980). The field of action of the plan is the historic centre and the pursued type of approach is a philological one, that is, targeted to revive, on the basis of archival records found, the original nineteenth-century colours of a piece of the city characterized by unified architecture. History is then at the same time the starting and arriving point of the plan: on the one hand, that is, it determines the type of conduct survey on colours and on the other the design outcome of the plan which will focus on the revival of colours and colour patterns originating in the buildings according to what emerged during the research.

From the colour scheme of Turin many plans have been carried out in a historical approach of philological type, aimed at the discovery, building by building, of the original colour state. The recourse to history in this kind of plans constitutes an extremely strong guarantee of legitimacy of the rules imposed by the plan that appears to have almost no project connotation by virtue of a supposed neutrality of the historical fact.

Even those colour plans that, in comparison with a restatement of the original colours move within the concept of traditional colours, are attributable to a historical approach. The chromatic ranges, in this specific case, are deduced from pre-existing history, from archival research, from local colouring materials that are defining a kind of “color loci”. Unlike the colour plans of philological matrix, the use of history is then not tied to the need for a faithful reproduction of what has been, but rather to the necessity of maintaining an identity or a historical continuity of the city through its colours, understood as part of its cultural heritage.

In the same years in which the colour plans are developing in Italy, in France Jean Philippe Lenclos introduces the concept of “geography of colour”, pointing out that the specificity of the colours of the traditional French built is closely related to regional environmental diversity and therefore, above all, to the use of local building materials (Lenclos and Lenclos 1982). The method of analysis developed by Lenclos in France is synthesised in colour palettes that reveal the chromatic character which form each place and contribute to the affirmation of a local, regional and national identity.

2.2 Colour plans of artistic matrix

When planning colour in a manner that can be defined as of artistic matrix, the process of

1 The analysis is the result of my doctoral research still in progress on the topic of colour urban planning and design at the University Lusíada de Lisboa, supervisor prof. Maria Isabel Braz de Oliveira, co-supervisor prof. Maria Cristina Giambruno and with the contribution of prof. Mario Bisson.

attribution of colour, is essentially linked to creative facts. The city is intended as a canvas on which to operate more or less freely, where the features of the architectural support, the structure of the built environment and its spatial relations become secondary to the expressive potential of colour.

In Russia in the Twenties the association of new architects (ASNOVA) suggested a reorganisation of Moscow colours on urban scale that will have to give to the Socialist state capital the most joyful and memorable appearance (Efimov 1992). The plan, presented in 1929, approved and never put in practice, appears as a superimposition in respect to the urban tissue that appears, indeed, as a canvas on which to operate indiscriminately in order to a radical transformation of the general image of the city.

This type of colour plans have been implemented especially in urban situations characterised by a poor quality of built, or by particular situations of decay, in which colour is used as a real corrective "make-up". The advantage, as Bruno Taut had noted in his *invitation to coloured architecture,* is that colour is at the same time the most economical, fast and effective way to transform urban environment and start a social strategy aimed at instilling visual pleasure and joy of living in the urban areas (Taut 1919/1974). It is emblematic the case of the city of Tirana that, since 2000, through a series of chromatic interventions on anonymous and degraded buildings of the Communist period, relies on the expressive and emotional potential of colour its desire for social change and re-appropriation of urban spaces.

2.3 Colour plans of perceptual matrix

The terms colour plans of perceptual matrix, define those plans in which the reading of the urban context and the architectural relationships that exist therein, take a dominant feature. In such plans, in addition to the intangible values of memory, affection and belonging, ultimately, even the tangible constructive value of colour that helps to determine, modify, valorise the image of the urban environment is enhanced. These plans normally integrate an analysis of historical kind with an analytical study of the quantitative and qualitative aspects linked to colour perception and configuration of the urban context.

The objective of the Colour Strategy, setup by Michael Lancaster and applied in many British cities, is to make coherent and legible the urban environment through the recognition, beside the historical and geographical parameters of colour, of the role of colour perception in order to achieve "a balance between the demands of historical authenticity and the need to create an effective colour composition for today" (Lancaster 1992).

Also those plans where the need to bring attention to and investigate all those elements that affect the city's image and not just the facades emerges, are attributable to a perceptive approach. Already Lenclos, in his reading of urban colour, brought to attention how the changing vitality of a place is not only related to the relatively stable colours of its built but also dictated by the "impermanent" variable colours typical for instance of landscape.

The colour plan of Moscow treats the colouristic image of the city as an aggregate of natural, social, economical, cultural and aesthetical factors, where in addition to the more permanent colours of the facades of the buildings, the variable colours such us the means of transport, outdoor advertising, street furniture, and even those colours subjected to constant changes such as, for example, the natural components that change with the seasons, were taken into account (Semenova 2010).

3. RESULTS AND DISCUSSION

From the analysis of the different colour plans, synthesized in this summary, to emerge is especially the complexity of the issues, as well as the diversification of the solutions as a result of the cultural, geographical, social and temporal specificity within which goals and strategies of the plan have been developed. If the sense of the colour "plan", indeed, is not to provide a set of immutable rules to be imposed, but of contributing to define and pursue a vision of the city, of its development, consistent with its needs and necessity, then, inevitably, each plan can only be a single event. The mistake is to consider the methods, the instruments, through which the plan is actualised, as the plan itself, ending to question on the meanings that colour can continuously assume in the city design.

4. CONCLUSIONS

The colour plans continue to show a great vitality. In front of the scepticism of those who look at colour as a secondary accident within the configuration process of the project, the colour plans attest, once again, how the values of colour go well beyond the iconographic, constructive or expressive value, assuming a cultural, social and psychological meaning. And it's always more to this complexity and interdisciplinarity that colour plans must be able to look at and respond to.

REFERENCES

AA.VV. 2008. Tirana. Architettura balcanica, *And*, (11): 10-73.

Brino, G., and F. Rosso, 1980. *Colore e città. Il piano del colore di Torino 1800-1850*, Milano: Idea Editions.

Efimov, A., 1992. The colour of Moscow. In *The colour of the city*, ed. by E. Taverne, C. Wagenaar. Laren: V+K Publishing, 30-55.

Lancaster, M., 1992. Norwich: a colourful city. In *The colour of the city*, ed. by E. Taverne, C. Wagenaar. Laren: V+K Publishing, 12-29.

Lenclos, J.P., and D. Lenclos. 1982. *Les couleurs de la France. Maisons et paysages*, Paris: Le Moniteur.

Semenova, T., 2010. Il colore nel centro di Mosca / Basics of the Moscow colour design. *Colore*. (66): 48-58.

Taut, B., 1919. Trad. It. 1974. L'arcobaleno. Invito all'architettura colorata. In *1920-1922 Frühlicht. Gli anni dell'avanguardia architettonica in Germania*, Milano: Mazzotta, 99-100.

Address: Arch. Cristina Boeri, Colour Lab, Department of Design,
Politecnico di Milano, via Durando 10, 20158 Milano, IT
E-mail: cristina.boeri@polimi.it

Cultural Discourse, Colour Heritage and Communication

Judith MOTTRAM,[1] Carinna PARRAMAN[2]
[1] School of Art & Design, Coventry University
[2] Centre for Fine Print Research, University of the West of England, Bristol

ABSTRACT

Our current digital technologies are as much a part of the cultural heritage of tomorrow as are the material objects we create and the discourses and narratives that bind theory and practice. In this fast moving technological environment, with increasing specialisation in those fields of practice engaged with colour, how do different disciplines in art, design and the sciences communicate theories and practice across their boundaries?

We propose colour as a meta-discipline, sitting above all and across many subjects, and by this definition as multi-disciplinary. Colour measurement, specification and replication bring challenges, but communication across colour fields also has conceptual barriers. This challenge of communicating different concepts, viewpoints, tools and methods, languages, terminology, and cultures cannot be avoided. We will suggest a framework for tackling the translation between natural language systems, matter and colour specification in the digital domain, which re-articulates how the science, practice and theory of colour can be used.

1. INTRODUCTION

We started thinking about the epistemology of colour in relation to cultural heritage and the built environment in Europe: what we build today is the heritage of tomorrow, as that built 200 years ago is our heritage today. We were focusing on reproduction in print, digital capture and restoration. Our ideas are however extendable across a wider territory and this paper will proceed on that basis. The proposition we argue is the need to get beyond cultural and disciplinary constraints and translation problems by revisiting how our knowledge sits in relation to three epistemological building blocks of colour knowledge: its science, its theory and knowledge of colour from within practice. Through this foundation could we negotiate the challenge of digital colour and virtual spaces to our perception of matter through lived experience?

When talking about colour in disciplines or cultures there are different languages in use. Our discourses include that of the practitioner who makes: their labels for the colours they use, and those of the suppliers, be they paint manufacturers or the suppliers of yarns or pigments or dyes. We have different terms used by graphic designers and printers, architects or interior decorators, and the historian's understanding of terms from records and archives. We have our colour specifications now, of those things that will become the historic artefacts of tomorrow. We have history to contend with – names change over time or ebb in and out of use. Who uses Fuchsia now? How does one imagine the colour Roan? And we have the challenge of digital colour rendering on all of our screen-based systems and the colour specification systems that should enable constancy and best management of global colour procurement. Colour is always seen in a context, and the observer has a certain objective, within a cultural framework, and with their own personal references and physiology. This means that technical measures of colour can never fully capture the human experience. This is our problem area and our engagement in teaching and research with the context of art and design education in the UK suggests further reasons why we need to take stock of the current position and develop strategies for future activity.

2. THE PROBLEM

We may expect that artists and designers know something about colour, as a key visual property that distinguish objects. If the object is realised through human action, the producer may influence its colour. This is true for the colour of cake, but scope for perceiving this as intentional, or meaningful, increases as we move to design, architecture, or art. In the UK, the bodies that oversee curricula do not say much about colour. The National Curriculum for Schools (Department for Education 2013) mentions colour as subject content for art and design for 5-7 year olds: 'Pupils should be taught creativity in art, craft and design by: …developing techniques in using colour, pattern, texture, line, shape, form and space using clay and printing to a large scale and in 3D'. At degree level, the UK Quality Assurance Agency (QAA) Subject Benchmark for Art & Design (2008) makes no explicit reference to colour, referring (for art) to 'conception, production, promotion and dissemination' of artefacts of our visual culture. Design covers 'decision-making in relation to the aesthetic, operational, user, market, production and/or manufacturing characteristics of artefacts and systems'. In Architecture, EU directives (EU 2005 then 2011) govern the content of degrees. Colour is not noted directly, but is implied as a component within aesthetic requirements. All of these frameworks are open to local interpretation and practice, but the absence of recognition of colour and scope for variation in delivery suggests that education may not be serious enough about colour.

In the 2012 report from the AIC Study Group on the Language of Colour, a proposal to improve international and interdisciplinary communication by establishing a 'basic standard palette' with the names in different languages of some 25 colours received little support. The Study Group felt that this was a problematic project. This paper resurrects the discussion, because we see colour specificity and colour difference as a distinguishing feature of our cultures and heritages.

Ask groups of artists or others to name or describe a colour and you get great variation. To address inter-cultural colour dialogue, Moroney (2012) is gathering 'natural' colour names. Mylonas (2011) has been exploring linguistic variation to facilitate within and between culture communication of basic and 'delicate' colour names. The most central issue for many professionals engaged in colour may be accuracy: how to communicate colour reproduction. In this context reproduction covers how to describe (through measuring and naming), how to capture (by cameras, video and scanning), and how to match appearance (by painting, printing or working on monitors). All these processes are an attempt to reproduce our phenomenological experience, and from this perspective, no device outside our perceptual system can accurately correlate with what we see. This enquiry began as early as 330BC by Aristotle (384-322 BC) (Nassau, 1998) and is still being explored today.

To source an image in the 21st century, the researcher has access to many reproductions, but has image quality increased? It seems the accuracy of reproduction has not improved over the last 100 years and search results can be less useful than the achromatic yet reliable black and white photograph of the past. An image search on the Internet for a Derain portrait of Henri Matisse generates 12 thumbnail images of varying colours and sizes. Looking at their colouration one wonders if they are from the same image, and, which one is the closest to the original? This is a problem for custodians and owners of visual material, but in a spiralling overload of visual information, we must also ask: if we cannot address the digital issues of today, how can we preserve our future digital heritage?

We can, however, consult Callen's annotated reproductions (1987) on this very same image, for a discussion of Derain's palette and the mixtures he used. She notes 'a brilliant touch of vermillion beneath the eye', 'a single sweep of red' for the pipe stem, a 'striking single brush-stroke of cobalt violet mixed with white' animating surrounding hues in the nose area. If we know the pigments within most of the oil paint ranges, these descriptions give a more accurate indication of the colour than do the reproductions from the web.

3. THEORETICAL FRAMEWORK

The model of the systematic search of physical science has been seen as the polar opposite to the intuitive creativity of literary and artistic intelligence. We see this classification as inappropriate since investigations of creative people in different fields have adjusted perceptions about the levels of intuitive deduction in science or mathematics and of systematic or 'theorisable' approaches to creative practice. There is however still evidence of 'science fright' in the arts, and worry about the arts from the science perspective. Recent debate on science in culture has discussed whether critical engagement with the arts, not the production of novels, or artworks, is what corresponds to science (Crossland 2012). She notes claims of no equivalents to natural and physical phenomena in literature, but for artists, designers and architects, we do see our products as objects of study.

Hardin (2012) talks of the problem of 'one preferred concept of colour', noting 'what colour it is depends not only on its intrinsic nature but upon the company that it keeps'. He advises not focusing on the different concepts, but on the 'different points of view from which colour could be understood'. Instead of doing colour science or theory badly, we will take on mapping all those perspectives on colour.

4. HYPOTHESIS

We need to find new models for engaging with the multidisciplinary nature of colour and propose colour as a meta-discipline drawing from many existing knowledge frameworks. Discussion within disciplinary paradigms reinforces silos and impedes innovation. If we accept creativity models that locate innovation at boundaries, with sufficient understanding of what is beyond, we have a platform for re-looking at how we might present knowledge within the meta-discipline, which may also have scope to influence in-discipline framing.

We need a framework for tackling the translation between natural language and digital specification systems. In the example of the Derain painting of Matisse we saw the problem of digital resources. From within the field of painting, looking gives us understanding of how different pigments mix and appear. This is different knowledge to that of the printer of gallery poster or book reproduction, or the web designer for the Tate. Different still is the knowledge for dying fabrics, or colouring concrete or render.

As part of our hypothesis of colour as a meta-discipline, we suggest that colour is both 'at risk' in terms of preservation and transmission of historic knowledge, but also offers new opportunities for expertise and understanding to stimulate cohesion, economic growth and appreciation of cultural heritage. Phenomenological colour can fight back against the digital, and cultural colour narratives could contribute to reworking colour in urban environments. The agile custodian of future colour needs to work across a greater realm.

5. CONCLUSIONS AND SUGGESTIONS FOR THE FUTURE

One of the challenges faced by a meta-discipline like colour is the great range of material that has to be encountered to move from novice to expert, whether for practice, for management, or for replication or restoration. To complement the colour meta-discipline as a space for creativity, we propose investigating a colour atlas and the utility of games as a repository and for generative learning tools for future *colour-ology*.

For Leonardo da Vinci, the embedding and demonstrating of his knowledge of science and technology in his drawings and art, shows ideas being explored through experience and the empirical process of *trial and error*. Venturi said of him: "The rational intellect (l'espirit géometrique) guided him in everything, whether in the art of analysing an object, in the stricture of his discourse, or in the care always to generalize his ideas" (Turner 1995; 86). This combining again of knowledge is our objective for colour in the 21st century.

ACKNOWLEDGEMENTS

Thanks to colleagues in 'Colour in our Cultural and Physical world' (FP7-SSH-2013-2)

REFERENCES

Callen, A., 1987. *Techniques of the Impressionists*, New Burlington Books.

Crossland, R., 2013. Cultivating common ground: interdisciplinary approaches to biological research. *New Phytologist*, 197: 362-365.

Department for Education, 2013. *2014 National Curriculum*. Available online, www.education.gov.uk/schools/teachingandlearning/curriculum/ Accessed: 1 April 2013.

EU (2005) Article 46 of the European Union Directive 2005/36/EC on the *Recognition of Professional Qualifications.*

Hardin, C. L. 2012. *Introduction*, Colour and Light - Concepts and Confusions. Ed. Arnkil H., Aalto University.

Moroney, N., 2012. *An Online Colour Naming Model* Available online, www.colornaming.net Accessed: 30 April 2013.

Mylonas, D., and L. MacDonald, 2012. Colour naming for colour communication, *Colour design: Theories and applications.* Ed. J. Best, Woodhead Publishing

Nassau, K., 1998. Fundamentals of Color Science. *Color for Science, Art and Technology.* Ed. Nassau, K., Elsevier Science, p.4.

Quality Assurance Agency (QAA) 2008. *Subject Benchmark for Art & Design*. Available online, www.qaa.ac.uk/Publications/InformationAndGuidance/Pages/Subject-benchmark-statement---Art-and-design-.aspx
Accessed: 1 April 2013.

Turner, R., 1995. *Inventing Leonardo, the Anatomy of a Legend.* London: Papermac.

Address: Prof. Judith Mottram, Coventry School of Art & Design,
Coventry University, Priory Street, Coventry, CV1 5FB, UK
E-mails: judith.mottram@coventry.ac.uk, carinna.parraman@uwe.ac.uk

Social Spectrum: Colour, Meaning and Fuzziness

Ken DEVINE
Artist, Senior Lecturer, School of Art Design and Media, University of Portsmouth

ABSTRACT

Recent years have seen the emergence of participatory and contributory arts practice identified most notably by Nicolas Bourriaud in 1998 as relational aesthetic. The impetus may be seen as emanating from the ideals of late 19th and early 20th Century European radical movements; its importance rising and waning corresponding to changing political climates. The constant throughout has been to work with and create artefacts relevant to wider social groups, other than the 'usual suspects'. Artist have taken up this cause from a variety of political positions but the present-day need for publicly funded arts organisation to prove 'value for money' has giving added impetus to the development of a cultural agenda that reaches beyond the traditional elite and aims at widened audiences. In response artists have developed practices that incorporate a widening cultural spectrum coinciding with the information processing ability of digital technology. Social data gathered to prove compliance with widening participation and as contributory content is a rich sources of contextual research into a contemporary societal landscape. Inadvertently many artists have become collectors, albeit chaotic ones at times, in an ethnographic study. This is an exploration of relationships in of one of these haphazard, fuzzy collections.

1. INTRODUCTION

In 1997 I answered a 'call for submission' for an artist residency at a junior school in Portsmouth on the south coast of England. My successful proposal was titled: Enigmatic Communities of Colour. The residency brief of sorts was, 'Do something that everyone can get involved with'. My simplistic response to this was to ask contributors from the array of establishments the project involved to tell me about a colour that held some meaning or association for them. This would be recorded on video and become the content for an interactive piece of artwork. I had recently been experimenting with this. I also collected demographic data for the reporting process. I was unaware that I had inadvertently wandered into a changing artistic landscape and it was quickly evident that what I was collecting was an unexpected collection of fascinating data.

2. LOCAL/NATIONAL SOCIAL/POLITICAL CONTEXT

The school residency was part of an SRB (Single Regeneration Budget) project. SRB was set up in 1994 to bring together a variety of initiatives from several Government departments. The main priority was to enhance the quality of life for local people in areas of need by reducing the gap between deprived and other areas, and between different groups by addressing economic, housing, social, environmental and community related issues through coordinated planning and implementation. Portsmouth's bid included provision for 'the arts' as active cultural engagement to raise the local population's aspirations. As well as the school the artist would engage in activities in two community centres and a contemporary art gallery. Enigmatic Communities of Colour was a digitally based project and therefore met a principle SRB criterion of helping to develop I.T. awareness and skills This Local/ National Social/Political Context was new territory. My work had until then been guided by a set of principles that had the 'artist' at the centre and the 'audience' at the periphery. The artist created the content, described the context and presented; the audience viewed, interacted, questioned and discussed. The artistic environment I related more to was founded in Aestheticism and Schiller's notion of the artist combined with ideas from Romanticism, the Classical and the Enlightenment. Schiller promotion of a philosophy of art that 'places the artist as the new the high priest in a secularized society' (Pevsner 1936).

3. PARTICIPATION – UNCERTAINTY

Since the 1960, there have been a number of contexts within which artistic practice has strove to move out of the gallery into wider social spaces. 'Out of the Box' by Carter Ratcliffe, (Allsworth Press, 2000), describes the process of breaking out of the Minimalist box and the white cube gallery, but this is in terms that are internal to a self-critical art establishment. Conceptual artworks by artists such as, Barry La Va, Walter De Maria and Robert Smithson et al while creating works that confronted the socially alienating exclusivity of the gallery, and the secular high priests controlling those spaces, its limitation, was the audience of usual suspects. It is in challenging hierarchical distinctions; the institutional paradigms of taste in the hand of the 'shamanic' artist that the confrontation to the social position of art(s) may be identified. The 'de-materialisation of the art object' identified in Lucy Lippiard's seminal book published in 1973 gives the sense of a space for wider participation being made evident through attempts to dissolve the division between artist and audience.

When the division between the artist and the audience dissolves uncertainty is introduce into the procedure. When you include 'others' who are not 'the usual suspects' it dramatically increases the uncertainty. There is a multivalent set of values and meaning brought to the table. Politically driven widening participation and contribution in the arts is, I would say, a driving force in the acquisition of and perception of new artistic knowledge. Authorship becomes a complex matter with viewers and creators merging, meaning is dispersed through multiple contributors and their own disposition, what Bourdieu refers to as 'habitus'; the sum of past events forming tendencies and behavior patterns in someone's life formed by the interaction between the 'social structures' they encounter and individual actions or strategies they adopt to navigate their way through these. Bourdieu while dealing with the politics of culture is also highlighting the complexity.

> "All relations that a determinate category of intellectuals or artists may establish with any and all external social factors — whether economic (e.g. publishers, dealers), political or cultural (consecrating authorities such as academies) — are mediated by the structure of the field...
>
> The sociology of intellectual and artistic production thus acquires its specific object in constructing the relatively autonomous system of relations of production and circulation of symbolic goods. In doing this, it acquires the possibility of grasping the positional properties that any category of agents of cultural production or diffusion owes to its place within the structure of the field..." (Bourdieu 1993)

When the agents are multiple anonymous but active contributors then there is an effect of a complex re-defining of 'the field'. In The Rules of Art (Stanford University Press, 1996) Bourdieu develops this further;

For Bourdieu, 'the principal obstacle to a rigorous science of the production of the value of cultural goods' is the 'charismatic ideology of "creation" ' to be found in studies of art, literature and other cultural fields.... [it] 'directs the gaze towards the apparent producer

– painter, composer, writer – and prevents us from asking who has created this "creator" and the magic power of transubstantiation with which the "creator" is endowed' (Bourdieu, 1996/1992: 167). (Hesmondhalgh 2006)

The 'charismatic' is represented in this project by the artist (myself) but the content and meaning belongs to and owes credibility to the multiple relatively anonymous contributors. It is in the collected data and narrative that the meanings are to be found and they express multiple sets of values and positions. The oldest contributor is over 80yrs the youngest is under 5yrs. This was not a programme of teaching the artistic paradigms of colour but asking the questions: What is it? What does it mean to you? Since the original residency successive iterations of the project has been to galleries, nationally and internationally, Army Barracks, Colleges, Schools, Community Centres and other public spaces increasing the diversity.

4. MULTIPLE MEANING EQUALS FUZZINESS

As a collector of colours; meanings and associations from contributors who had scant or little regard to the 'rules of colour' the range of habitus' and fields represented were inconsistent and uncertain. Fuzziness is a principle that abandons the simplicity of bivalency for the complexity of multivalence.

> "Logicians in the 1920s and 1930s first worked out multivalued logic to deal with Heisenberg's uncertainty principle in quantum mechanics, ... This math principle says that if you measure some things precisely, you cannot measure other things as precisely. The principle suggests that we really deal with three-valued logic: statements that are true, false, or indeterminate... Polish logician Jan Lukasiewicz chopped the middle "indeterminate" ground into multiple pieces and came up with many-valued or multivalued logic.... [later termed fuzzy]". (Kosko1994)

To try to find 'a representative colour' of a group (a set) would be as meaningless as averaging all of the colours in order to reach simplicity. All needs to be represented: The; usual, expected, aberrant, quirky, mystifying, unfathomable, reasoned, unreasoned. My method for representing this is called the Haphazard Analytical Colour Engine.

5. SINGLE COLOUR TO THE SPECTRUM, THE INDIVIDUAL IN THE COLLECTIVE

The Haphazard Analytical Colour Engine creates analytical spectra derived from the collection of data relating to contributors' colour associations. It uses free-form narrative and questionnaire. It has the capacity to search and create spectra of either associated colours from single words or complex word searches, using 'and' or 'or' functions. It also creates word maps from free-form narrative by choosing a colour. The free-form narrative can be single word or complex stories. The questionnaire covers issues related to; the objective and rational, feeling and opinion, geography, socio/political/economic location, life style, gender and ethnicity. Some contribution start with the choice of a colour, some originate from a text e.g. a poem and the colour is arrived at synesthetically. It currently has 1000+ contributions.

The following are sample searches and the resulting spectrum. Each search is carried out 3 times. The colours appear randomly and self-organise using an RGB attraction algorithm. There can therefore be variation depending on the sequence of colour selection.

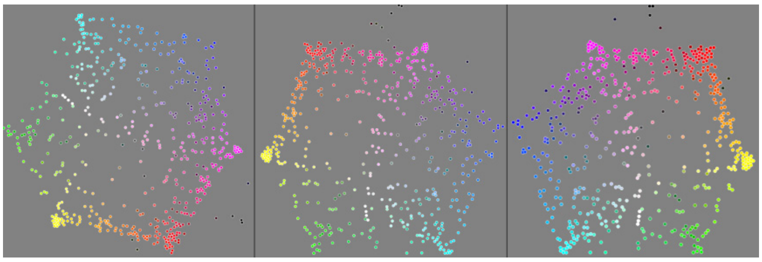


Figure 5: Gender – Female

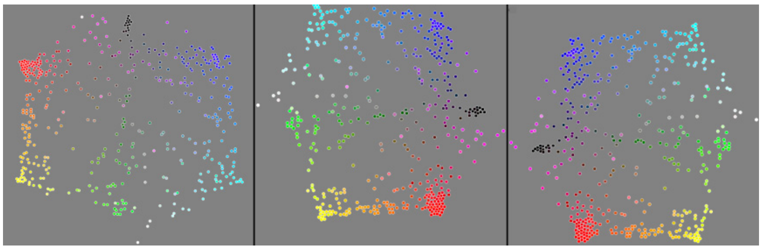


Figure 6. Gender – Male

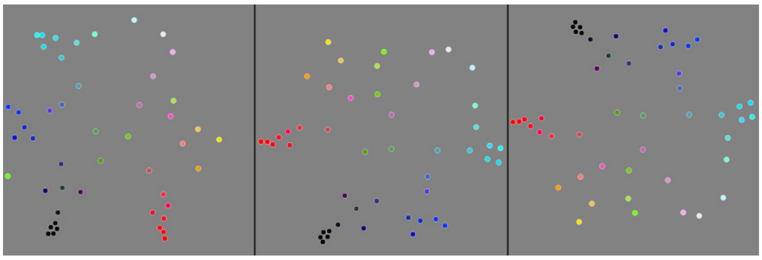


Figure 16. Army – Tidworth

CONCLUSION

This project is not attempting to establish a scientific truth. It is visualising a collection of associations with colour. In that sense it is art, a made artefact, that attempts to represent, using colour as a widely accessible abstract quality, some of the social and political relationships that are not dependant on expert knowledge. It's not complete; there can't be a conclusion. It is variable, people are too unpredictable and changeable in mood and temperament but it does show something of the complex relationships we have with colour. The maps are almost distinctive for their lack of distinctiveness. The male and female e.g. are much closer than I expected, similarly France and the U.K. are also. However, there seems to be a proportionate bias in the army towards red and black but I was surprised by the number of blues to greens. I thought the politically Very Left would be far more red. These 'surprises' tell us more about my position that the subjects. What these don't tell you are the sometimes remarkable stories. That's another series of work.

BIBLIOGRAPHY

Pevsner, N., 1936. *Pioneers of Modern Design*. (p.21) Faber and Faber.

Bourdieu, P., 1993. *The Field of Cultural Production* (p.132). Columbia.

Hesmondhalgh, D., 2006. *Bourdieu, the media and cultural production* (p.212), OU.

Kosko, B., 1994. *Fuzzy Thinking*. (pg19) HarperCollins.

Address: Ken Devine , School of Art, Design and Media,
Faculty of Creative and Cultural Industries, Eldon Building,University of Portsmouth,
Winston Chuchill Avenue, Portsmouth, Hants. PO1 2DJ
E-mail: ken.devine@port.ac.uk

Teaching Color to Architecture Students

Ralf WEBER, Thomas KANTHAK
Faculty of Architecture, Institute for Spatial Design, Dresden University of Technology

ABSTRACT

Teaching principles of color to architecture students requires a different kind of approach from teaching color to art students. 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 incorporate thinking about materials in the initial design phase of creating architectural shape and space, instead of merely draping a finished design with color, texture and lighting at the end of the design process and thus disregarding their role as intrinsic components of that 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 from the beginning phase and possibly generate new innovative ideas for design?

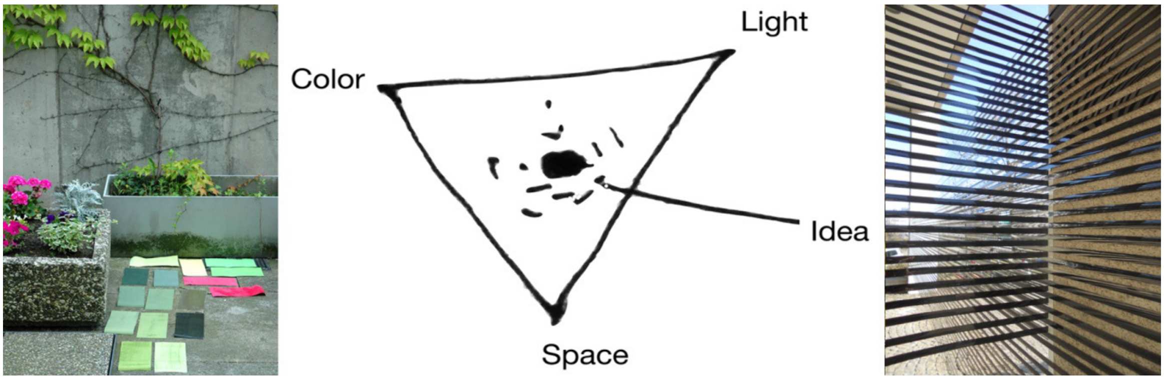


Figure 1: Color Swatches among architectural space; The Triad of Space, Color and Light, with the idea somewhere in between. (Burghardt, Matthias 2008); "Tapes" a student project for the opening of the Studio of the "Sammlung Farbenlehre" in 2011.

1. 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, 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. They begin by selecting samples from nature such as plants and rocks that they collect they then analyse the range of colors inherent in these samples. As a result of their analysis they produce a multitude of large color swatches which they mix themselves. Through this process they learn to value color as a sensual medium and its importance in architecture.

Higher 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 and that the knowledge of these become sources of inspiration for spatial design in architecture. One example of the teaching exercises used is the transposition of a specific character and atmosphere 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 "Sammlung Farbenlehre" or "Color Collection" at our Institute of Spatial Design, and the „Historische Farbstoffsammlung" or the "Collection of Color Pigments", established 150 years ago by the Faculty of Chemistry at the University of Dresden. Both are essential resources for teaching and research. We will also discuss our collaborations with other research institutions in Germany and Switzerland and our plans to offer extension classes to practicioners in the building trade to provide the opportunity for professional development.

2. 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 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 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.

Figure 2: Fist colour exercise: "Natural Color Palette": collecting samples from nature, analyse the essential colors and reproduce it by mixing tempera to get color swatches and recreate a) the quality of the color palette and b) the quantity of the color composition.

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 realize that the effect of color is relative as Albers demonstrated with his experiments. And they also astonish that a shade of color itself is neighter ugly nor beautiful for them; the same shade in compositions can be more or less disgusting, sweet, loud, mad or anything else. 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 began to appreciate some of the variations of formally less favored colors.

Three Weeks of Color - The college implemented an entirely restructured curriculum in 2011 which allows us to offer for the first time three intensive weeks of color instruction. With this extra time 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 the meaning of color. We offered excursions to the University‘s color collections, museums in Dresden and theater productions. Guest lectures offered by scientists and artists rounded out the program.

3. 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 imminent part of the architectural concept, as shown in Figure 1. 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. 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 of Color, Space and Light.

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 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. 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.

Figure 3: "Speed Dating with Luis (Barragan)" a project in the course "Space Colour Light 2011/12", other students dated with Tadao (Ando), Steven (Holl) or Peter (Zumthor).

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.

REFERENCES

Bendin, E., 2008. *Sammlung Farbenlehre - Instrument zur Wissenschaftskommunikation*. Lecture given at the Annual Meeting of the Deutschen Farbenzentrums. 24 - 26 Oct. 2008. MS. Deutschen Farbenzentrums.

Weber, R., 2010. *Space Colour Light. Ambassadors to Dresden*. Brochure of student projects at the Technical University Dresden.

Postal address: Prof. Ralf Weber, TU Dresden, Fakultät Architecture 01062 Dresden
E-mails: ralf.weber@tu-dresden-de, thomas.kanthak@tu-dresden.de, raumgestaltung@mailbox.tu-dresden.de

Colour traditions in Lower Silesia Architecture

Karolina BIALOBLOCKA
Faculty of Architecture, Wroclaw University of Technology

ABSTRACT

The research on original colour schemes in architecture of Wroclaw and Lower Silesia, Poland began on a bigger scale in the mid 90s. Since then we have noticed increased interest in restoring façades and interiors to their original colours. Examinations of many important historic buildings have been conducted and their results have brought new and significant information. This paper focuses on original colour schemes characteristic of Lower Silesian architecture. Selected examination results of both exteriors and interiors from different époques are briefly presented in three case studies.

1. INTRODUCTION

Throughout centuries local colour traditions gradually declined due to technology development and accessibility to unlimited choice of paint hues and building materials. Thus, our cities have lost another of their characteristic features, which, consequently, led to the birth and development of a new discipline in urban environment planning; namely, colour planning. Simultaneously, an increased interest in original colour schemes conservation can be observed.

Lower Silesia local colour traditions could have been shaped by builders and craftsmen coming from such areas as Bohemia, Habsburgs' Empire and Germany, which had a huge influence on Silesian architecture. But hues were determined by building materials and pigments locally available (Kirby 2010)

2. METHOD

This paper contains information on original colour schemes used in Lower Silesia region and derived from analysis of historic colour schemes examinations of buildings[1] and compared, if possible, with iconography and old architectural designs. Moreover, additional information was provided by treaties for architects and artists, and historical descriptions of the area.

3. CASE STUDIES

Wroclaw, Kurzy Targ 4 [2], 1554

This medieval dwelling house was refurbished in Renaissance style in 1554. From the late Middle Ages until mid 20th century, the building housed an apothecary on the ground floor. A recent paint examination of internal details of eight Renaissance columns arranged in pairs between windows revealed first phase colours. All of them were originally richly decorated in four different colour schemes. Highly saturated colours were used and juxtaposed in contrasting compositions. The pair of columns on the ground floor was originally covered in few hues imitating marble. Bases and imposts were painted red with black and white veins.

1 Reports from examinations are stored in archives of local conservation offices in Poland.

2 Examinations were conducted by Piotr Wanat.

Shafts of columns were covered in ochre with black and light colour. A yellow hue was discovered on the capital of columns. The columns on the first floor had capitals painted red and blue with gilding. Their bases were blue with gilding. A red colour was discovered on the edge of their shaft. On the second floor in the front room capitals and bases of columns were painted light cream or light grey colour with black in the background. The shafts were covered in imitation of veined blue marble. The bottom part of its shaft was probably painted red. The last pair of columns situated in the back room on the second floor had capitals painted red, shafts light yellow ochre and bases red and green. Details on shafts were also painted red and green (see Figure 1).

Figure 1: Columns' capitals after reconstruction. Photo by Dorota Kozak. Column shaft detail- Reconstruction of original colour schemes by author based on results from examinations.

Wroclaw, Rynek 6, 1721[3]

The dwelling house was refurbished in baroque style at the beginning of 18th century. At that time the facade was kept in grey hues, ranging from black to bluish grey. The wall was painted charcoal black or dark grey. Decorative details were grey or yellow ochre. Pilaster shafts were dark grey (Figure 2).

Figure 2: Wroclaw, Rynek 6, front elevation. During lasted refurbishment colour scheme did not follow the examination results. Photo by author.

Two examinations of the house representative room have brought different results. Details such as pilasters, bases, cornices and niches were decorated with two coloured stucco imitating marble. Gilding and silvering were introduced to some ornaments (see Figure 3).

According to the first examination the walls were possibly covered with fabric in raspberry red colour with golden ornament of acanthus leaves. A small piece of fabric was discovered in a hidden area behind a wall extractor fan. The origin of the existent fabric was roughly dated to mid 16th or mid 17th century. The authors of the examination, in fact, describe two layers of different fabric covering the walls. According to them, the two layers were different in texture but similar in colour, which may mean that walls were decorated with fabric in Renaissance and then in Baroque. The pink-painted ceiling was ornamented with ceiling plaster pattern of an ivory hue. The room doors were originally painted ivory

3 Examinations of facade were conducted by Agnieszka Witkowska and Piotr Wanat. Examinations of baroque room were conducted first by Zielinska Grazyna and Maria Taszycka (fabric). It was repeated thirty years later by Wieslaw Piechowka.

with an imitation of green marble square with gilded frames (see Figure 3).

The other examination revealed ten technological layers on a small area behind an old furnace. There were traces of light blue paint similar to Prussian blue pigment on lime-sand base. It is presumed to have been the original colour of the first phase. During the renovation works similar bluish hue was discovered on the ceiling. The hue of stucco corresponded to wall and ceiling colours.

The time span of 30 years between the two examinations recalled above and development of research methods may help explain the differences of results. However, colour schemes may also come from early and late baroque period and indicate the change of taste in colour throughout that long epoch. Apparently, during the refurbishment in the early 17th century a decision was made to use Prussian blue pigment - a newly discovered and enthusiastically welcomed hue (Eustaugh 2004) . [4]

Figure 3: Wroclaw, Rynek 6, baroque room. Fragments of wall with niche and door. Colour reconstruction was partial during lasted refurbishment. Photo by author.

Wroclaw, the Centennial Hall and the Four Domes Pavilion [5], 1912-1913

The Centennial Hall and the Four Domes Pavilion were erected in 1912-1913. Examinations of both external and internal original colour schemes were conducted during the latest renovation works. Although the buildings were designed by two different architects, elevations of both of them were painted the same colour. Yellow ochre was applied to all the surfaces. Walls were covered either with a thin layer of paint or painted transparently (Laska 2010). External doors had a warm red hue. Only windows were treated differently. Warm red brown Australian timber was used originally in the Centennial Hall whereas the Four Domes Pavilion windows were painted white with the exception of those directed towards courtyard, which were painted black. The Centennial Hall's main entrance area was painted yellow ochre and white. Red and bluish grey were applied respectively on metal and timber balustrades. Interiors of the Pavilion were also multicoloured. Grey, bluish grey, yellow ochre and black, used for details, dominated in different rooms in the first phase. Wallpapers are believed to have decorated some rooms, yet they did not survive.

4. CONCLUSIONS

Selected examples[6] of original colour schemes coming from different epochs presented in this paper depict unknown past of Lower Silesian architecture. All of them manifest unexpected colour dispositions, often quite different from our idea or taste. Recently growing

4 Due to commercial purpose of this examination and lack of their standard in Poland pigments analysis were not provided.

5 Examinations were conducted by Ryszard Wojtowicz.

6 Presented information in the paper is part of author's PhD research on historic colour schemes in architecture of Wroclaw.

interest in results of colour scheme examinations paves the way to discussions, so far nearly non-existing, on well-balanced development of colour conservation in Lower Silesia among architects and architectural heritage conservators. It may be a start to understand and restore historic colour schemes characteristic of the area.

ACKNOWLEDGEMENTS

The author wishes to thank heritage conservators for their cooperation and direct provision with some of the materials from examinations.

REFERENCES

Eustaugh, N.; Chaplin, T.; Siddall, R.; Walsh, V. 2004. *Pigment Compendium. A dictionary and Optical Microscopy of Historical Pigments*. Oxford: Elsevier Butterworth- Heinemann.

Eysmont, R.; Ilkosz, J.; Tomaszewicz, A.; Urbanik, J., ed. 2011. *Leksykon architektury Wroclawia*. Wroclaw: Via Nova.

Kirby, J.; Nash, S.; Cannon, J., ed. 2010. *Trade in artists' materials. Markets and commerce in Europe to 1700*. London: Archetype Publications.

Kobler, F.; Koller, M. 1981. 'Farbigkeit der Architektur' [in:] *Reallexikon zur deutschen Kunstgeschichte*, Bd.VII, 274-428. Stuttgart: Belseldruck

Laska, W. 2010. 'Renowacja elewacji Hali Stulecia we Wrocławiu - przykład scalenia powierzchni betonowych' [in:] *Renowacje i zabytki* (1) 2010:133-141.

Address: Karolina Bialoblocka, Faculty of Architecture,
Wroclaw University of Technology, ul. B. Prusa 55/57, Wroclaw, POLAND
E-mail: karolina.bialoblocka@pwr.wroc.pl

Trees of Buenos Aires Changing the Colour of the City

Maria Luisa MUSSO
Facultad de Arquitectura, Diseño y Urbanismo, Universidad de Buenos Aires

ABSTRACT

Buenos Aires is well known for the cultural value of its trees, part of the urban ecosystem intimately related to the inhabitants life. According to recent studies, in the streets and squares of Buenos Aires there are more than 420,000 trees, equivalent to one tree every seven inhabitants.

For the inhabitants of city centre in particular, the trees are the most conspicuous elements of the vegetable kingdom. They grow for the ornamentation of our public spaces and for shade and shelter, differing in size, shape and colour, but also in the type and number of leaves and flowers, in the form and texture of their trunks and branches. This paper refers only to the trees from its ornamental point of view, from the colour of its flowers that modifies the colour of the city during the long spring and summer time.

1. INTRODUCTION

Trees are the most prominent elements of urban nature. Their benefits and uses range from intangible psychological and aesthetic benefits to amelioration of urban climate and mitigation of air pollution. A nature-oriented city may provide urban people with the opportunity to recover from daily stress. Trees reduce wind speed and traffic noise, provide valuable shading from the sun as well as improves the landscape.They contribute to a better quality of living environment in cities. Aesthetic benefits relate to people experiencing different colors, structure, forms and densities. Much of the aesthetic experience is subjective in nature and has impacts on people's mental and emotional state. (Tyrväinen "et al" 2005). Colour is at first a purely physical effect when the eye itself is enchanted by beauty and the multiple delight of it. Color makes only a superficial impression upon a soul hardly developed to sensitiveness, while when that impressions reach highly developed people is communicated immediately to the senses.(Kandinsky 1946).

2. ABOUT ITS HISTORY

We can trace the history of the trees of Buenos Aires from the colonial period. During the viceroydom of Vértiz, the first street of Buenos Aires was founded, called the "Alameda", it was just a street with ombú trees, alongside the river. Until 1885 development in streets and squares was scarce and was related to the initiatives of the inhabitants. In those days, there were about 1,100 city trees. During the presidency of Domingo Faustino Sarmiento (1868-1874) the trend of planting trees, starts as a constant.The tendency increased with the arrival in Argentina of the french architect Jules C. Thays. Thanks to his initiative 21,250 examples were planted. Around 1901 there were some 65,000 trees throughout the city. Jules C. Thays, a disciple of Édouard André, French landscape architect and botanist, came in 1889, to design Sarmiento Park in Córdoba. After moving to Buenos Aires he was named the city's Director of Parks & Walkways in 1891. In the competition to qualify for this position he wrote: "The man, especially one that works, has need for distraction and is there something healthier, nobler, truer, than the contemplation of the trees, the beautiful flowers, when they are arranged with taste? The spirit then rests, and the aspect of beauty, of purity, produces an immediate effect on the heart" (Berjman 2002). This position gave him significant influence over the design of the city's open spaces, and his legacy is still strongly felt in the city today. Major projects included tree planting along streets, remodeling and designing public plazas and walkways as well as designing completely new parks and expanding older ones. Thays worked in Buenos Aires precisely at a period where the city was growing extremely fast as a result of immigration. He travelled around the country looking for species that would serve to decorate streets, parks and squares.From the north and northeast of Argentina brought several species including some exotic ones.

3. ORNAMENTAL TREES

Lapacho, *Tabebuia avellanedae,* or Pink Lapacho (1), (*Family Bignoniaceae*), is a native tree of America, distributed from northern Mexico to northern Argentina, naturally found in the wild of Central to South American forests. It is widely planted as ornamental tree in public squares and boulevards due to its impressive and colorful appearance of it magenta flowers. It is a rather large deciduous tree, reaching 30 m height. Usually a third of that height is trunk, and two thirds are its longer branches. It has a large, globous, but often sparse canopy.

The flower is large, tubular shaped, arranged in terminal panicles up to 30 cm long. Its corolla is pink or magenta, though exceptionally seen white. As soon initiated the spring in Buenos Aires, as an announcer of that, still without foliage, the tree spreads its thousands of pink flowers that dazzles with its extraordinary beauty. Flowering season is in early spring, in September, before the new leaves appear, but the ephemeral spectacle lasts only a few days. (ref. NCS S1040-R30B)[1]

Palo Borracho, (drunk sticks), *Chorisia speciosa* or Floss-Silk Tree, (2) (*Family Bombacacea*) is a deciduous tree native to Argentina and Brazil (Dalgas Frisch 1995). It grows fast when water is abundant, and sometimes reaches up to 25 metres in height, with broad crown, hemispheric. Its trunk is bottle-shaped, generally bulging in its lower third, measuring up to 2 metres in girth. It is studded with thick conical prickles. Flowers are hermaphrodite, solitary, pedunculated, with 5 petals oblong, 7-9 cm, long and 2-3 cm wide, pink with dark spots on the base. It bloom in December, lasting to May but there are specimens that bloom early as October. The pink flowers, very showy, open before the leaves show and then remain for a long period. Decorative species in all its stages, for their flowers and for their fruits. When they open show the silky white cotton, which surrounds the seeds.(ref.NCS S0540-R30B). The Chorisia insignis is the variety with cream white flowers (ref.NCS S0505-Y).

Paraiso, *Melia azedarach, (*3*) (Family Meliaceae*) is a species of deciduous tree in the mahogany family. This tree, well known as Persian lilac, is native to India and Pakistan but is now grown in all the warmer parts of the world. It has showy and fragrant flowers, numerous on slender stalks, white to lilac in color, while the stamina-tube is usually dark purple. In winter, no leaves remain, only the "China Berries" fruit, a small, yellow, olive-like drupe, in cluster, that are also very ornamental. (ref. flower NCS S1020-R80B, fruit S1020-Y20R)

1 The NCS colours mentioned are only referential. The colour that we perceive is influenced by the intensity, angle and composition of the illumination, by the surrounding colours and by other factors that vary with the situation as for instance date and time. Colours perceived in complex situations depend on many other things than the physical radiation and the reflection qualities of the surface. (Fridell Anter 1996 / Gibson 1966). In the case of these flowers, differs also from flower to flower, from tree to tree of the same species, the site where they grow.

Tipa tree, *Tipuana tipu*, known as Rosewood, (4, 5) (*Family Leguminosae*) is a South American tree that can reach 40 meters high; providing shade and cooling effect in the summer heat. Notable for his size and elegance of the port, it is one of the most conspicuous and well known trees of our flora. The flowers are bright yellow in colour, in showy terminal and axillary panicles. They bloom only briefly in November when the yellow of the flowers mixed with the green of the leaves, and upholster then with gold, the lawns, driveways and sidewalks. They are also called 'the daughters of Thays' because before this landscape architect started to redesign the green areas in Buenos Aires, there were only 3 of them. He recommended the use of this tree in the city and now it is found everywhere. Tipa tree line many of the broad avenues where they grow in their normal development, spreading their branches. However, when they line narrower streets, they rise great height seeking ligth and meet in the middle. They make us imagine within a green cathedral with high vaults. (ref. NCS S1060-Y10R)

It is impossible to move in Buenos Aires in November without experiencing the joy of jacarandas in blossom. *Jacaranda mimosifolia (6) (Family Bignoniaceae)*, a sub-tropical tree native to South America that has been widely planted elsewhere because of its beautiful and long-lasting blue flowers is in bloom all over the city. The tubular flowers are up to 5 cm long, grouped in panicles. They appear in spring and early summer, before the new leaves appear, and last for up to two months. The profuse flowering of these trees grace the plazas, parks, line the major avenues, and provide explosions of unexpected colour as they peek out on small streets among the others trees. The cemeteries have jacarandas; monuments and embassies have a dialog with them. You can't avoid finding yourself with jacarandas wherever you may be. (7) People are aware of the benefits they receive from this beautiful gift of colour. (Messore 2011) (ref. NCS S1040-R70B). María Elena Walsh, very well known for her work that revolutionized the way to understand the relationship between poetry and childhood, dedicated her Canción del Jacarandá, song for children, to this tree.

It is very impressive how the colour of flowers modifies the urban environment. There is a sense on the need to enjoy the colour in nature that surrounds us, even in a big city like Buenos Aires.

REFERENCES

Berjman S. 2002.Carlos *Thays: sus escritos sobre jardines y paisajes*. Buenos Aires. ISBN 987-507-226-5 ISBN 84-95823-09-8

Dalgas Frisch C. 1995. *The Hummingbird Garden*. Sao Paulo. ISBN 85-85015-03-09.

Fridell Anter K. 2000. *What colour is the red house?* Stockholm. Royal Institute of Technology

Gibson J. 1966. *The Senses Considered as Perceptual Systems*, Boston.

Kandinsky W. 1946. *On the spiritual in art.*New York: Hilla Rebay Editor. Published by The Solomon R. Guggenheim Foundation.

Messore. I. 2011.*Haciendo verde Buenos Aires. El libro verde*. Buenos Aires. Editors l C. Conte-706114

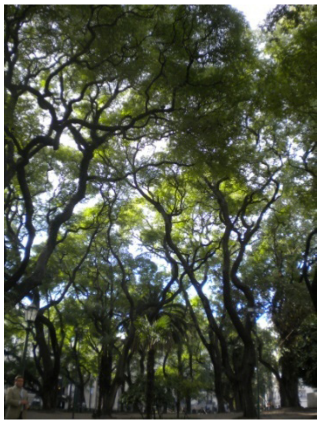
Tyrväinen L., S. Pauleit, K. Seeland, S. de Vries. 2005. *Benefits and Uses of Urban Forests and Trees, chapter 4 in Urban Forests and Trees.* Berlin. Springer. ISBN 9783540276845.

1- Lapacho, Tabebuia avellanedae

2- Palo Borracho, Chorisia speciosa

3- Paraiso, Melia A.fruits

4- Tipa, Tipuana tipu



5- Tipa, Tipuana tipu

6- Jacaranda, Jacaranda mimosifolia

7- Jacarandas in the City

Address: Prof.Maria Luisa Musso, Facultad de Arquitectura, Diseno y Urbanismo,
University of Buenos Aires , Argentina
Personal address: Carbajal 3281. C1426EMA, Buenos Aires, Argentina,
E-mail: colormlm@gmail.com

Present Condition of Landscape Color in Kyoto City in Japan

Masako MIYAMOTO,[1] Ryuichi NAKAMURA,[2]
Yasuto WATANABE ,[3] Kozaburo MURAKAMI [4]
[1] School of Human Culture, The University of Shiga Prefecture
[2] Otemae University, [3] Archetype Koubou, [4] Murakami Design Office

ABSTRACT

The number of modern buildings has increased in present-day Kyoto City. As a result, it can be assumed that the landscape itself has changed. However, it is necessary to think about the landscape color in the future that does not deny, but is based on, the current state. Therefore, we investigated the present condition of landscape color in Kyoto.

Twenty four typical areas are chosen from the areas shown in "Limitation of the form design of the building provided in the city planning" as the targets of our investigation. In each area, color quality was evaluated, visual colorimetry was performed, and a photograph was taken.

The color of the natural landscape district has high brightness. The bright colors of mud walls and plaster, and the dark colors of the red oxide, the bricks, and the antiquated wooden boards received an evaluation of "excellent" in the historical district. The color with high brightness is evaluated in the route district compared with other districts. From now on, it is necessary to think the landscape color of Kyoto for the characteristic in each area to be made the best use of.

1. INTRODUCTION

Kyoto City enacted a "Design standard for buildings and others" based on the new landscape policy in 2007, which also includes color standards. The basic range of "Colors other than the roof" as "Colors that harmonize with a natural landscape", "Colors that harmonizes with a historical town", and "Colors that harmonizes with a route and an urban town" is written in "Limitation of the form design of the building provided in the city planning". Moreover, prohibited color groups are clearly shown. Because this is a common standard, these colors cannot be used for buildings and other structures (with some exceptions) in the aesthetic district, the district formed aesthetic, and the landscaping district of buildings in Kyoto City. However, the number of modern buildings has increased and the landscape may have been changed in recent Kyoto. Therefore, we should think about future landscape colors after ascertaining the current situation.

Table 1: Prohibited color groups.

Hue	
R	Over Chroma 6
YR	
Y	Over Chroma 4
GY	Over Chroma 2
G	
BG	
B	
PB	
PB	
RP	

2. METHOD

2.1 Object of Investigation

Twenty four typical areas were chosen from the areas shown in "Limitation of the form design of the building provided in the city planning".

2.2 Classification of Areas

The investigation areas were classified into three patterns: “District that should be assumed to be a color which harmonizes with a natural landscape”, “District that should be assumed to be a color which harmonizes with a historical town”, and “District that should be assumed to be a color which harmonizes with a route and an urban town”.

2.3 Survey Content

Survey content consisted of: color quality evaluation (“excellent color ◎”, “slightly desirable color ○”, “slightly undesirable color Δ”, and “undesirable color ×”), visual colorimetry, and taking a picture. The investigation was basically done by a group of two in each area.

2.4 Method of Colorimetry

There are three methods used for visual colorimetry: the JIS (Japan Industrial Standard) standard color chart, the Munsell System Color Chart (20 hues) or Standard Paint Colors (JPMA). Furthermore, the names of the components and materials are included to the extent possible, and evaluation comments are provided.

3. RESULTS AND DISCUSSION

The following color ranges were derived from the results of the survey as an “Excellent composition color range” in each district.

3.1 Color range that harmonizes with the natural landscape

Table 2: Excellent Composition Color Range 1.

Hue		
N		Brightness is from 4 to less than 8.5
R	Less than 5R	Does not appear at all.
	5R or more	Chroma is less than 3.5, and brightness is from 3 to less than 6.5.
		A little red brick color appears.(Chroma is from 6 to less than 7, and brightness is from 4 to less than 5.5)
YR		Chroma is from 3 to less than 3.5, and brightness is from 4 to less than 8.
		Chroma is less than 3, and brightness is from 4 to less than 9.
Y	Less than 5Y	Chroma is from 2.5 to less than 3, and brightness is from 5 to less than 8.
		Chroma is less than 2.5, and brightness is from 5 to less than 9
	From over 5Y to 10Y	Not an excellent composition color.
GY		
G		
BG		
B		
PB		
P		
RP		

3.2 Color range that harmonizes with the historical town

Table 3: Excellent Composition Color Range 2.

Hue		
N		Brightness is from 4 to less than 8.5. The color of natural material (plaster, red oxide) with brightness outside range produces the characteristic in the area.
R	Less than 5R	Does not appear at all.
	5R or more	Chroma is less than 4, and brightness is from 3.5 to less than 6.5. Red brick color produces the characteristic in the area.(Chroma is from 6 to less than 7, and brightness is from 4 to less than 5.5)
YR		Chroma is from 2.5 to less than 4, and brightness is from 4 to less than 8. Chroma is less than 2.5, and brightness is from 4 to less than 8.5. Red brick color produces the characteristic in the area. (Chroma is from 6 to less than 7, and brightness is from 4 to less than 5.)
Y	5Y or less	Chroma is less than 3.5, and brightness is from 5.5 to less than 8.5.
		Beige gives the impression of an old street. (Chroma is from 2 to 3, and brightness is about 8.)
	From over 5Y to 10Y	Not an excellent composition color.
GY		Chroma is less than 2.5, and brightness is from 5.5 to less than 7 The green rust of the roof produces the characteristic in the area. (Chroma is from 3 to less than 4, and brightness is from 5.5 to less than 7.)
G		Not an excellent composition color.
BG		
B		Chroma is less than 1.5, and brightness is from 4.5 to less than 7.
PB		Not an excellent composition color.
P		
RP		

3.3 Color range that harmonizes with the route and the urban town

Table 4: Excellent Composition Color Range 3.

Hue		
N		Brightness is from 5 to less than 9.5. The low brightness color of a natural stone such as granite produces the characteristic in the area. (Brightness is from 2 to 2.5.)
R	Less than 5R	Does not appear at all.
	5R or more	Chroma is less than 3, and brightness is from 4 to less than 6.5. Red brick color appears, but its relative evaluation is a little low. (Chroma is from 6 to less than 7, and brightness is from 6 to less than 7.)
YR		Chroma is from 3.5 to less than 4.5, and brightness is from 4.5 to less than 8. Chroma is from 2 to less than 3.5, and brightness is from 4.5 to less than 8.5. Chroma is less than 2, and brightness is from 4.5 to less than 9. The color whose brightness is four or less appears in the case of a small area.
Y	5Y or less	Chroma is from 2 to less than 3.5, and brightness is from 5.5 to less than 8.5.
		Chroma is less than 2, and brightness is from 5.5 to less than 9.5.
	from over 5Y to 10Y	Not an excellent composition color.
GY		Chroma is less than 2, and brightness is from 7.5 to less than 9. (Almost all are the colors of the glass.)
G		Not an excellent composition color.
BG		
B		Chroma is less than 2, and brightness is from 4 to less than 6.
PB		Not an excellent composition color.
P		
RP		

3.4 Discussion of the Results

The color of the natural landscape district has high brightness. Taking advantage of the beauty of the natural color scheme is required in the natural landscape district, and high saturation and high brightness is not preferred.

The bright colors of mud walls and plaster, and the dark colors of the red oxide, the bricks, and the antiquated wooden boards received an excellent evaluation in the historical district. The slightly darker color is used, and the image with an excellent texture is desired.

The color with high brightness in the route district is evaluated as being more superior to those in other districts.

4. CONCLUSIONS

These results show that the landscape color in Kyoto became bright in recent years. However, it is necessary to think about the landscape colors in Kyoto which make the best use of the characteristics in its area.

ACKNOWLEDGEMENTS

This research was conducted by the special investigation study group established by Kyoto City on the issue of colors in the city.

REFERENCES

City Planning Bureau of Kyoto City, 2007. *Design standard for buildings and others*.

Research Group for Colors in Public Usage, Kyoto; 2011. *Consideration on the Cityscape in Kyoto City* (Symposium memorial book).

Address: Assoc. Prof. Masako Miyamoto, Department of Living Design,
School of Human Culture, The University of Shiga Prefecture,
2500 Hassaka-cho., Hikone, Shiga, 5228533, JAPAN
E-mail: Miyamoto@shc.usp.ac.jp

symposium: sustainable coloration

Novel Design Opportunities when Using Ink-jet Printing

David M. LEWIS[1], Peter J. BROADBENT[2], Muriel L. RIGOUT[2],
Carl HAUSER[3], Chris SUTCLIFF[4]
[1]The University of Leeds, Department of Colour Science, Leeds LS2 9JT, UK
[2]Department of Textile and Paper, School of Materials, The University of Manchester, Manchester M13 9PL, UK
[3]TWI Technology Centre, Rotherham, S60 5TZ, UK
[4]School of Engineering, University of Liverpool L69 3GH

ABSTRACT

Ink-jet printing has generated a true technological revolution in such diverse fields as paper printing, electronic device printing, textile printing, micro-fabrication and even printing living tissue. Not all of these areas are fully mature and some such as the tissue engineering area can only be described as fledgling.

This paper will firstly describe the status of textile printing using ink-jet, along with a description of some new studies in our laboratories into ways to use new pre-treatments to activate cotton and wool towards ink-jet printing with reactive dyes, the possible development of 'all-in' inks which may avoid the necessity to pre-treat fabrics and to use ink-jet to print discharge/resist styles.

The second aspect will deal with the role of ink-jet printing in the security industry; there is demand for variable data printing of both covert and overt features to prevent or deter counterfeiting of high value textiles.

1. INTRODUCTION

This lecture discusses simple mildly acidic pretreatments for cotton fabric which can then be readily ink-jet printed with reactive dye inks. Surprisingly simple carboxylate salts at pH 6.5, when used at 50-100g/dm^{-3}, perform better than the usual alkali prepares. A mechanism is proposed which involves reaction of the carboxylates with the reactive group on the dye.

In order to avoid the pre-treatment all together, the above observation was taken a step further by simply adding lithium acetate to the reactive dye inks.

High-tech aspects of security printing form a third aspect of the lecture and includes a discussion of phosphors and photochromic prints.The unusual aspects of the TacJet process are fully described. TacJet allows the ink-jet printing of large solid particles for example OVI pigments, thermochromic pigments,thermographic powder (hence Braille printing), iron powder, and gold or silver metal. The latter allows the printing of conductive circuits.

An alternative method of printing conductive circuits is to first print with an aqueous ink containing sodium ascorbate and overprint with a second ink containing silver nitrate solution; silver metal is formed by the reductive properties of the ascorbate solution.

2. METHODS

Reactive dye ink-jet prints on prepared cotton fabrics:

If reactive dye based ink formulations containing an alkali were prepared for the ink-jet printing of cotton, then the ink would have an extremely limited storage life due to the dye becoming rapidly hydrolysed to a non-reactive form. In order to prevent dye hydrolysis in the cartridges, ink formulations containing the dye plus solubilising agents are prepared and applied to cotton substrates that have been pre-treated prior to ink-jet printing with an alkali . An alternative approach was to pad cotton with a slightly acidic solution (pH 6.5) containing a dye activator (50 gdm^{-3}) and Cellcosan 2000 (8 gdm^{-3}); the padded fabrics being dried at 60°C for 3 minutes. The 'activators' investigated were: sodium formate, sodium acetate , sodium propionate, sodium lactate, sodium benzoate, sodium malate, sodium citrate, sodium phthalate, sodium pyruvate, sodium tartrate, sodium malonate, sodium oxalate, sodium thiocyanate, sodium cyanate, sodium trichloroacetate and sodium borate. All the above activators, with the exception of sodium cyanate and sodium trichloroacetate buffer the initial pH so that the pH of an aqueous extract from the fabric after steaming remains at pH 6.5; the trichloroacetate anion and the cyanate anion decompose during steaming to form hydroxide anion (Fuchs 1974, Lewis 1981) and thus, in these two cases, following steaming the pH of the fabric extracts was above 10.

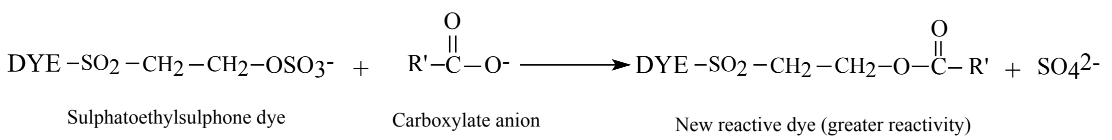
Ink formulation: Reactive dye based inks suitable for ink-jet printing pre-treated cotton substrates have been formulated in accordance with the following recipe:

100 gdm^{-3} reactive dye, 150 gdm^{-3} N-methylmorpholine oxide, 20 gdm^{-3} propan-2-ol, 25 gdm^{-3} 2-pyrrolidinone - adjust to pH 6.5 and make to 1 litre with distilled water.

Ink-jet printing process: Prepared cotton fabrics were mounted on A4 size pieces of paper and ink-jet printed on a HP 540 Deskjet printer using a tri-colour cartridge containing the reactive dye based inks. The printed fabrics were steamed (Mathis laboratory steamer) at 104°C for 10 minutes to promote the fixation reaction and then rinsed with cold water. Finally, the prints were soaped at 100°C for 15 minutes with an aqueous solution of Sandozin NIE (2 gdm^{-3}).

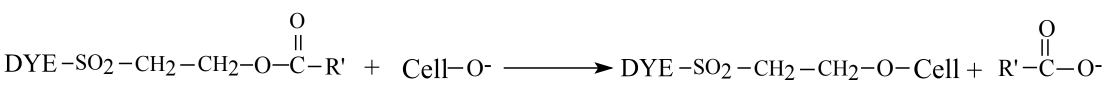
3. RESULTS AND DISCUSSION

The 'activators' offering the highest levels of reactive dye fixation were: sodium formate and sodium acetate. The promotion of dye fixation at pH6.5 is most unusual and it is suggested that the following reactions occur (Schemes 1-2):



where DYE represents the dye chromophore and R/ is H, alkyl or aryl.

Scheme 1. Formation of a new reactive O-carboxyethylsulphone dye



where Cell represents cellulose.

Scheme 2. Reaction of the O-carboxyethylsulphone dye with cotton

The likelihood that carboxylates react with halotriazine residues in a similar manner has been reported by Rayle and Fellmeth (1999).

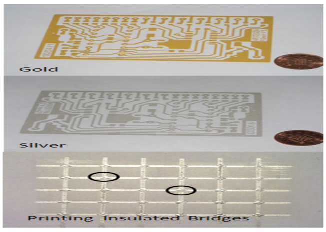
The All-in Process: lithium acetate was observed to be the most suitable 'activator' tested for inclusion with a reactive dye in a single ink formulation. The highest degree of reactive dye fixation was achieved for ink formulations containing dyes of medium reactivity; a typical ink formulation is 100-200 gdm^{-3} reactive dye, 100 gdm^{-3} lithium acetate, 200 gdm^{-3} N-methylmorpholine-N-oxide, 20 gdm^{-3} 2-pyrrolidinone, 25 gdm^{-3} propan-2-ol, 20 gdm^{-3} Ludigol (BASF) - adjust to pH 6.5 with acetic acid - make to 1 litre with distilled water.

Printing electronic devices using ink-jet

In recent years, there has been much interest in the production of electronic devices, such as RFID tags, on flexible paper or plastic substrates using simple, low cost techniques. Significant interest has concentrated on the application of electrically conductive inks to such

The TacJet (Lews, n.d.) process can be used to print a tack generating ink to form a sticky template; passing the printed substrate containing the tack template through a conductive material, such as silver metal flake, and finally removing non-adhered conductive powder leaves a conductive track on the substrate. Silver tracks printed using Powdertronix's TacJet process exhibited resistance values of 0.05-0.1 ohms/square without the need for any post-processing baking step.

Printed circuits produced by Powdertonix's TacJet printing process on paper substrates using either gold or silver flake as the conductive material are shown in Figure 1.



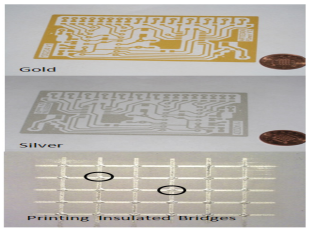


Figure 1. Printed circuits produced by Powdertonix's TacJet printing process on paper substrates using either gold or silver flake as the conductive material.

A comparison of the electrical conductivities of silver electrodes produced on paper using the TacJet printing process or ink-jet printed using a commercially available silver ink, SunTronic UV5603 (Sun Chemicals) is presented in Table 1. Figure 2 illustrates the silver electrodes that were produced using the TacJet printing process.

Table 1. Comparison of the electrical conductivities of silver electrodes produced on paper using the TacJet printing process or ink-jet printed using a commercially available silver ink.

Resistance	Single Print		3 Over-laying Prints		5 Over-laying Prints	
R_{AD}(W)		R_{BC}(W)	R_{AD}(W)	R_{BC}(W)	R_{AD}(W)	R_{BC}(W)
TacJet	2.1	0.4	-	-	-	-
SunTronic U5603	5.38	1.2	2.5	0.6	2.36	0.5

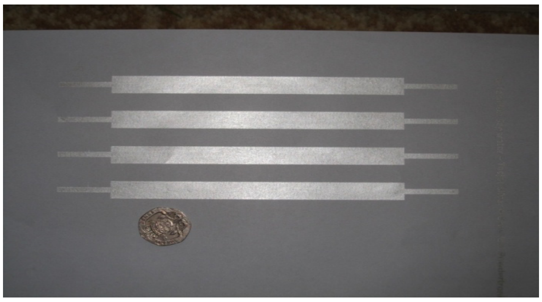


Figure 2. Silver electrodes prepared using the TacJet printing process.

An alternative method of depositing silver was published by S. M. Bidoki et.al. (2007). In this case silver nitrate was selected as the silver precursor in the ink-jet deposition process because of its very high water solubility, reasonable price and availability. Silver nitrate and sodium ascorbate could deposit silver metal on water absorbing surfaces whilst the surface structure and its interaction with the inks can affect on conductivity level of the

4. CONCLUSIONS

This lecture has described some of the exciting developments open to the ink-jet printer in both textile design and high-tech materials.

REFERENCES

Fuchs, H., and H. Konrad, 1974. *Melliand Textilber*, **55**:458.

Lewis, D.M., 1981. *J.S.D.C.*, **97**:365.

Rayle, H.L., and L. Fellmeth, 1999. *Org. Process Research and Development*, **3**:172.

Lewis, D.M., and P.J. Broadbent, *PCT GB 05/001763*.

Bidoki, S.M., D.M. Lewis, M. Clark, A. Vakarov, P.A. Milner and D. McGorman, 2007. *Micomech. Microeng.*, **17**:967.

Address: Prof. David Lewis, Department of Colour Science, School of Chemistry, University of Leeds, Leeds, LS2 9JT, UK
E-mail: d.m.lewis@leeds.ac.uk

The Role of Dye and Pigment Colorants in the Generation, Storage and Output of Digital Still Images

Algy KAZLAUCIUNAS
Colour Science Analytical, Department of Colour Science,
School of Chemistry, University of Leeds

ABSTRACT

Colorants in the form of dyes and pigments play an integral part in the digital still imaging process, from the initial conversion of the original grey-scale image into a full-colour RGB additive image, followed by electronic image storage and finally to hard copy output via non-impact printing technologies such as inkjet and thermal dye transfer. In addition, both dyes and pigments are also utilised for image generation in electronic paper display technologies.

1. INTRODUCTION

Digital cameras, in their many formats, are the dominant force in high quality still-image capture at the present time, replacing the previously popular and highly successful range of film cameras.

From the very early days of both additive and subtractive colour photography processes, dyes and pigments have played an essential part in the image capture and/or image reproduction process. Examples of their respective contributions include Auguste and Louis Lumiére's additive Autochrome Process, Louis Dufay's Dioptichrome (and later Dufaycolor) process, the Autotype Carbro process, and the Cibachrome positive-positive silver dye-bleach print process.

The majority of the present day digital cameras revert back to the additive principle of image capture associated with the early colour photographic processes by incorporating RGB filter masks to generate full colour images. These use both dyes and pigments to create the red, green and blue chequer-board pattern of the filter mask.

Of the technologies currently capable of being used for long-term image storage e.g. tape media, RAID and Cloud storage, only optical data storage systems incorporate organic dyes i.e. CD-R and DVD-R systems and Blue-Ray BD-R LTH (low to high polarity). However, three-dimensional optical data storage, potentially incorporating photochromic dyes, is expected to emerge in the very near future.

Although the majority of digitally captured photographic images are still predominantly output onto silver halide papers, non-impact printing systems such as drop-on-demand inkjet and thermal dye transfer are widely accepted methods for producing photo-realistic images. Whereas inkjet printing utilises both dye and pigment colorants to create the image, thermal dye transfer solely utilises dyes.

A current area for potential progress is electronic paper. Electronic paper (or e-paper) technologies reflect light just like ordinary paper (Heikenfeld 2011). E-readers like the popular Kindle series are able to display digital versions of books and e-paper magazines. Electrophoretic technology utilise titanium dioxide pigment and black dyes to create the text. Companies working within the e-paper field such as Ricoh, Samsung and Fuji Xerox are working towards full-colour electronic paper, with video capability.

2. GREYSCALE CONVERSION TO FULL COLOUR

For the majority of digital cameras, conversion of the initially captured greyscale image is achieved by means of the Bayer filter, patented in 1976 by the recently deceased Bryce E. Bayer. An imaging sensor is in essence a monochrome sensor which responds to light intensity with little or no specificity to wavelength (Nakamura 2006). The filter, or a modified version, is used as a method for separating colours in the sensor to reproduce an image of a coloured scene, and is present in digital cameras, video cameras and camera-phones. The image captured is known as a Bayer pattern image and the spectral transmittance of the colour filter array elements, together with the use of demosaicing algorithms (which use the concept of spectral interpolation) to estimate the missing colour components, are responsible for the colour rendition produced for full-colour RGB information at every single pixel location (Gunturk 2005). The colorants used for producing the on-chip colour filter arrays fall into two categories, namely dyes or pigments. Initially dyes were the preferred option and early patents filed by Polaroid mention both RGB additive and CYM subtractive colour filters. Specific dyes disclosed for the RGB optical colour filter were C.I. Solvent Red 8, C.I. Solvent Yellow 88 and C.I. Solvent Blue 36, with mention being made of hydroquinyl groups giving advantageous stability characteristics through hydrogen bonding of the dye to the resin, in the photo-resist material. A further series of patents from the Sumitomo Chemical Company indicates the use of a triallylmethane blue dye, a pyridine yellow azo dye, a copper phthalocyanine/pyridine azo dye combination, and also a xanthene/pirazolone dye combination. More recent patents make reference to the use of anthraquinone dyes, azo dyes and cyanine dyes.

An early indication for the use of pigments is provided in the Fuji Photo Film Company patent on colour imaging recorded methods. This patent focuses on improved resistance in the photo-resist process by using pigmented photo-resist materials. More recent patents involving the use of pigments for colour filters and imaging sensors, mention diketopyrrolopyrrole pigments, anthraquinone blue pigments and phthalocyanine pigments.

There is one current commercially available imaging sensor that does not utilise any form of Bayer filter mask to achieve a full-colour image, this being the Foveon X3 CMOS imaging sensor (Kazlauciunas 2006). A further alternative has been proposed by Panasonic (Nishiwaki 2013). The general idea is that instead of using colour separation by absorption, a Micro Colour Splitter will split light by near-field interference effects, thereby providing enhanced signal levels for dense small-pixel image sensors. This should lead to a light sensitivity increase of one whole stop, which in turn will improve electronic noise performance.

3. IMAGE STORAGE

In the area of digital still image storage, there are currently three vying technologies i.e. electronic, magnetic and optical. It is in the area of optical data storage where colorants have been, and continue to be, a key component of the process. Organic dyes are utilised as the recoding layer for CD-R, DVD-R and BluRay optical data image storage systems. The dyes primarily used tend to be cyanine, phthalocyanine and azo-metal complexes (Mustroph 2006), with cyanine dyes being the most extensively exploited (Kim 2006).

One possibility for the future is three-dimensional optical data storage. Information could then be recorded, or read, with 3D resolution as opposed to 2D resolution, as on a conventional CD. If successful, petabyte level image storage on DVD-type disks would become available. A device based on two-photon writing, reading and erasing involving a photochromic dye embedded in a polymer matrix has been devised (Rentzepis 1989).

4. HARD COPY NON-IMPACT DIGITAL PRINTING

Amateur photographers, who require hard copy prints of their images, tend to use a conventional image processing outlet, where the prints are mostly generated from Minilab printer systems e.g. the Fujifilm Frontier series. However, photo-realistic non-impact digital printing technology, in the form of inkjet and thermal dye transfer, have become alternative methods for hard copy output, particularly for semi-professional and professional photographers. Both methods of print output use either dye or pigment colorants to generate the final image. Whereas thermal dye transfer uses dyes, inkjet utilises both dyes and pigments.

Initially dyes used for thermal dye transfer printing were textile sublimation dyes. Following confirmation that the process was mainly one of dye diffusion, new dyes were designed to fulfil the necessary requirements, such as ease of transfer and high extinction coefficient. Although many patents have been granted which have described thermal dye transfer dyes the structures of commercially used dyes have not been disclosed.

Some of the more common pigments used for pigment-based inkjet formulations are C.I. Pigment Blue 15:3, C.I. Pigment 122, C.I. Pigment Yellow 74, C.I. Pigment Violet 19 and C.I. Pigment Black 7. Other pigments that are currently used, and others that are being actively promoted, have been documented (Kazlauciunas 2010).

With respect to dye-based inkjet formulations, the principal dye types that are used for the purpose of photorealistic ink-jet printing are anionic water-soluble dyes. These include acid dyes, direct dyes and passivated reactive dyes. Typically the black, yellow and magenta dyes tend to be azo dyes (often their hydrazone tautomers due to their greater stability in water-based ink-jet ink formulations). Phthalocyanine dyes provide the cyan and light cyan colorants namely C.I. Direct Blue 199. Other dyes that have been previously used are well documented (Gregory 2002).

Recent work (Zhang 2010) showed that the majority of people preferred dye-based inkjet photorealistic images compared with equivalent pigment-based inkjet and conventional silver halide images, when asked a range of questions appertaining to a selection of images. Interestingly there was one question on skin-tone representation where the dye-based image was not preferred. In this particular case conventional silver halide was voted superior.

5. ELECTRONIC PAPER (E-PAPER)

As mentioned in the introduction an area that is currently undergoing development, regarding high-quality colour images and video, is electronic paper technology. The current existing electronic paper technologies, unlike conventional backlit flat panel displays which emit light, perform like ordinary paper in that they reflect the light. Thus, in this mode reading and viewing are preferred due to reduced eye-strain (Nishimura 2008). Currently there is a number of existing electronic paper technologies that are vying for this future market that already have existing commercial monochrome devices. Many of these devices use dyes and pigments to generate on-screen text. For most of these electronic paper technologies, the potential for creating full-colour photo-quality images on screen, together with video, to an acceptable level, is a distinct possibility in the near future. However, at the current time some of the most promising full-colour electronic paper technologies are unable to provide the speed required for advanced touch interface's, or video media. Technologies that are currently commercial, or have demonstrated proof of concept, and incorporate either dyes and/or pigments to create the images, are Electrophoretic (uses black and white pigments in a microencapsulated oil and in theory it should be possible to use coloured pigments to achieve full-colour images, or black and white pigments coupled with a CYM or RGB filter), Electrokinetic (prototypes have been demonstrated using CYM pigments), Liquid powder (flexible full-colour prototypes have been demonstrated using a RGBW colour filter), Electrochromic (chemisorbed viologen molecules provide poorly saturated colour when compared with standard RGB and CYM pigments), Electrowetting (uses oil-soluble dyes), and Electrofluidic (uses white pigment dispersion plus black dyed oil plus RGBW filter).

REFERENCES

Gregory, P., 2002. Colouring agents for non-impact printing – A survey*, Surface Coatings International, Part B: Coatings Transactions* 85(1) 9-17.

Gunturk, J., et al., 2005. Demosaicking: colour filter array interpolation. *Signal Processing Magazine* 22 44-54.

Heikenfeld, J., et al., 2011. A critical review of the present and future prospects for electronic paper. *Journal Society Information Display* 19(2) 129-156.

Kazlauciunas, A., 2006. Digital image capture – Filmless camera technology and techniques. *Surface Coatings International Part B: Coatings Transactions* 89(3) 193-199.

Kazlauciunas, A., 2010. Photorealistic ink-jet digital printing – factors influencing image quality, image stability and print durability. *Coloration Technology* 126(1) 135-144.

Kazlauciunas, A., M. Zhang and J. Ball, 2010. Investigation into digital print hard copy quality, longevity and durability. In *Journal Physics Conference Series* 231 012012.

Kim, S-H., 2006. *Functional Dyes.* Amsterdam: Elsevier.

Mustroph, H., M. Stollenwerk and V. Bressau, 2006. Current developments in optical data storage with organic dyes. *Angewandte Chemie Int. Ed.* 45(13) 2016-2035.

Nakamura, J., 2006. *Basics of image sensors.* Boca Raton: CRC-Taylor & Francis.

Nishimura, K., N. Omadami and J. Imai, 2008. Novel evaluation method for visibility of reflective electronic paper display by comparative examination with liquid crystal display. *SID Symposium Digest* 39 1355-1358.

Nishiwaki, S., et al., 2013. Efficient colour splitters for high-pixel-density image sensors. *Nature Photonics* 7 240-246.

Porthenopoulos, D.A., and P.M. Rentzepis, 1989. Three-dimensional optical storage memory. *Science* 245 843-845.

Algy Kazlauciunas, Colour Science Analytical, Department of Colour Science,
School of Chemistry, Leeds University LS2 9JT
E-mail: ccdak@leeds.ac.uk

Environmental Stimuli-responsive Inkjet Ink Printed Textiles for Self-indicating Radiation Alert System and their Potential Multi-purpose Applications

Shah M. Reduwan BILLAH[1, 2]
[1] Department of Chemistry, Durham University, Durham DH1 3LE, UK
[2] School of Textiles and Design, Heriot-Watt University, Galashiels TD1 3HF, UK

ABSTRACT

Environmental stimuli responsive materials (such as, photochromic, thermochromic, ionochromic materials) were used to formulate inkjet inks to produce stimuli-responsive inkjet-printed textiles (such as, cotton, wool, silk, nylon). The printed textiles were responsive to UV light (when printed with photochromic dye based inks), temperature (when printed with thermochromic dye based inks) and ionic environment (when printed with ionochromic material based inks). The technical performances (such as, light fastness and washfastness) of the inkjet printed photochromic, thermochromic and ionochromic textiles were evaluated using specifically developed methodologies. Some of the printed textiles showed very high technical performances which made them suitable for various potential applications, including, self-indicative UV alert system, adaptive and active camouflage, fashion and design, protective security systems. This current paper very briefly illustrates different characteristic features of stimuli-responsive materials based inkjet inks, printed textiles and some their potential applications.

1. INTRODUCTION

Externally controllable stimuli-responsive smart surfaces are potentially important for multipurpose applications in molecular based devices, not least as discrete switching elements. The use of stimuli, such as light, pH and temperature, to switch surfaces using molecular systems which give rise to reversible colour changes are of particular interest in this current study for a variety of applications, including flexible surface-based molecular switching for adaptive camouflage, fabric-based chemical sensors, protective clothing and also for fashion and design applications [Billah 2012]. During this current study, a range of photochromic, thermochromic and ionochromic systems was carefully selected to formulate molecular switch based inkjet inks for printing on different types of textiles (for example, cotton, silk, nylon, wool) and other related substrates (e.g. paper and leather). After a rigorous study several series of stimuli-responsive materials (such as, photochromic, thermochromic and ionochromic molecular switches) based inkjet inks (both aqueous and solvent type) were formulated and optimised to ensure the inks were benign to the inkjet printhead and also to show desired good jettability, longer product life and higher technical performances. This current paper very briefly highlights different characteristic features of stimuli-responsive materials based inkjet inks, printed textiles and their conventional and high-tech application potentials.

2. EXPERIMENTAL

For this current study, a spirooxazine (6'-sulfonato-1,3,3-trimethyl spiroindolinonaphth[2,1-b]

[1,4]oxazine-monosodiumsalthydrate),threediarylethenes(cis-1,2-dicyano-1,2-bis(2,4,5-trimethyl-3-thienyl)ethane or CTME; 1,2-bis(2,4-dimethyl-2,4-dimethyl-5-phenyl-3-thienyl)-3,3,4,4,5,5-hexafluoro-1-cyclopentane or 6FDA; 2,3-bis(2,4,5-trimethyl-3-thienyl)malimide or Bismid), a naphthopyran (3,3-diphenyl-*3H*-naphtho[2,1-b]pyran) and a spiropyran (1'-(2-hydroxyethyl)-3',3'-dimethyl-6-nitrospiro[1(*2H*)-benzopyran-2,2'-indoline]) were used as photochromic molecular switches for ink formulations. Inkjet inks were formulated (using modified formulation techniques typically used for aqueous and solvent based inkjet ink formulations) and images were printed using a piezoelectric printhead (e.g. Xaar Omnidot 760) to print identical solid block patterns on textile substrates (such as, cotton, nylon, silk and wool). After printing the printed substrates were then dried in the air. For assessment, the inkjet printed substrates were irradiated using UV light (365 nm, maximum wavelength) for specific times and the photochromic switching behaviour was evaluated in terms of the colour build-up using reflectance spectroscopy, by measuring the reflectance which was then converted to the K/S value. Colour differences (ΔE) before and after UV irradiation were also measured. In addition, a range of ionochromic and thermochromic inkjet inks was formulated. For example, an ionochromic inkjet ink was formulated based on the indicator cresol red using a typical water-based inkjet ink composition whilst a thermochromic inkjet ink was formulated using an appropriate composition using different components, including crystal violet lactone, propyl gallate and butyl acrylate together with a suitable humectant. Both the ionochromic and thermochromic inkjet inks were used to print images on different substrates using the piezoelectric printhead. In the case of the ionochromic ink, printed images on different substrates were exposed to aqueous media with different pH values or to ammonia gas. On the other hand, for thermochromic inkjet ink, the printed images on different substrates were exposed to ice and the reflectance and coloured difference were measured.

3. RESULTS AND DISCUSSION

Fig. 1(a) indicates the behaviour of inkjet printing of cotton using spirooxazine based inkjet ink when printed as a soild block on cotton from one (termed as 1X) to 10 times (termed as 10X) in terms of colour difference of the printed contton substrates from the unprinted one. It shows a significant level of increase in the background colour of the printed solid block on cotton obtained after ten subsequent printing on the same solid block sample (10X). To produce a jettable inkjet ink suitable for a microdisposal from a drop on demand piezoelectric printhead to a target textile substrate (such as, cotton) we modified the ink formulation using a variety of rheological modifiers and additives for particular purposes which sometimes resulted in prodcing this type of background colour due to the impact of a matrix on a photochromic molecule [Billah 2010]. It was also observed that when printed on different textile substrates they produce a very pale colour and sometime no colour (Figs. 1(e) and 1(f) when printed with naphthopyran and 6FDA based inks) at all depending on the nature of the ink additives due to a number of reasons, including, the similar effect as already mentioned. Fig. 1(b) indicates that there is a different level of photochromic colour build up (after UV irradiation for 1 min) and fading behaviour (after removal from UV irradiation for different times) from the printed cotton samples 1X to 10X. It also shows that photochromic colour build up from 10X printed cotton is much higher compared to the photochomic colour build up on the 1X printed cotton due to high level of dye concentration in the 10X printed sample. Fig. 1(c) illustrates the impact of matrix on photochromic colour build up. Fig. 1(d) shows the effect of UV irradiation time on photochromic colour build up. It demonstrates a medium to intense blue colour build up on spirooxazine based inkjet ink printed cotton (10X) (in terms of K/S from before and after exposure to UV irradiation) from a nearly clourless state depending to the time of UV irradiation from 15 seconds to 120 seconds. It reaches at the highest level after continuous UV irradiation for 60 seconds, however, due to generation of heat for continuos UV irradiation for 120 seconds photochromic colour build up is reduced to some extent [Billah 2012]. Fig 1(e) shows the photochromic yellow colour build up (after UV irradiation) from naphthopyran and reddish purple colour build up from spiropyran based inkjet ink printed substrates. Fig. 1(f) indicates different level of photochromic colour build up (yellow, reddish-purple and purple) from cotton (10X) printed with different types of diarylethenes (Bismid, CTME and 6FDA) based inks after UV irrdiation. Besides this, some of the printed substrates, as shown in this paper, showed photochromic colour build up for a considerable period and also different significant level of technical performances depending on the nature of the molecular switch, matrix and surrounding environments [Billah 2012].

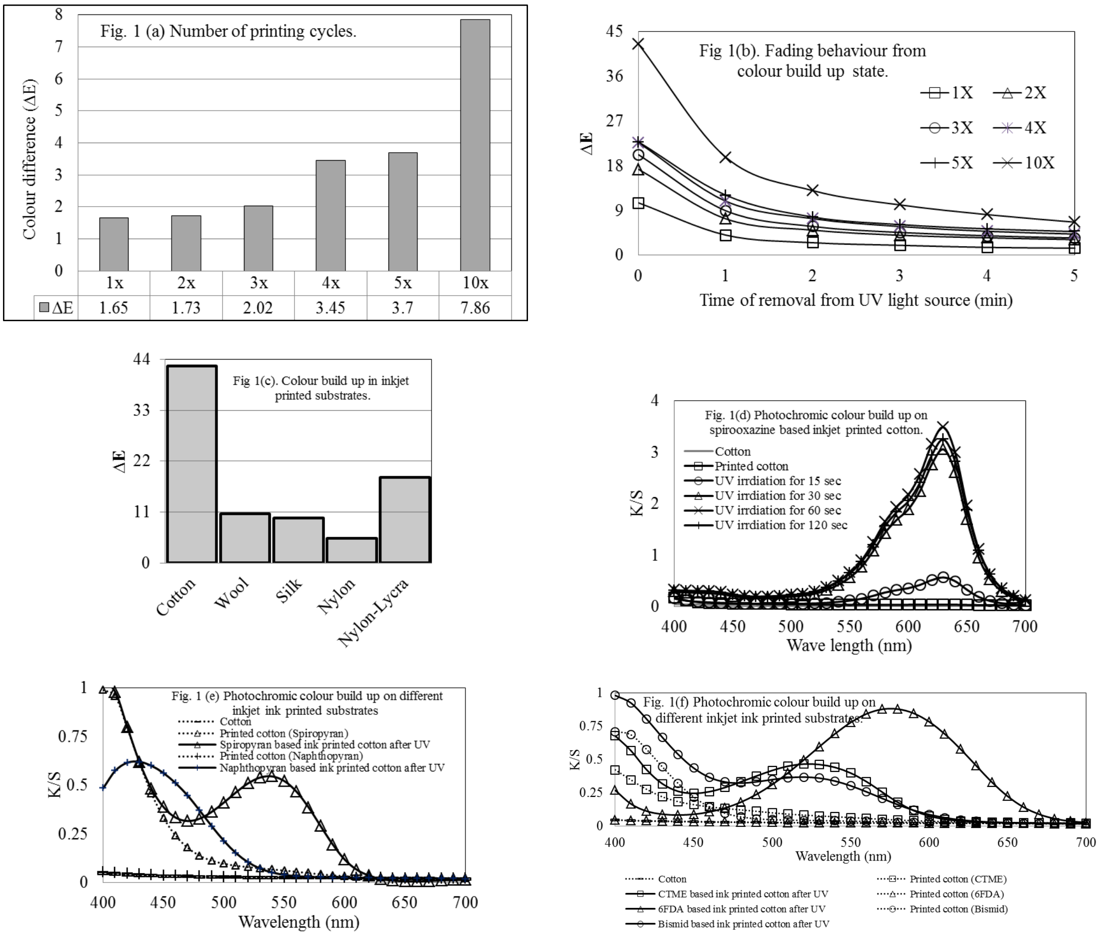


Figure 1. Photochromic behaviour of inkjet printed substrates.

The reversible colour change from an inkjet printed stimuli-responsive surface has many potential applications, including designing textile based self-indicating irradiation alert systems when integrated within fashion and design materials (e.g. textile based UV dosimeter integrated to a garment), security printing, brand protection, authentication and anti-counterfeit applications [Billah 2010]. In addition, cresol red based inkjet printed substrate showed a reversible colour change when exposed to ionic environments and to toxic gases (such as ammonia) and crysal violet lactone based inkjet inks showed reversible thermochromic colour change when exposed to ice [2] making them suitable for application to protective textiles for environmental warning systems along with many other potential applications.

4. CONCLUSION

Stimuli-responsive colour build up on inkjet printed substrates depends on a variety of factors, including the nature of the molecular switch and the substrate, exposure time, and the surround environments. This study reveals that stimuli-responsive inkjet printed textile surfaces have a variety of application potentials. However, there are quite a lot of challenges to produce stable, jettable and high quality inkjet inks using molecular switches to retain their switching behaviour for a long time for practical industrial applications which will be discussed in future publications.

REFERENCES

Billah, S.M.R., R.M. Christie and R. Shamey, 2012. Direct coloration of textiles with photochromic dyes. Part 3: dyeing of wool with photochromic acid dyes. *Coloration Technology*, 128(6): 488-492.

Billah, S.M.R., R.M. Christie and R.H. Wardman, 2010. Inkjet printed textile based molecular switches. In *Textile Institute World Conference Proceedings*, November 3-4, 2010, Manchester, UK, ISBN: 978-0-9566419-1-5, 1-10.

Address: Dr. Shah M. Reduwan Billah, Department of Chemistry, Durham University, South Road, Durham DH1 3LE, UK,
E-mail: s.m.r.billah@durham.ac.uk *or* shahmrbillah@gmail.com

Determining the Environmental Impact of Dyes and Pigments in Construction Products

Andrew DUTFIELD
Centre for Sustainable Products, Building Research Establishment (BRE),
Watford, WD25 9XX, UK

ABSTRACT

Colour is an important factor in giving a building its atmosphere and character. The dyes and pigments used to colour construction products may be of organic or inorganic origin and may be combined to achieve the desired shade, and then blended with the material or printed onto the material's surface. However, what is the environmental impact of dyes and pigments in the construction of a building? Work done by BRE using Life Cycle Assessment (LCA) to assess the environmental impact of construction products for the compilation of the Green Guide to Specification included the assessment of dyes and pigments. This paper specifically compares the environmental impacts of dyes and pigments within typical building elements to their contribution to total mass and the results show that their impact is disproportionately high. The datasets used for this analysis were compiled from both literature and industrial sources, but some were of variable geographical origins and time periods. It is in dye and pigment producer's interests to provide data that reflects current practice so that informed decisions on the use of dyes and pigments can be made in the construction industry from an environmental perspective.

1. INTRODUCTION

Many types of dye and pigment are used to colour construction products, for instance, EN 12878:2005 classifies pigments for colouring cement. Another example is the aqueous dyeing of carpets where mainly acid dyes are used for dyeing in fibre, yarn or fabric form. Environmental impact can be assessed by the use of LCA which is a method to measure and evaluate the environmental burdens associated with a product system or activity, by describing and assessing the energy and materials used and released to the environment over its life, i.e. from 'cradle to grave'. This means taking into consideration all the impacts from the first time that humanity has an impact on the environment until the last. This includes the extraction of raw materials, production of the material, installation, maintenance, repair, refurbishment, and finally the disposal at end of life.

Using BRE's Environmental Profiles Methodology (2007) this paper compares the environmental impacts of dyes and pigments within typical building elements to their contribution to total mass.

2. USING LIFE CYCLE ASSESSMENT (LCA) TO ASSESS ENVIRONMENTAL IMPACT

LCA data is not available for all pigments such as those classified in EN 12878, or for all types of aqueous dye. If a specific dye or pigment is used in a system which has no reference LCA data then a proxy is generally chosen to represent that material. Table 1 lists the main dyes and pigments for which data exists and which proxies are used to represent those for which there is no data.

Table 1: Classification and availability of LCA data for dyes and pigments

Pigment	**Colour Index (C.I.) Pigment designation**	**Classified in EN 12878**	**LCA data exists**	**Comments**
Iron Oxide	Yellow 42 & 43 Red 101 & 102 Brown 6 & 7	Yes	Yes	Only data for industrial sources, same impact assumed for all pigment colours. Dataset compiled by BRE from industrial data (2005-2009)
Titanium Dioxide	White 6	Yes	Yes	Data for both sulphate and chloride manufacturing processes from generic European industrial data.
Chromium Oxide	Green 17	Yes	Yes	Data for flakes from variable geographical origins and time periods
Carbon Black	Black 6 & 7	Yes	Yes	Data from variable geographical origins and time periods
Ultramarine	Blue 29	Yes	No	Titanium dioxide used as a proxy in LCA
Phthalocyanine	Blue 15 Green 7 & 36	Yes	No	Carbon black used as a proxy in LCA
Dye	**Colour Index (C.I.) Dye designation**			
Anthraquinone	Many dyes listed	No	Yes	Data from variable geographical origins and time periods
Azo compounds	Many dyes listed	No	No	Anthraquinone used as a proxy in LCA

2.1 Method of Assessment of dyes and pigments using LCA

LCA software to assess environmental impact uses specific datasets from databases such as ecoinvent, the Swiss Federal database. Each dye and pigment was measured using these datasets against 13 different impact categories which form the basis of the BRE methodology. This process is called characterisation. The BRE methodology also has further stages of normalisation (to the impact of an EU citizen) and weighting so that the aggregated sum of these categories can provide a single score in ecopoints.

3. RESULTS AND DISCUSSION

The relative impacts on a 'cradle to gate' basis are shown in Figure 1. The impact of chromium oxide is much higher, and this is due to high Human Toxicity, one of the impact categories chosen for the BRE Methodology. However since these datasets are the best available, they have been used to establish the ranges of environmental impact compared to mass for dyes and pigments typically used within building elements.

It should be borne in mind that not all materials within a building element will last the same length of time. For example paint on an internal wall may only last for 5 years but the plasterboard and other components inside the wall may last far longer. Only the exterior visible surfaces within each element are included within this assessment. For example, in a roof specification, iron oxide and carbon black are used in the fibre cement roof tiles and titanium dioxide is used in the internal emulsion paint.

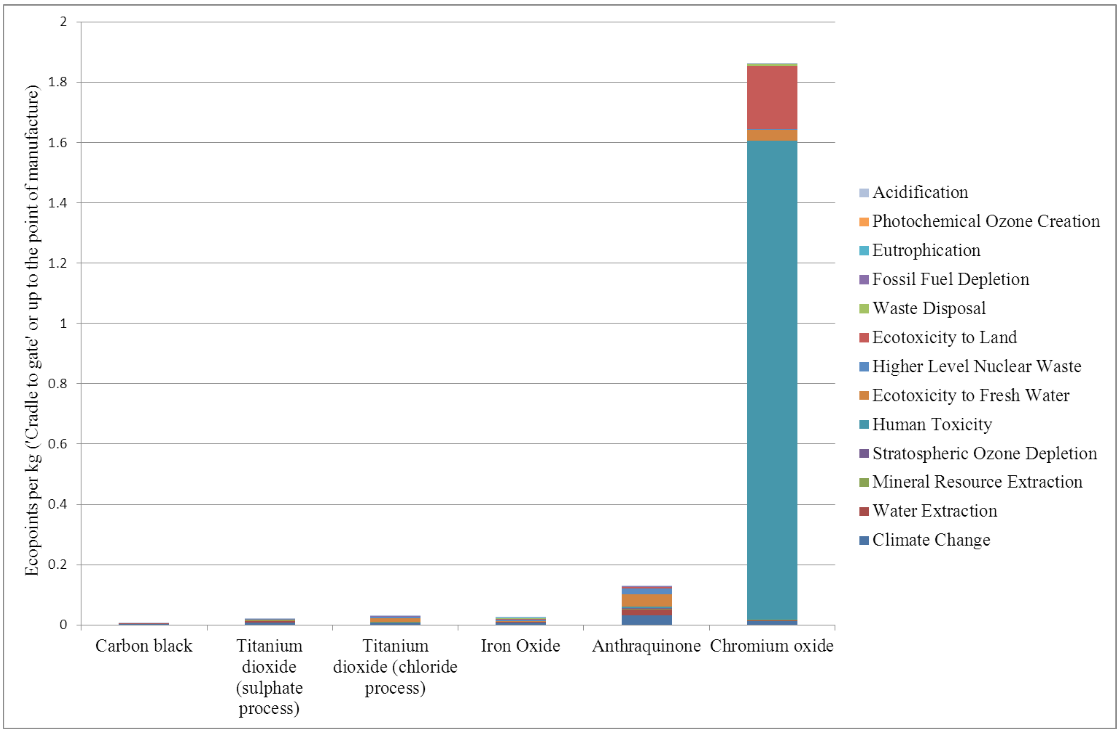


Figure 1: Environmental Impacts of Dyes and Pigments on a 'cradle to gate' basis using the BRE impact categories for assessing environmental impact.

The ratios of environmental impact of dyes and pigments, as shown in Figure 1, to overall mass within a selection of building elements are listed below in Table 4:

Table 4: Comparison of mass of dyes and pigments in building elements with environmental impact.

Building element (coloured material)	**Dyes or pigments typically used**	**Ratio of environmental impact to overall mass**
Roof specification (fibre cement tiles and paint)	Iron oxide, carbon black, titanium dioxide	1 to 2
External walls (paint)	Titanium dioxide	3 to 6
Internal walls (paint)	Titanium dioxide	1 to 2
Timber windows (paint or stain)	Iron oxide, titanium dioxide	6 to 8
PVC windows (white profile)	Titanium dioxide	5 to 6
Wool/nylon carpet (aqueous dyed yarn)	Acid dyes	6 to 10
Vinyl flooring (print layer)	Carbon black, titanium dioxide & other organic/ inorganic pigments	3 to 6

It can be seen from the above results that although the results vary considerably for the different building elements, the environmental impact of dyes and pigments used is always equal to or several times higher than their overall mass within the element.

4. CONCLUSIONS

Since the results of LCA studies can be used to make decisions on the use of raw materials such as dyes and pigments, there is need for reliable underlying data or these studies will be in danger of influencing inappropriate choices. It is in dye and pigment producer's interests to provide data that reflects current practice so that either LCA Practitioners or in-house studies can provide the appropriate results for the users of dyes and pigments - the construction product manufacturers. This will in turn enable the designers of buildings to specify materials using low environmental impact dyes and pigments which will contribute to better ratings in whole building assessment tools such as BREEAM[1], where the Green Guide is used for assessing the impacts of the materials used. The choice of dyes and pigments may also in the future help to fulfil the requirements of the new EU Construction Products Regulation Basic Requirement 7 – Sustainable use of natural resources.

ACKNOWLEDGEMENTS

I would like to thank the SDC for the opportunity in presenting this paper and to BRE for their support.

REFERENCES

British Standards Institute (BSI), 2005. BS EN 12878, *Pigments for the colouring of building materials based on cement and/or lime - Specifications and methods of test*, London: BSI

British Standards Institute (BSI), 2010. BS EN ISO 14025, *Environmental labels and declarations – Type III environmental declarations – Principles and procedures*, London: BSI

Building Research Establishment (BRE), 2007. *Methodology for Environmental Profiles of Construction Products: Product Category Rules for Type III environmental product declaration of construction products*. Also available online at http://www.bre.co.uk/greenguide

Anderson J., K. Steele and D. Shiers, 2008. *The Green Guide to Specification*: 4th Edition, London: Wiley Blackwell

Althaus, H.-J., et al., 2004. *Life Cycle Inventories of Chemicals*. ecoinvent report no. 8, Swiss Centre for LCI, EMPA-DU. Dübendorf: Switzerland

Address: Andrew Dutfield, Centre for Sustainable Products,
BRE, Bucknalls Lane, Watford, WD25 9XX, UK
E-mail: dutfielda@bre.co.uk

1 Building Research Establishment Environmental Assessment Method

Biomedical Imaging using Dyes and Fluorochromes (“stains”): why, how and what has been achieved?

Richard W. HOROBIN
School of Life Sciences, University of Glasgow

ABSTRACT

In the mid-19th century three transitions occurred. Synthetic dyes largely replaced natural products as colourants of textiles. Microscopes became items of commerce, not one-off specialist devices. A new vision arose of medicine as a science, not only a healing art. These transitions, occurring in the same timeframe, transformed our view of the lifeworld, both literally and metaphorically. Cells became visible as colourful, colour-coded, microscopic entities — such images allowing the indentifying of multiple cell types, the specifying of their localisations, and the clarification of changes of cells and tissues in development and disease. Later, the chemical character and content of cells became demonstrable using dyes and microscopes. Still later, many properties of living cells could be assessed — including physical properties such as acidity or viscosity, and biological properties such as transportation within cells, and indeed viability itself. In the 21st century, selective colouration with dyes and fluorochromes continues to advance biomedical knowledge. So imaging of the switching on and off of genes, visualising single molecules within a cell, and detection of infective foci or metastasized tumours within intact creatures are all now possible.

1. THE 19TH CENTURY AND “WHY?”

150 years ago the industrial manufacture of synthetic dyestuffs began, and abruptly the world became more colourful. At much the same time microscopes became available as items of commerce, not merely as one-off specialist instruments, and our view of the lifeworld became, slightly more slowly, more detailed and rich. And in a third transition, medicine became envisaged, at least in part, as a science as well as a healing art – which view was substantially driven by the conception of living creatures as built from cells, of varied types with varied functions, which could be imaged and observed using microscopes. Then for the next century and a half these three factors – dyes as colourants of life, not just shirts and socks; imaging of the tiny, not just the stars; and the biomedical motivation and worldview – have continued to interact. And in so doing have transformed how we see the world of life, both literally and metaphorically.

The concept of life as a cellular phenomenon was a key element to this transformation. And cells are tiny, hence microscopes were indeed needed. But why were dyes important? Because these colourants could transform the translucent ghosts of typical cells into colourful objects, visible, countable and measurable. And more that that – differential colouring of different types of cells, and of different parts of cells, provided colour-coding of biological microstructures. Consequently, such staining could answer questions such as: how many *kinds* of cell are present? how *many* cells are there? *where* in the body do they occur? how do they *change* during development and disease?

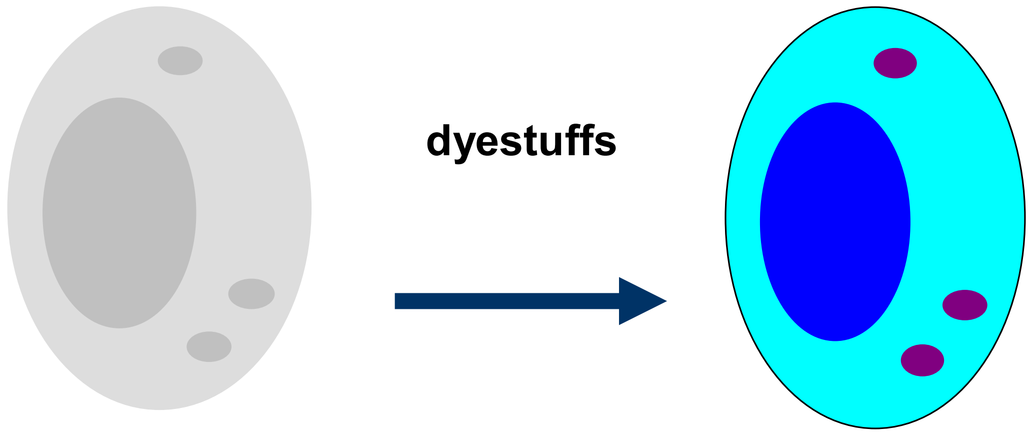


Figure 1: Why cell visualistion required dyes as well as microscopes.

Driven by the medical agenda, early studies focussed on us humans. However investigation of other animals and of plants, and of course of our microparasites, bacteria and fungi, also took place. The story of these early achievements has been told several times, perhaps in most detail by Clark and Kasten (1983).

2. THE 20TH CENTURY: "WHAT?", "HOW?" & BACK TO "WHAT?"

Later too, *chemical and biochemical analyses* using selective staining also became possible. Below are a few examples of what can be imaged in this way.

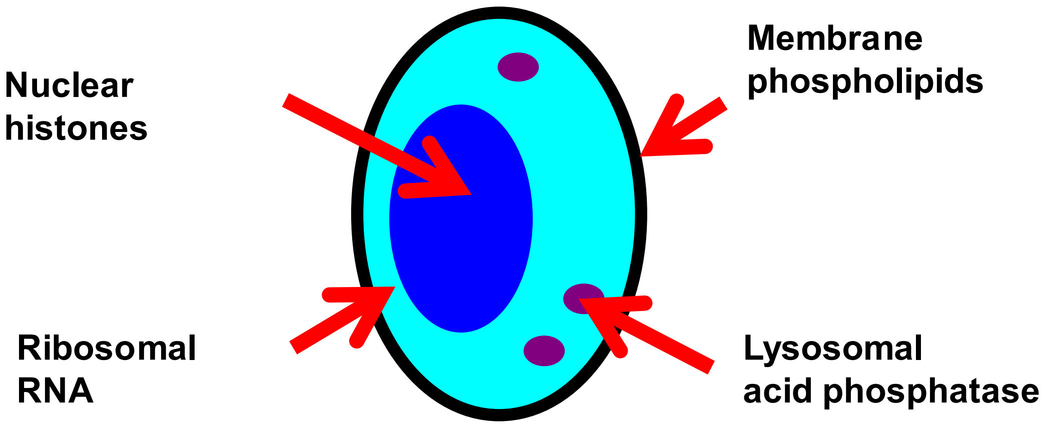


Figure 2: What selective dye uptake can tell us about cell contents – some examples.

There are many more identifiable targets of interest to research biologists wishing to understand living creatures, including us; as well as to clinicians hoping to diagnose and treat human pathologies.

The ability of rather small and simple molecules, such as dyes, to interact selectively with such a range of biological targets may seem surprising. However dyes are numerous, and vary in size, shape, electric charge, water/oil solubility and chemical reactivity. Different biological structures vary in ease of penetration, shape, electric charge, oiliness, chemical reactivity. It is the interaction of these properties, in dyes and cells, which gives rise both to dye binding and to selective colour-coding. For an extended account of how such procedures work mechanistically see Horobin (1982).

At this point an admission must be made. Such colour-coding was originally mostly (not entirely) focussed on once-alive but now-dead specimens. For instance, cells and tissues which had been chemically or physically treated to preserve their chemical content and spatial forms, e.g. by "fixation" or by freezing. Such preservation can be effective, but at the cost of killing the cells. As another technical point, note that in the first part of the 20th century the dyes used were mostly originally devised as colourants of textiles or of related industrial materials.

However, late in the 20th century new fluorescent dyes, having no textile applications, were synthesised in increasing numbers specifically for biomedical use. And once these dyes, together with new types of microscope, were sold commercially, biological and clinical investigators could routinely study still-living cells. Such dyes and fluorochromes are described in several handbooks, for instance that of Horobin and Kiernan (2002).

Some of the information concerning cell and tissue properties obtained in this way parallels that obtained from fixed or frozen materials – namely knowledge of biological structures and of chemical contents. So subcellular entities which can be identified include:

- *Microstructures*: chromosomes; the cytosol; endoplasmic reticulum; Golgi complex; lipid droplets; lysosomes and endosomes; mitochondria; nuclear chromatin; nucleoli; and the plasma membrane.
- *Nanostructures*: genes, receptors, ribosomes, and transporters.
- *Bio/chemical constituents*: a variety of lipids; metal ions, especially calcium; nucleic acids, including DNA and RNA; some polysaccharides; and proteins, whether enzymic, signally or structural.

Dramatically, application of suitable dyes to live cells also allows detection, and sometimes measurement, of physicochemical properties, biological functions and more subtle structural features of living creatures. Below are listed some characteristics which can be assessed via dye staining and suitable optical analysis:

- *Physicochemical properties*: acidity/alkalinity within membrane-bound structures; electrical potentials across cell membranes; viscosity of such membranes, and also of solutions, within cells.
- *Biological functions*: transport of materials along nerve axons; uptake of materials into cells by pinocytosis or phagocytosis; & indeed viability, so we can ask "Is this cell alive or is it dead?"
- *Subtle structural features*: interconnections of structures within cells; connections between the interiors of adjacent cells; connections between the membranes of cells; and dynamic tracing of cells within developing embryos.

3. THE 21ST CENTURY: "AND FOR OUR NEXT TRICK"

So, in the 21st century, are dyes still used to advance biomedical knowledge? Indeed yes, technical innovation continues. So 19th century methods, such as the use of aluminium haematoxylin, are still being tweaked for new situations; and specific dye-biopolymer binding in fixed biopsies are still being explored, for instance to identify heparin using a carefully tailored cationic dye. However the emphasis of current investigation and innovation is firmly on living cells. Some current growth points include:

- Detection of histone acetylation, to further the growing interest in epigenetics.
- Observation of single molecules – albeit large ones – moving within cells.
- Imaging events and materials within complete, intact, multicellular creatures.

The third application area is one which could revolutionise medical diagnosis, so deserves further comment. This approach involves new dyes, absorbing in the near infra red to permit deeper penetration into the tissues. Moreover the approach also involves new imaging technology, namely whole-body infrared fluorescence scanners. In this way foci of bacterial infection, or of Alzheimer-derived amyloid, or of metastasised tumours can be detected within an animal's body. But not yet the human body – so far only within smaller animals, such as mice. However the triumvirate of new dyes plus new optical devices plus the framework of biomedical knowledge and motivation, first arising in the mid-19th century, is still driving on today. So the message is, "You ain't seen nothin' yet".

4. A NOD TO THE BIGGER PICTURE

Dyes and fluorochromes have numerous applications in biology and medicine additional to biomedical imaging. For instance, as reagents in analytical chemistry, clinical diagnostics and flow cytometry, for marking and tracking whole creatures from gulls eggs to lobster larvae, and as photoactivated antibacterial or anticancer drugs. Consequently a considerable infrastructure of regulation and standardisation has grown up – involving such organisations as the Biological Stain Commission, the International Standards Organisation and the Society for Dyers and Colourists.

ACKNOWLEDGEMENTS

RWH thanks Dr. R. Aitken, School of Life Sciences, College of Medical, Veterinary and Life Sciences, University of Glasgow, for providing facilities.

REFERENCES

Clark, G., and F.H. Kasten, 1983. *History of staining*, 3rd ed. Williams and Wilkins.

Horobin, R.W., 1982. *Histochemistry: an explanatory outline*. Fischer.

Horobin, R.W., and J.A. Kiernan, 2002. *Conn's biological stains: a handbook of dyes, stains and fluorchromes for use in biology and medicine*, 10th ed. Bios.

Address: Dr. Richard .W Horobin, School of Life Sciences,
University of Glasgow, Scotland UK,
Email: richard.horobin@gla.ac.uk

colour imaging

Evaluating Complexity in Photographic Images using Perceptual, Eye-tracking, and Segmentation Methods

Susan FARNAND and Mark FAIRCHILD
Munsell Color Science Lab, Rochester Institute of Technology

ABSTRACT

The complexity of pictorial scenes was examined in three ways. An experiment was conducted to perceived complexity by asking observers to identify the important areas of pictorial scenes by circling those areas. The scenes were then segmented electronically using an algorithm developed at RIT. Finally, eye movements of observers examining the images in the context of a perceptual experiment were evaluated. Observers' verbal descriptions of the images were also collected.

The data generated in these experiments indicated that the circling and segmentation results generally correlated extremely well. The top three-quarters of the scenes had an average correlation coefficient of about .9. For half of the scenes evaluated, the fixation data correlated well with both the circling and segmentation results. For the scenes having low correlations, there seemed to be an issue of scale. In these scenes, the gaze data indicated that the full scene had one object of interest. In the close-cropped renditions, in which only this object appeared, the observers did not have a single point of focus.

The results of the experiments in this study indicate that perceptual methods (circling and descriptors), segmentation, and eye-tracking generally provided consistent results with regard to image complexity. The exceptions involved issues of scale such that scenes viewed from afar could blend into one significant object while this one 'object' viewed up close could result in the lack of a point of focus for attracting gaze.

1. INTRODUCTION

Pictorial scenes produce a more complex visual experience than color patches. In an experimental setting, scenes present a greater opportunity than do uniform patches for observers' individual differences to significantly impact the process. Judd et al. (2011), in a study comparing fixation patterns of images at a wide range of resolutions, found that inter-observer fixation consistency depended on the complexity of the target image with simple images being more consistent. This work also indicated that object recognition influenced fixation patterns. This finding is supported by a study involving image content and fixations by Einhäuser et al. (2008) that found that objects contained within images better predict what catches observers' attention than early saliency.

A study was conducted to evaluate the impact of image complexity on visual attention in perceptual experiments. To select appropriate scenes, the concept of what constitutes a complex image was first considered. The perception of complexity was investigated by having observers identify the important areas of pictorial scenes. The complexity of these scenes was also evaluated using electronic segmentation. A subset of the scenes was selected for the experiment examining eye movements as a function of image complexity. The results of the three analyses are compared.

2. METHODOLOGY

Image complexity was evaluated in three ways: perceptually, using image segmentation, and by analyzing observer eye movements. Perceived image complexity was evaluated by asking observers to circle the important areas of pictorial scenes. This experiment included 60 scenes, each having full (at least 5 important areas), mid-cropped (3-4 important areas), and close-cropped (1-2 important areas) renditions, Figure 1. Each observer saw one rendition of each scene. The majority of the scenes were selected from the Corel® database at RIT. Four categories of scenes were included in the experiments: ‘People’, ‘Manmade items’, ‘Outdoor Scenes’, and ‘Still Life’. The experimental setup is shown in Figure 2.

Figure 1: Examples of scenes used in the circling experiment. The full scene is on the left, followed by the mid-cropped image, and the two closely-cropped images. These scenes were obtained from the Corel® database at RIT.

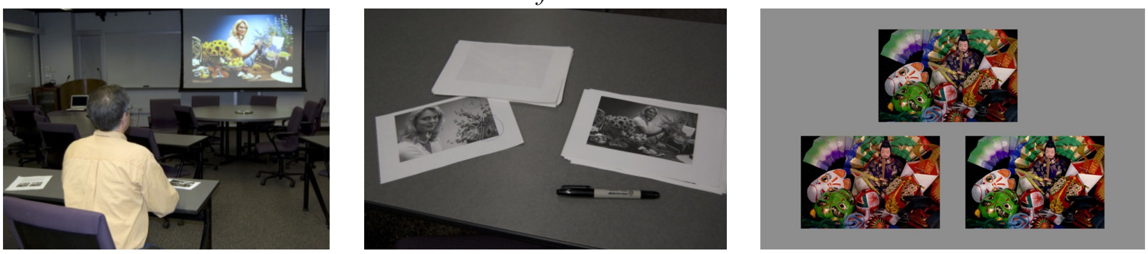


Figure 2: The setup for circling experiment (left and center). ‘Paint Girl’ image provided by Lexmark®. Image triplet used in eye-tracking experiment (right).

The scenes were also segmented electronically using an algorithm developed at the Rochester Institute of Technology (Garcia et al., 2009). Using the segmentation results, the number of segments covering 1% or more of the image area was counted.

The third analysis examined the impact of image complexity on eye movements. The experiment followed a forced-choice paired comparison protocol in which the observers were asked to identify which of two images more closely resembled an ‘original’, Figure 2. While the observers were completing this exercise, their eye movements were monitored using the SMI remote eye-tracking hardware and software. The images were divided into areas of interest, or AOIs. The software reported the fixation counts and time for each AOI. Along with evaluating eye movements, observers were asked to describe the test scenes using up to five keywords, an approach similar to that of Einhäuser et al. (2008).

A total of 32 observers participated in the ‘circling’ experiment and 27 in the eye-tracking experiment. The observers were naïve to the objectives of the experiments and generally did not have experience with image evaluation. All observers provided informed consent.

3. RESULTS AND DISCUSSION

The perceived complexity, segmentation and fixation consistency results were compared. This comparison indicated that the visual and segmentation results generally correlated quite well; with a mean correlation coefficient of .69. Further, it was found that the correlation coefficient was greater than .6 for 75% of the scenes (45 of 60). The mean correlation coefficient for these scenes was .86. This varied by scene category. For the 'People' scenes, the mean correlation was .84 and none of them were in the bottom 25%. In contrast, the 'Manmade' and 'Scenic' categories had mean correlations of .66 and .51, respectively, and each with about one-third of the scenes in the bottom 25%.

One of the scenes with the lowest correlations is 'Sunset', Figure 3. For this scene, the observers felt that the full scene had the most important areas of the three renditions. However, the segmentation results indicated that the full scene had half segments of the mid-cropped rendition. This could be the result of the segmentation routine failing to separate scene elements that were close in appearance; something that observers were readily able to do.

Figure 3: The segmented versions (top) of the 'Sunset' scene (bottom) with the full scene on the left, the mid-cropped rendition in the center, and the close-cropped rendition at right.

The fixation results were compared to the circling and segmentation results. The data were analyzed by comparing by crop – full-to-full, mid-to-mid, and close-to-close for each scene. The fixation results correlate well with the segmentation and circling results for about half of the scenes, with an average correlation coefficient of about -.9 for both cases. They correlate well with one or the other (segmentation or circling) for a few other scenes. For the 'Sunset' scene, observers looked consistently in fewer areas in the Full scene than the Mid-cropped image, as predicted by the segmentation algorithm. The participants in the circling experiment identified more areas on average for the Full scene than the Mid-cropped image. A summary of the data for the 'Sunset' scene is shown in Table I.

About one-quarter of the scenes that were evaluated had poor correlations. These scenes had closely-cropped images with no distinct point of focus. And some of these had Full scenes that included faces. The participants in the circling experiment identified about as many areas in these images as they did for the mid-cropped renditions, while the segmentation results suggest that the full scenes were more complex than the mid-cropped ones. The results suggest that it was not specifically the crop that was the key factor; it was the presence of a point of focus.

Table I: The circling, segmentation, and fixation results for the 'Sunset' scene. The fixation results are the percentages of the top fixated areas represented by the Main AOI. A higher percentage indicates higher consistency.

Results-Sunset	Full	Mid	Close
Circling	4.3	3.6	3.6
Segmentation	4	8	3
Fixation	41%	28%	41%
Descriptors	4	4	3

4. CONCLUSION

The results of the experiments in this study indicate that perceptual methods (circling and descriptors), segmentation, and eye-tracking generally provided consistent results with regard to image complexity. The exceptions involved issues of scale such that scenes viewed from afar could blend into one significant object while this one 'object' viewed up close could result in the lack of a focal point for attracting gaze. To select scenes for perceptual experiments that will elicit relatively consistent fixation patterns, having a single point-of-focus is a more important consideration than level of crop.

ACKNOWLEDGEMENTS

The authors are deeply grateful to Dr. Jeff Pelz for his generosity in providing both access to the eye-tracking equipment and extremely helpful advice and to the many observers who participated in these studies.

REFERENCES

Einhäuser, W., M. Spain, and P. Perona, 2008. Objects predict fixations better than early saliency. *Journal of Vision*, 8(14), 18, 1-26.

Farnand, S.P., and M.D. Fairchild, 2012. The effect of experimental instructions on the number of areas identified as important in photographic images, *Proc. of IS&T's Color, Graphics, Imaging, and Vision conference*, Amsterdam, The Netherlands.

Farnand, S.P., 2013. *Designing pictorial stimuli for perceptual image difference experiments*, Color Science Dissertation, Rochester Institute of Technology.

Garcia, L.E., E. Saber, S.R. Vantaram, V. Amuso, M. Shaw, and R. Bhaskar, 2009. Automatic Image Segmentation by Dynamic Region Growth and Multiresolution Merging, *IEEE Transactions on Image Processing*, 18(10), 2275-2288.

Judd, T., F. Durand, and A. Torralba, 2011. Fixations on low-resolution images. *Journal of Vision*, 11(4), 1-20.

Address: Susan Farnand, Center for Imaging Science, College of Science,
Rochester Institute of Technology, 54 Lomb Memorial Drive
Rochester, NY 14623-5604, USA
E-mail: farnand@cis.rit.edu

An Automatic Gamma Adjustment Operator

Jakkarin SINGNOO,[1] Graham D. FINLAYSON[2]
[1] School of Science and Technology, University of the Thai Chamber of Commerce
[2] School of Computing Science, University of East Anglia

ABSTRACT

Gamma adjustment probably is one of the simplest tone reproduction operators since the operator only requires one 'gamma' parameter. By applying a gamma to an image, the output image can be made brighter or darker. To achieve optimum results without the need of the manual parameter tuning, in the previous study, the user's choice of gamma parameter has been investigated by conducting a double staircase psychophysical experiment. The goal was to investigate the relationship between the theoretic derived gamma that maximizes the entropy of image and the preferred gamma obtained from the experiment. The result indicated that there was a linear relationship between the two gammas. In this work, this relationship has been revised. The revised version was found to be a logistic function, which more reflected the experimental data. In fact, the combination of entropy calculation together with the revised function we effectively provide an automatic algorithm for gamma adjustment operator. Finally, to validate the image quality of the proposed operator, a paired-comparison psychophysical experiment has been conducted on a large image dataset. The result indicates that the gamma adjusted images are preferred over their original counterpart suggesting that gamma adjustment is proportional to the gamma that maximizes entropy. Put another way our work indicates that the observer is behaving in as an 'optimal information processor'.

1. INTRODUCTION

In the context of tone reproduction operator, gamma adjustment provides contrast adjustment. The simplest form of the operator is defined as:

$$V_{out} = V_{in}^{\gamma} \tag{1}$$

where V_{in} and V_{out} are the input and output intensities, respectively, and are typically in the range of [0, 1]. If the gamma is larger than 1, the output image will be brightened. In contrast, if gamma is smaller than 1, the output will be darkened. Typically, gamma parameter is mannually assigned by a user such found in the Gamma adjustment slider within the Exposure dialog in Photoshop, or automatically assinged using some sort of fomular, which is the focus of this work.

Recently, Finlayson and Xu (2012) proposed a formula to optimally derive the gamma in the information theoretic sense using an entropy of image and called it "Optimal gamma". The optimal gamma is calculated as:

$$\gamma_{optimal} = -1/mean(\log 2(V_{in}) \tag{2}$$

Applying the optimal gamma to an image will maximize the image entropy (make details theoreically most visible). This is resemble to the histogram equalization (HE) although the the amount the image changes will be less since HE can apply a wiggly 'high frequency' curve (compared to the power-law curve of the gamma) to the image.

In our previous study (2010), a double staircase psychophysical experiment (1962) has been conducted on a set of luminance images to investigate the user's preferred gamma. Two staircases beginning with bright and dark images with respect to which gamma adjustment are made. The user progressively darkens and lightens the respective images until the staircases converge (the image of the two staircases are the same image).

Interestingly, when plotting the optimal gamma against the actual gamma chosen by the observer ($\gamma_{preferred}$), there is a pattern of relationship between the two gammas (see Figure 1), indicating that the combination of entropy calculation together with a regression that approximates this pattern could effectively provides an autoamatic way to define the gamma. In that literature, the regression was forced to be a linear function and is defined as:

$$\gamma_{preferred} = 0.62\gamma_{optimal} + 0.38 \tag{3}$$

In this work, the linear function has been revised. In addition, to evaluate the image preference of the revised function, a paired comparison psychophysical experiment was conducted on a large image dataset.

2. THE OPERATOR

When we thought about using the regression function as an automatic gamma adjustment, we visually considered the possibility that a linear regression might not the best way to fit the scatter plot of the data (see Figure 1) since it is rather visually observed as an s-shaped pattern. Thus, in this work, we propose an s-shaped curve as the revised formula for determing the gamma. The revised formula is in the form of logistic function and is defined as:

$$\gamma_{preferred} = \frac{4.38 - \ln(2.31\gamma_{optimal} - 1)}{4.14} \tag{4}$$

Figure 1 illustrates the proposed logistic regression (red solid line) along with its linear counterpart (blue dash line) previously presented (Equation 3).

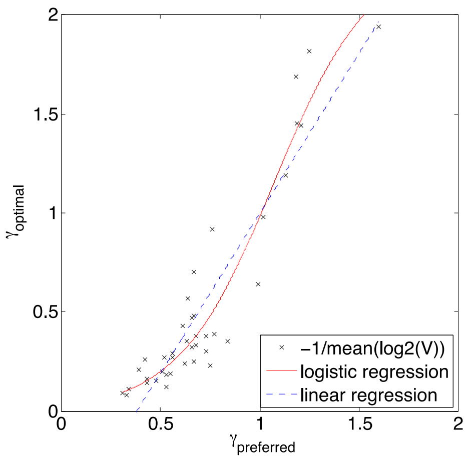


Figure 1: Relationship between the experimental gamma ($\gamma_{preferred}$) plotted against the theoretical optimal gamma ($\gamma_{optimal}$).

The correlation coefficient R^2 of the regression is now improved from 0.85 to 0.92 indicating the more fit of the logistics compared to the linear function.

3. THE EXPERIMENT

To evaluate the image preference of the proposed operator, a paired comparison experiment is conducted. The goal is to investigate whether the proposed operator could be utilized as a tone reproduction operator. There are two stimuli in the experiment: input image and its gamma-adjusted (apply Equation 4 to the input) counterpart. The observer's task is to choose the image that is more visually pleasing. Our hope is that the adjusted images are preferred over the input counterparts. The image dataset used in the experiment are acquired both from our images and the internet. The images were chosen to have different average intensities ranges from very dark to very bright. There are 200 images in total. Most of them are categorized as incorrect exposure images i.e. either brighter or darker than they should be (see Figure 2, top row). These images were evaluated by 24 observers (twelve males and twelve females) with normal color vision, naïve to the goal of the experiment under the control experimental environment. The whole experiment took approximately 15 minutes per observer.

Figure 2: Some images in the dataset along with their gamma-adjusted counterparts. (Top) Incorrect exposure images. (Bottom) Gamma adjusted counterparts obtained from the proposed operator. The proposed operator delivers more pleasing images with correct exposure compared to the input counterparts.

3. RESULTS AND DISCUSSIONS

The percentages of observers choice are transformed into preference scores using Thurstones Law of Comparative Judment Case V (1927). Figure 3 shows average preference scores for all images. The error bar represents the 95% confidence interval for 24 observers wihch has the value of 0.28. To interpret the data the higher the preference score the operator has the more often it was preferred by the observers. From the figure, it is clear that, on average, the proposed operator is broadly preferred over the inputs for the tested images (the score difference far exceeds the error bar).

4. CONCLUSIONS

A common way to adjust tone reproduction of an image is to carry out gamma adjustment. Recent work provided the evidence that there is a relationship between theoretically inspired optimal gamma and the gamma adjustment made by human observers. In this paper, the logistic relationship is proposed and utilized as a tone reproduction operator resulting in preferred outputs over a wide range of images implying that the proposed operator is suitable for utilizing as an automatic gamma adjustment operator.

Some possible applications of the operator are to used it as a guideline in the interactive gamma adjustment, or to use it as an automated operation (similar to Autolevel feature in Photoshop).

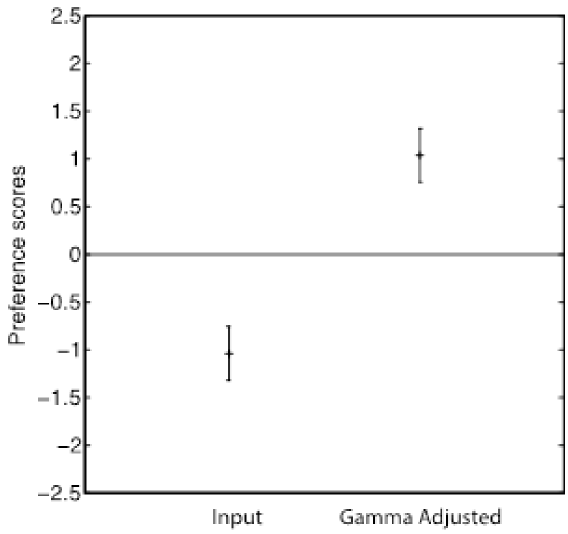


Figure 3: The experimental result.

ACKNOWLEDGEMENTS

We would like to thank Al-ameen Sawa-ae for the useful comments on the regression analysis.

REFERENCES

Cornsweet, T.N., 1962. The staircase-method in psychophysics, *American Journal of Psychology*, vol. 75, 485-491.

Finlayson, G.D., and R. Xu, 2012, *Gamma Adjustment for Maximizing Information in Images*, US Patent 2012/0114236 A1.

Singnoo, J., and G.D. Finlayson, 2010. Understanding Gamma Adjustment of Images, In P*roceedings of IS&T Eighteenth Color Imaging Conference*, 134-139, San Antonio.

Thurstone, L.L., 1927, A law of comparative judgment*. Psychological Review*, 34(4), 273-286, ISSN 0033-295X.

Address: Jakkarin Singnoo, School of Science and Technology,
University of the Thai Chamber of Commerce, 126/1 Vibhavadi Rangsit Road.,
Dindaeng, Bangkok, 10400, Thailand
E-mails: jakkarin_sin@utcc.ac.th, singnoo@gmail.com

Segmentation of Multispectral Textile Images Based on Fuzzy C Means and Kernel-based Clustering Analysis

Si-Jie SHAO,[1] John H. XIN,[1] and Hui-Liang SHEN[2]
[1] Institute of Textiles & Clothing, the Hong Kong Polytechnic University
[2] Department of Information and Electronic Engineering, Zhejiang University

ABSTRACT

In this paper, we present a kernel-based fuzzy C-means clustering (KFCM) methodology for the multispectral textile image segmentation. By introducing kernel function into FCM algorithms, the proposed KFCM algorithms provide a new effective and flexible method to fuse different pixel information in the textile image segmentation. In addition, a spectral extension method is proposed to incorporate the geometric features of spectra into similarity measures. It is shown that the algorithm can more accurately segment spectral colour regions of multispectral textile images when compared with traditional fuzzy C-means clustering algorithms.

1. INTRODUCTION

Multispectral imaging technology combined with images analysis and spectroscopy technology as a whole is widely used for various colour-related industries. Image segmentation of multi-colour textile samples is the first step towards the colour specification and colour quality control. The surveys of image segmentation can be found in references (Fu, 1981). In general, fuzzy c-means (FCM) algorithm (Bezdek, 1981) is a popular method used in gray and colour image segmentation. Although the conventional FCM algorithm works well on most noise-free images, it is sensitive to noise and imaging artefacts. The kernel FCM (KFCM) algorithm (Chen, 2004) is an extension of FCM, which maps the original inputs into a much higher dimensional Hilbert space by transformed function and make the complex pattern classification problems more easily to be separated or clustered. Till now, few attempts have been tried on the multispectral textiles image segmentation. In this study, we propose a new algorithm for multispectral textile images segmentation based on a combined fuzzy c-means and kernel-based (KFCM) clustering analysis.

2. METHOD

2.1 Pre-processing of Multispectral Textile Image

The spectral colour image of textile fabrics is captured by a multispectral imaging system consisting of monochrome digital camera and sixteen narrowband filters. The spectral reflectance in the image is recovered by Wiener method (Shen, 2007) from the camera response values. The non-local mean filtering method (Tomasi, 1998) is used to remove noises arising during spectral colour image acquisition while preserving edges and good texture structure in each spectral channel image. On the other hand, the centering and normalization of colour spectral are aimed to reduce the influence of shadows and highlights on image segmentation.

2.2 Spectral Reflectance Conversion

The pre-processed spectral colour images are converted into the spectral-light dependent colour signal data under illuminant F11 condition since that spectral reflectance can be reduced to a small range with the exception of some wavelength and lower data variability to speed the clustering computation.

2.3 Spectral Extension

In this work, a spectral colour image with two-dimensional spatial grid (*s*,*l*) of pixels and ρ channels can be viewed as a set of spectral vector θ composed of $\eta = sl$ data with channels. The geometric features of colour spectra such as the slop and curvature are additionally offering significant cues for spectral image clustering. The slope φ and curvature ψ of the spectral curve can be computed by the finite difference method. The fused data space of combining magnitude, slope, and curvature of spectra with a concatenate method after weighting is denoted by $X = \{x_i\}_{i=1}^{\eta}$.

2.4 Combined Fuzzy C-means and Kernel-based clustering image segmentation

The kernel FCM (KFCM) algorithm is an extension of FCM. Define a nonlinear map as

$\Phi : x_k \rightarrow \Phi(x_k) \in F$,

where $x \in X$ denotes the input data space and **F** is the transformed feature space with higher dimensions. KFCM minimized the following objective function:

$$J_m(U,V) = \sum_{i=1}^{c}\sum_{k=1}^{\eta} u_{ik}^{m} \|\Phi(x_k) - \Phi(v_i)\|^2 \tag{1}$$

where c is the number of specified cluster, u_k the membership of x_k in class *i*, satisfying $\sum_{i=1}^{c} u_{ik} = 1$, m the quantity controlling clustering fuzziness and v is set of control cluster centers.

where $\|\Phi(x_k) - \Phi(v_i)\|^2 = K(x_k, x_k) + K(v_i, v_i) - 2K(x_k, v_i)$ (2)

where $K(x,y) = \Phi(x)^T\Phi(y)$ is an inner product of the kernel function. If the Gaussian function as a kernel function, $K(x,y) = \Phi(x)^T\Phi(y)$, then K(x,x) = 1. According to Eq. 2, Eq.1 can be rewritten as

$$J_m(U,V) = 2\sum_{i=1}^{c}\sum_{k=1}^{\eta} u_{ik}^{m} (1 - K(x_k, v_i)) \tag{3}$$

Minimizing Eq. 3 under the constrain of u_{ik}, m > 1 we have

$$u_{ik} = \frac{(1 - K(x_k, v_i))^{-1/(m-1)}}{\sum_{j=1}^{c}(1 - K(x_k, v_i))^{-1/(m-1)}} \text{, and } v_i = \frac{\sum_{k=1}^{\eta} u_{ik}^{m}(1 - K(x_k, v_i))x_k}{\sum_{k=1}^{\eta} u_{ik}^{m} K(x_k, v_i)} \tag{4}$$

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

After filtering and pre-processing of multispectral textile images, the relative spectral power distributions of CIE standard illuminant D65, A and F11 were selected to test the effects of spectral conversion in this study. Figure 1 shows an example about reflectance conversion of the spectral images of a printing fabric. After spectral reflectance conversion, it reveal that illuminant F11 will result in a dark image since it decreases spectral values closer to zero except at few wavelengths. This spectral conversion can be also viewed as down-sampling spectral image in the spectral space to increase the speed of the following clustering.

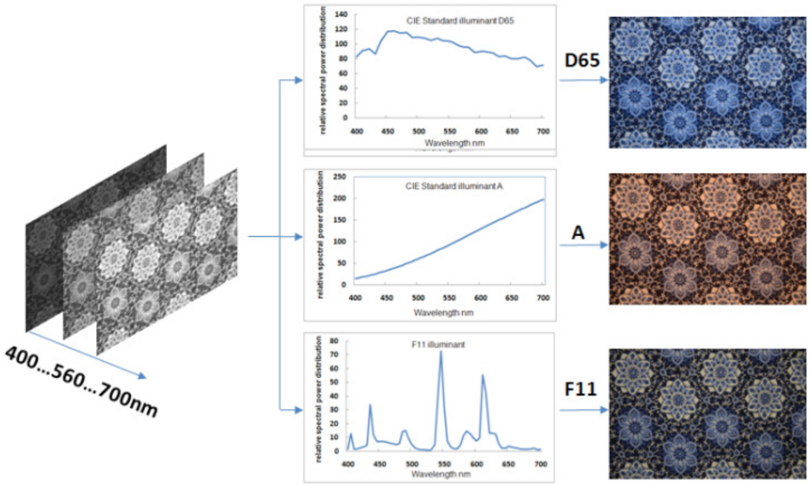


Figure1. Spectral reflectance conversion of printing fabric image.

Figure 2 shows the results of FCM and KFCM segmentation methods. Our approach displayed in the right column in Figure 2 performs better in terms of accuracy, when compared with a traditional FCM segmentation method showed in the middle column in Figure 2. More specifically, FCM can produce noisy results since some isolated pixels in the image of printing fabric and small interleaved segments of yarn-dyed fabric image are misclassified. Our method deals with the above aspect more effectively by incorporated kernel method and spectral geometric features.

4. CONCLUSIONS

In this paper, an improved KFCM is introduced to the image segmentation of multispectral textile image. The Non-local mean filtering and pre-processing method are applied to remove noise and reduce the effect of shade and highlight contained in images during the image acquisition.

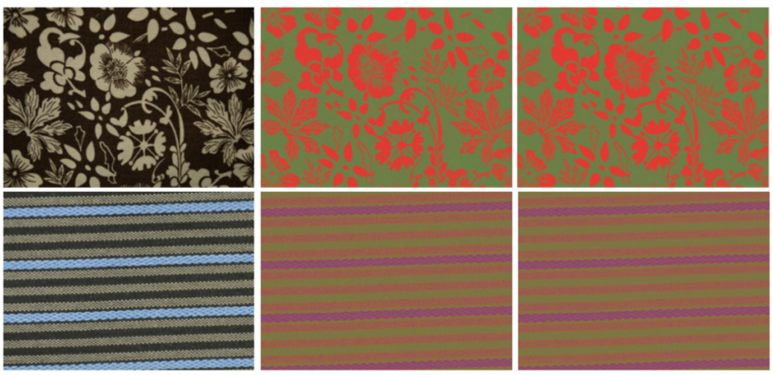


Figure 2: The results of segmentation by FCM and KFCM.

To facilitate the clustering, spectra reflectance conversion under illuminant F11 is implemented to speed the clustering computation. In addition, two spectral geometric features such as slope and curvature are incorporated in the KFCM method. The experimental results have shown that the proposed KFCM method obtains a satisfactory segmentation results and is feasible and promising in the application of multispectral textile image segmentation.

ACKNOWLEDGEMENTS

This work was supported by the HKRITA project ITP/001/10TP of the Innovation and Technology Commission of the Hong Kong SAR Government.

REFERENCES

Fu, S.K., and J.K Mui, 1981. A Survey on Image Segmentation, *Pattern Recognition*, 13, 3-16.

Bezdek, J.C., 1981. *Pattern Recognition with Fuzzy Objective Function Algorithms*, New York: Plenum Press.

Chen, S., and D. Zhang, 2004. Robust Image Segmentation Using FCM With Spatial Constraints Based on new Kernel-Induced Distance Measure, *IEEE Transactions on Cybernetics, Systems, Man, and Cybernetics*, Part B, 34(4), 1907-1916.

Shen, H.L., J. H. Xin, and S.J. Shao, 2007. Improved reflectance reconstruction for multispectral imaging by combining different techniques, *Opt. Express* 15, 5531-5536.

Tomasi, C., and R. Manduchi, 1998. Bilateral filtering for gray and color Images, in *Proceedings of IEEE International Conference on Computer Vision*, 839-846.

Address: Dr. Si-jie Shao, Prof. John H Xin, the Institute of Textiles and Clothing, the Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
Emails: tcsjshao@polyu.edu.hk, tcxinjh@polyu.edu.hk, shenhl@zju.edu.cn

The Dichromatic Object Colour Solid

Alexander LOGVINENKO[1], Pouya BASTANI[2], and Brian FUNT[2]
[1] Department of Life Sciences, Glasgow Caledonian University
[2] School of Computing Science, Simon Fraser University

ABSTRACT

The set of all possible cone excitation triplets from reflecting surfaces under a given illuminant forms a volume in cone excitation space known as the *object-colour solid* (OCS). An important task in Color Science is to specify the precise geometry of the OCS as defined by its boundary. Schrödinger claimed that the *optimal* reflectances that map to the boundary of the OCS take on values of 0 or 1 only, with no more than two wavelength transitions. Although this popularly accepted assertion is, by and large, correct and holds under some restricted conditions (e.g., it holds for the CIE colour matching functions), as far as the number of transitions is concerned, it has been shown not to hold in general. As a result, the Schrödinger optimal reflectances provide only an approximation to the true OCS. For the case of dichromatic vision, we compare the true and approximate OCS by computing the set of true optimal reflectances, and find that they differ significantly.

1. INTRODUCTION

Light reaching the eye from a reflecting surface generates a triplet of cone responses. Formally, the *color signal* triplet (ϕ_1(x),ϕ_2(x),ϕ_3(x)) can be written as the integral over the visible spectrum:

$$\phi_i(x) = \int_{\lambda_{\min}}^{\lambda_{\max}} x(\lambda) I(\lambda) s_i(\lambda)\, d\lambda,$$

where $x(\lambda)$ is the spectral reflectance of the surface, $I(\lambda)$ is the spectral power distribution of the illuminant, and $s_i(\lambda)$ is the spectral sensitivity of the i^{th} sensor. The set of all such color signals, represented as points in 3D space with Cartesian coordinates (ϕ_1,ϕ_2,ϕ_3), forms a volume referred to as the *object-colour solid* (Wyszecki and Stiles 2000). This volume can be precisely described by its boundary, formed by the so-called *optimal reflectances*, reflectance functions whose corresponding colour signals map to the boundary of the OCS. Thus, determining the set of reflectances that are *optimal* under a given illuminant is a crucial step in defining the geometry of the OCS.

The first part of Schrödinger's assumption (1920) about optimal reflectances is correct; namely, that they are *elementary step functions* taking on values of 0 or 1 only. However, the restriction that they contain only 2 or fewer transitions holds only under restricted conditions. Nonetheless, it has been a commonly held view (Koenderink 2010, MacAdam 1935, Wyszecki and Stiles 2000) that optimal reflectances in general have no more than 2 wavelength transitions. This 2-transition assumption has been shown to be incorrect (Logvinenko and Levin 2013, Maximov 1984, West and Brill 1983) and any colour solid based on it is only an approximation.

As shown by Logvinenko and Levin (2013) for continuous linearly independent spectral sensitivity functions, $s_1(\lambda)$,...,$s_n(\lambda)$ the transition wavelengths λ_1,...,λ_m of an optimal reflectance function are determined by the zero-crossings of the following equation, where k_1,...,k_n

are arbitrary real numbers, at least one of which is not zero:

$$g(\lambda) = k_1 s_1(\lambda) + \cdots + k_n s_n(\lambda) = 0 \qquad (1)$$

While the analogue of Schrodinger's assumption in the case of dichromatic vision would state that the optimal reflectances have at most 1 transition (the *1-transition assumption)*, our results reveal that for tritanopic vision the number of transitions can be up to 3. By computing transition wavelengths of optimal reflectance functions using equation (1) the precise loci of optimal stimuli, and hence the boundary of the OCS, can be determined. In this paper, we compare the difference between the true dichromatic OCS and its 1-transition approximation and find it to be significant.

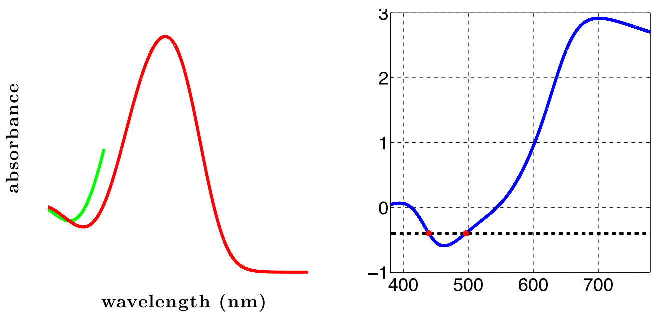


Figure 1: Left: normalized spectral sensitivity of M- and L-cone photopigments with peak sensitivities at 530 and 560 nm, respectively. Right: log(L/M) cone response ratio. The dashed line is one example of a horizontal line that intersects the curve more than once.

2. DICHROMATIC OBJECT-COLOUR SOLID

In this section, we consider the case of tritanopic vision, where S-cones are not present. To study the 2-dimensional OCS for this dichromatic visual system we first note that the cone sensitivity functions $s_i(\lambda)$ can be factored as $s_i(\lambda) = t(\lambda)p_i(\lambda)$, where $t(\lambda)$ is the transmittance spectrum of the ocular media and is the spectral absorption of the i[th] photopigment. Since $t(\lambda) > 0$ over the visible spectrum, the zero crossings of Equation (1) are the same as those of the following equation:

$$k_1 p(\lambda;\, \lambda_1^{\max}) + \cdots + k_n p(\lambda;\, \lambda_n^{\max}) = 0, \qquad (2)$$

where $p(\lambda;\, \lambda_i^{\max})$ is the i^{th} cone-photopigment absorbance spectrum with peak absorbance at $\lambda_i^{\max}$. The following results are based on Govardovskii et al. (2000) model of absorbance spectra for cone photopigments. In accordance with electrophysiological studies of the cones in the human retina (Schnapf and Schneewels 1999), we set the model parameter for photopigment optical density to 0.3, and use peak absorbance wavelengths of 530 nm and 560 nm for the M- and L-cones (cones with peak sensitivity in the middle, and long wavelength range of the visible spectrum), respectively. Figure 1 (left) shows the spectral sensitivities of the M- and L-cone photopigments obtained using the Govardovskii model with the above parameter values. Throughout this paper we will use λ_{min} = 380 nm and λ_{max} = 780 nm.

For such a dichromatic visual system, Equation (2) with n = 2 can be re-written as $p(\lambda;\, \lambda_L^{\max})/p(\lambda;\, \lambda_M^{\max}) = k,$ where is an arbitrary real number. Figure 1 (right) shows a semi-logarithmic plot of the ratio of L-cone to M-cone responses. As is clear from the picture, there are values of for which a horizontal line intersects the curve at more than 1 location, indicating that the above equation has more than one zero-crossing in the visible spectrum for certain values of , thus violating the 1-transition assumption. The dashed line, for instance, intersects the curve at λ_1 = 439 nm and at λ_2 = 496 nm, resulting in a pair of complementary optimal reflectance functions $x(\lambda)$ and $x'(\lambda) = \lambda - x(\lambda)$. Reflectance $x(\lambda)$ is zero everywhere except for $x \in [439, 496]$, where it is one. In fact, each k in Equation (1) determines zero-crossings, which in turn determine a pair of complementary optimal reflectance functions that map to points on the boundary of the object-colour solid that are symmetrically situated about its center. Figure 2 (left) shows the boundary of the true OCS and its 1-transition approximation obtained under the flat-spectrum illuminant, $I(\lambda)$. Note that the latter, shown dashed, lacks the convex geometry that the OCS is known to possess (Logvinenko and Levin, 2013).

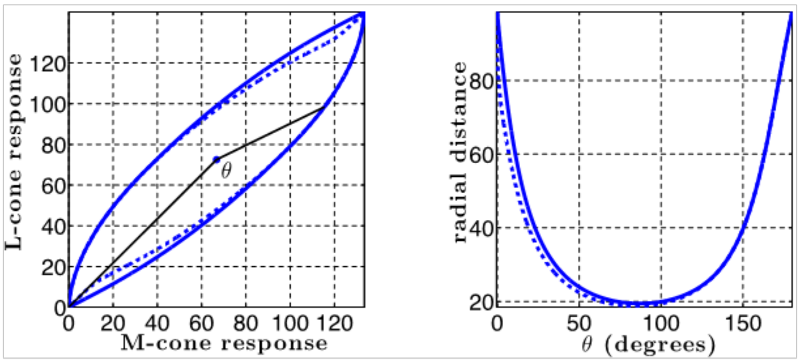


Figure 2: Left: boundary of the true tritanopic OCS (solid curve) and its 1-transition approximation (dashed curve). Right: radial distance from the center to the boundary of the dichromatic OCS (solid curve) versus its 1-transition approximation (dashed curve).

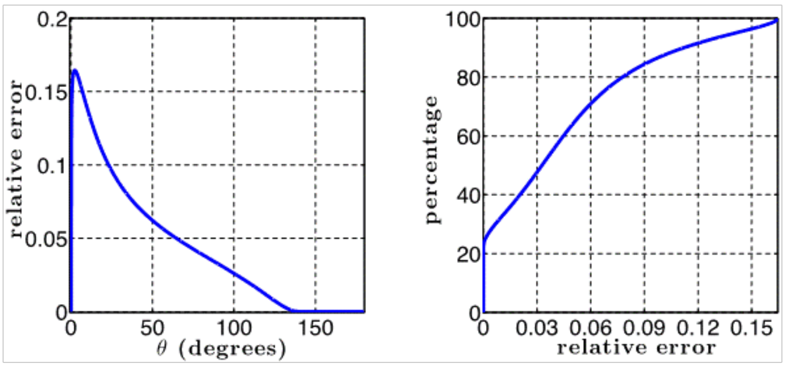


Figure 3: Left: relative error, as a function of polar angle, in the 1-transition approximation of the tritanopic OCS as measured by the ratio of radial distances to the boundary. Right: cumulative distribution plot of the relative error.

This boundary can be described by the radial distance from the center as a function of the polar angle measured counter-clockwise with for the direction to the origin (see Figure 2 left). Figure 2 (right) shows the plot of the radial distance to the boundary of the tritanope's OCS and its 1-transition approximation (since the OCS is symmetric about its center, only is considered). The plot of the relative error in the radial distance of the approximate and true OCSs (Figure 3, left) indicates that the difference can be as high as 16%, though it decreases rapidly with Figure 3 (right), showing a cumulative distribution plot of the relative difference, gives a good idea of the significance of the error in computing optimal stimuli based on the 1-transition approximation. As can be seen, only 23% of optimal reflectance functions are correctly predicted (i.e., have a relative error of zero) using the 1-transition assumption, and 13% of the radial distances are underestimated by 10% or more.

CONCLUSION

The true dichromatic OCS was computed and compared to its approximation based on the assumption that the optimal reflectances are 1-transition functions taking values of 0 and 1 only. It was found that the optimal reflectances for the dichromatic OCS include not only 1-transition reflectances, but 2- and 3-transition reflectances as well. A quantitative comparison between the true and approximated tritanopic OCS was performed using the radial distances to the boundary of the OCS. The approximation error due to the 1-transition assumption was shown to be as large as 16%, with over 77% of optimal stimuli computed inaccurately.

REFERENCES

Govardovskii, V. I., N. Fyhrquist, T. Reuter, D.G. Kuzmin and K. Donner, 2000. In search of the visual pigment template. *Visual Neuroscience*: 17, 509-528.

Koenderink, J.J., 2010. *Color for the sciences*. Cambridge, Massachusetts; London, England: The MIT Press.

Logvinenko, A.D., 2009. An object-colour space. *Journal of Vision*, 9 (11), 1-23.

Logvinenko, A.D., and V.L. Levin, 2013. *Foundations of Colour Science* (in preparation).

MacAdam, D.L., 1935. The theory of the maximum visual efficiency of colored materials. *Journal of the Optical Society of America:* 25, 249-252.

Maximov, V.V, 1984. Transformatsii tsveta pri izmenenii osvescheniya [Transformations of colour under illumination changes]. Moscow: Nauka.

Schnapf, J. L., and D.M. Schneewels, 1999. Electrophysiology of cone photoreceptors in the primate retina. In K.R. Gegenfurtner and L.T. Sharpe (Eds.), *Color vision: From genes to perception* (pp. 103-112). Cambridge: Cambridge University Press.

Schrodinger, E., 1920. Theorie der Pigmente von grosster Leuchtkraft. *Annalen der Physik,* 62, 603-622.

West, G., and M.H. Brill, 1983. Conditions under which Schrodinger object colors are optimal. *Journal of the Optical Society of America*, 73, 1223-1225.

Wyszecki, G., and W.S. Stiles, 2000. *Color science: Concepts and methods*, *quantitative data and formulae* (2nd ed.) New York: John Wiley and Sons.

Address: Prof. Alexander D. Logvinenko, Department of Life Sciences
Glasgow Caledonian University, City Campus, Cowcaddens Rd, Glasgow, G4 0BA, UK.
E-mails: a.logvinenko@gcu.ac.uk

Visual effects of Real Light Sources of Arbitrary Spectra on Real Objects and Scenes

Sérgio NASCIMENTO, Osamu MASUDA
Centre of Physics, Gualtar Campus, University of Minho, 4710-057 Braga, Portugal

ABSTRACT

The goal of this study was to investigate how real light sources of adjustable spectral composition affect the visual perception of natural objects and complex scenes. Scenes with a diversity of real fresh fruits and vegetables were mounted inside a light box. A spectrally tunable light source based on the Digital Light Processor (DLP) technology was used as the illumination. The spectral composition of the illumination could be tuned very fast with a spectral resolution of 20 nm. Daylight-like spectra were used as testing illuminants. These were synthesized from Judd's daylight spectral basis functions for a grid of chromaticities on and around the Planckian locus with correlated color temperatures (CCT) ranging 2,222 - 20,000 K. Two conditions were tested in different randomized sessions, naturalness and preference. In each trial, the observers adjusted the illumination on the grid to obtain the best impression for each condition and scene. Six color normal observers did the experiments. It was found that CCT for naturalness was on average about 3400 K and the CCT for preference was on average about 4900 K. Both these values were a little lower than similar experiments carried out using a calibrated monitor screen and suggest that the perception of naturalness and preference may be influenced by the viewing media used, producing higher CCT for monitor screens.

1. INTRODUCTION

Naturalness and aesthetic preference are two of the most important aspects of color rendering. Many indices have been developed to capture these perceptual aspects (Guo and Houser 2004). The empirical work underlying these indices has been, however, constrained to the set of existing light sources. Only recently less spectrally constrained sources, like LEDs with real objects (Smet, Ryckaert et al. 2011) or almost unconstrained spectra on monitor screens (Nascimento and Masuda 2012; Masuda and Nascimento 2013) have been used. These experiments represent real progress but the spectral limitations of the LEDs and the limitations of using monitor displays, may the constraint generalization of the results.

The experiments reported here addressed naturalness and preference. Scenes with a diversity of real fresh fruits and vegetables were mounted inside a light testing box. A spectrally tunable light source based on the Digital Light Processor (DLP) technology was used as the illumination on the testing light box. The spectral composition of the light source could be tuned very fast with a spectral resolution of 20 nm using in-house software. In the experiments only daylight-like lighting was used and the observers were asked to adjust the spectral composition of the source to maximize the perception of naturalness and preference.

2. METHODS

2.1 Scenes

The two scenes are shown in Figure 1. One had a variety of fruits and the other a variety of vegetables. All the fruit or vegetable elements were fresh and special care was taken to replace the fruits before they start showing signs of reduced freshness. When a specific fruit or vegetable was starting to look less fresh it was replaced by a fresh one as similar as possible. This guaranteed that the scenes were stable and the same for all observers and sessions. The lighting box was a box with the dimensions 40 cm (width) × 30 cm (height) × 30 cm (depth) painted in grey with Munsell N7 matt emulsion paint (VeriVide Ltd, Leicester, UK) (see Figure 1).

Figure 1: The two scenes tested had a variety of fruits and of vegetables.

2.2 Illuminants

Daylight-like illuminants were synthetized from Judd's daylight spectral basis functions (Judd, MacAdam et al. 1964) with variable coefficients such that their color defined a chromaticity grid over and around the Planckian locus. The chromaticity difference DC represents the distance between the chromaticities of the light source and of the Planckian radiator of the same color temperature on CIE 1960 UCS diagram. Figure 2 represents this grid expressed in CIE 1960 uniform chromaticity scale (UCS) diagram. The grid points had CCT in the range 2,222-20,000 K. The grid was equally spaced in reciprocal color temperature (RCT)(Wyszecki and Stiles 1982).

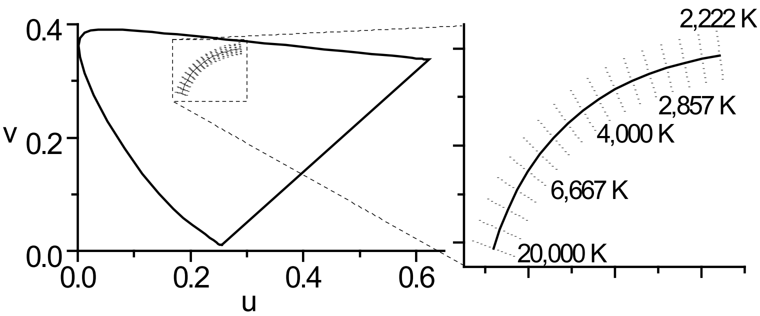


Figure 2: Illuminant chromaticities tested expressed in the CIE 1960 UCS diagram.

2.3. Tunable light source

A spectrally tunable light source based on the Digital Light Processor (DLP) technology (OL 490 Agile Light Source, Gooch & Housego) was used as the illumination on the testing light box. The light from the tunable source was diffused by an optical diffuser (10DKIT-C2

25º, Newport) mounted in the flexible liquid light guide. The illuminance in the box was, on average, about 200 lux. The spectral composition of the light source could be tuned very fast with a spectral resolution of 20 nm using in-house software.

2.4 Procedure

Two conditions were tested in different randomized sessions, naturalness and preference. In each trial, the observers adjusted the CCT and DC of the illumination to obtain the best illumination for each condition and scene. In each trial the chromaticity of the initial illuminant was selected randomly from the grid. The observer then adjusted the chromaticity of the illuminant with 4 buttons on a joypad. Each image was repeated 6 times per session, condition and observer. There was no adaptation period before each trial or session. Each observer did two sessions for each condition. Conditions and trials were tested in random order. The observation distance was 65 cm at which the scenes subtended about 30 deg.

2.5 Observers

There were 6 observers. All but one of the authors (OM) were naïve to the purpose of the experiment. Each observer had normal or corrected-to-normal acuity and normal color vision accessed by Rayleigh anomaloscope and Ishihara plates. The experiments were performed in accordance with the tenets of the Declaration of Helsinki and informed consent was obtained from all observers.

3. RESULTS AND DISCUSSION

Figure 3 shows the results. For the naturalness condition the average CCT across observers and scenes was about 4900 K and the value of DC was -0.004. For the preference condition the average CCT across observers and scenes was about 3400 K and the value of DC was -0.003. The difference obtained between the best CCT for naturalness and preference is consistent with previous studies for similar experiments using calibrated monitor displaying stimuli derived by hyperspectral imaging (Masuda and Nascimento 2013). The absolute values obtained here are, however, a little lower. This suggests that the viewing media has influence of the judgments of naturalness and preference.

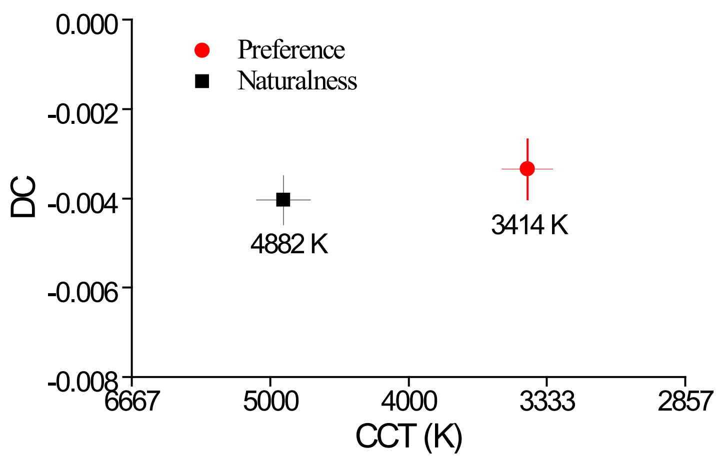


Figure 3: Results averaged across the two scenes observers. Error bars show the standard errors of the means. For readability the horizontal axis is labeled in CCT but is spaced uniformly in RCT.

4. CONCLUSIONS

Experiments carried out with spectrally tunable light sources illuminating complex scenes of fruits and vegetables have shown that the best CCT for preference was around 3400 K and for naturalness was about 4900 K. These values are a little lower than similar experiments carried out using a calibrated monitor screen, which suggest that the perception of naturalness and preference may be influenced by the viewing media used, producing higher CCT for monitor screens.

ACKNOWLEDGEMENTS

This work was supported by the European Regional Development Fund through Program COMPETE (FCOMP-01-0124-FEDER-009858) and by National Portuguese funds through Fundação para a Ciência e a Tecnologia (grantPTDC/EEA-EEL/098572/2008).

REFERENCES

Guo, X., and K.W. Houser, 2004. A review of colour rendering indices and their application to commercial light sources, *Lighting Research and Technology* 36(3): 183-199.

Judd, D.B., D.L. MacAdam, G. Wyszecki, H.W. Budde, H.R. Condit, S.T. Henderson and J. L. Simonds, 1964. Spectral distribution of typical daylight as a function of correlated color temperature*, Journal of the Optical Society of America* 54: 1031-1040.

Masuda, O., and S.M.C. Nascimento, 2013. Best lighting for naturalness and preference*,* J*ournal of Vision,* in press.

Nascimento, S.M.C., and O. Masuda, 2012. Psychophysical optimization of lighting spectra for naturalness, preference, and chromatic diversity, *Journal of the Optical Society of America A-Optics Image Science and Vision* 29(2): A144-A151.

Smet, K., W.R. Ryckaert, M.R. Pointer, G. Deconinck, and P. Hanselaer, 2011. Optimal colour quality of LED clusters based on memory colours, *Optics Express* 19(7): 6903-6912.

Wyszecki, G., and W.S. Stiles, 1982. *Color Science: Concepts and Methods, Quantitative Data and Formulae*. New York, John Wiley & Sons.

Address: Sérgio M.C. Nascimento, Department of Physic, Gualtar Campus
University of Minho, 4710-057 Braga, Portugal
E-mails: smcn@fisica.uminho.pt, masudaosamu3@gmail.com

Testing the Recursive Rejection Method for Training Set Selection in Spectral Reflectance Estimation: Performance Evaluation when Few Data are Provided as Input

Eva M. VALERO, Timo ECKHARD, Javier HERNÁNDEZ-ANDRÉS, Javier ROMERO
Optics Department, University of Granada, SPAIN

ABSTRACT

We have previously developed a global training set selection approach for spectral estimation called Recursive Rejection method, which needs some application reflectances as input. In this study, we test how critical is this necessity by performing several experiments with few or none measured reflectances fed to the algorithm. The results show that our method is able to provide a good selection of samples for training even if only an estimation of the application data is provided.

1. INTRODUCTION

It is well known that training set selection is crucial for spectral estimation. Selection methods can be classified primarily into global and local approaches. In global methods, the same training set is used for estimating all test samples, while in local methods a specific training set is selected for each sample. Local schemes generally outperform the global ones (Zhang et al. 2011), but they can be computationally expensive if there is a large amount of training data available. Global training set selection schemes based on clustering, (Kang et al. 2004, Mohammadi et al. 2005)) can instead deal with this limitation. In previous work (Eckhard et al. 2013) we have developed a clustering-based global training set selection scheme, called Recursive Rejection (further: RR) method. It introduces the novelty of using information about the target application reflectances, and is specifically designed to reduce large training datasets while preserving estimation quality.

The RR method requires the user to provide a set of application data as input. The main aim of this work is to examine different possibilities for simplifying this requirement. We have tested how the RR aproach behaves when only a reduced number of application samples or only estimated application reflectances are provided. The data used are obtained within the context of a specific application (a mustispectral system for colorimetric quality assessment of printed samples on paper, TruePixa from Chromasens GmbH). However, the method offers a great potential for reducing the amount of training samples in other applications, like in spectral imaging of outdoor scenes for material or object recognition.

2. METHOD

2.1 The Recursive Rejection algorithm

The RR algorithm (Eckhard et al. 2013) has the entire pool of available training data as input. K-means clustered subsets of the pool are sequentially rejected from the training set if their absence does not reduce the spectral estimation performance significantly (tested on target application data). Those clusters not rejected are used as input to a recursive call of the RR algorithm and this process is continued until only significant parts of the initial training pool are left. The performance of the algorithm depends on a proper choice of a threshold value for cluster rejection, which is influenced by the data provided as input, among other factors. The parameter selection process can be performed in an automatic and unsupervised fashion. In previous work (Eckhard et al. 2013), the RR method has been found to outperform other global training set selection methods both in spectral and colorimetric quality and also in computation time.

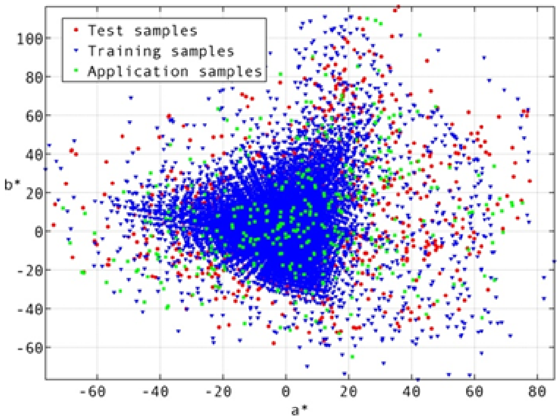


Figure 1: Training, test and application data sets. First run of Experiment 2.

2.2 Data and metrics for performance assessment

In our experiments, the test and application data were extracted from mutually exclusive partitions (70% and 30% respectively) of a set of 1270 measured reflectances of printed Pantone colors. The initial pool consisted of 15898 training reflectances of printed inks on paper, either measured (Toyo, HKS and KPE sets (Eckhard et al. 2013,Valero et al. 2013)) or modelled (Eckhard et al. 2013). See Figure 1 for a CIE a^*-b^* plot of the gamut spanned by the different sets. The samples were shuffled within each set, and three runs of the experiment were performed corresponding to different random 30-70% partitions of the Pantone set used as application and test data.

We have simulated the acquisition of the samples by a multispectral device with 12 channels (TruePixa line-scan camera by Chromasens GmbH). The camera responses were simulated as shown in eq. (1), where S(λ) stands for the spectral reflectance, E(λ) is the SPD of the LED illumination system of the device and q(λ) are the channel responsivities. Additive signal dependent noise $n_{i,j}$ was also modelled corresponding to a mean SNR of 40 dB for the whole set.

$$r_{i,n_j} = \sum_{\lambda=\lambda_1}^{\lambda_2} S(\lambda)E(\lambda)q_i(\lambda) + n_{i,j} = r_i + n_{i,j} \quad (1)$$

In our experiments, the performance of RR is analyzed by using two spectral metrics (cGFC (Eckhard et al. 2013), and RMSE) and one color difference metric (ΔE_{00}).

3. RESULTS AND DISCUSSION

3.1 Experiment 1 (few application data)

In Table 1 we can see the estimation quality results when either 381 or only 32 samples from the Pantone set, corresponding to 30% and 2.5% of the full set, are provided as application data for RR.

Table 1. Estimation results for Experiment 1.

	381 samples			32 samples		
Metric	RMSE	cGFC	ΔE_{00}	RMSE	cGFC	ΔE_{00}
Mean	0.0197	0.0031	0.95	0.0197	0.0030	0.96
Std	0.0109	0.0043	0.57	0.0112	0.0042	0.61
95 pctl	0.0393	0.0096	2.04	0.0404	0.0094	2.14

When we provide less than 10% of the original number of samples, we can see a slight decrease in performance for the estimation results in two of the metrics analyzed (RMSE and ΔE_{00}) but mainly it seems that the number of application data provided is not very critical for the RR performance. We also compared the RR approach with other global selection approaches (Mohammadi et al. 2005 and Kang et al. 2004) and with training with all the samples in the initial pool (further : ALL). RR was the only approach able to outperform ALL, as previously found (Eckhard et al., 2013).

3.2 Experiment 2 (estimated application data)

From Experiment 1, it seems that we need to provide only few samples of our application data set for the algorithm to obtain a good performance. Still, having to measure the reflectance data each time the application changes can be time-consuming, so we have conducted a second experiment in which the application data are not measured, but estimated via the pseudoinverse approach (Nieves et al. 2005) using as training set the whole initial pool of reflectances.

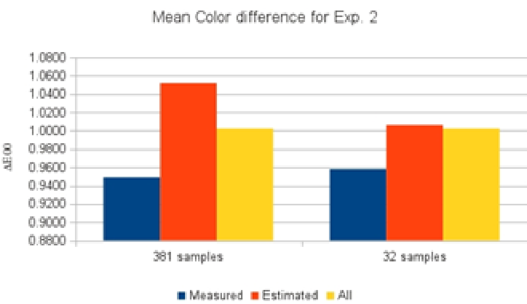


Figure 2: summary of color difference results for Experiment 2.

In Figure 2, we show the color difference results; the trends for the spectral metrics are also consistent with them (mean RMSE of 0.0217 and 0.0256 for 32 and 381 samples; mean cGFC of 0.0037 and 0.0056). In this experiment, the RR results are not outperforming ALL, and even some times random selection performs better than RR. Also, the quality indices are worse than those obtained when using measured application samples (Experiment 1).

3.3 Experiment 3 (estimated application data, HKS and KPE not included)

Analyzing the distribution of selected samples among the different subsets forming the initial pool, we noticed that a significant amount of them (around 25% for Experiment 2) were selected from the HKS and KPE sets, which only represented 1.2% of the initial pool. And this percentage was increased with respect to Experiment 1, which would be indicative of a certain amount of overfitting happening in the selection process. So we excluded these two sets from the initial pool and performed again the experiment with 381 application samples (see Table 2 for RMSE; similar trends were found for the other metrics). We can see then that for the modified initial pool RR outperforms ALL, which was the best among the other global training set selection methods tested.

Table 2. RMSE results for Experiment 3 (381 application samples).

Application data	Measured	Estimated	ALL
Mean	0.0181	0.0194	0.0219
Std	0.0104	0.0107	0.0112
95 prc	0.0368	0.0392	0.0422

4. CONCLUSIONS

The three experiments performed show that the RR approach is robust to the shortage of application data provided. Also, given the findings of this work, it was illustrated that the RR algorithm does in fact not necessarily require measured application data, but performs similarly well with estimated spectral data.

ACKNOWLEDGEMENTS

We thank Chromasens GmbH for providing the sensor responsivities of the simulated capture system and the measured reflectances used, and partially financing the research (Grant nr. 3303, Joint agreement between University and Company). This research has been supported by the Spanish Ministry of Science and Technology (Project reference: DPI 2011-23202).

REFERENCES

Eckhard T., E.M. Valero, J. Hernández-Andrés, and M. Schnitzlein, 2013. Adaptive global training set selection for spectral estimation of printed inks using reflectance modeling, Submitted to *IEEE Trans. Image Proc*.

Kang, J., K. Ryu, and H. Kwon, 2004. Using cluster-based sampling to select initial training set for active learning in text classification. *Proc. of Advances in knowledge discovery and data mining (8th Pacific Asia Conference)*, 384-388.

Mohammadi, M., M. Nezamabadi, R. Berns, and L. Taplin, 2005 A prototype calibration target for spectral imaging, *Proc. of the 10th AIC Meeting*, 387-390.

Nieves, J., E. Valero, S. Nascimento, J. Hernández-Andrés, and J. Romero, 2005. Multispectral synthesis of daylight using a commercial digital ccd camera, *Applied Optics* 44, 5696.

Valero, E.M., Y. Hu, J. Hernández-Andrés, T. Eckhard, J.L. Nieves, J. Romero, M. Schnitzlein, and D. Nowack, 2013. Comparative performance analysis of spectral estimation algorithms and computational optimization of a multispectral imaging system for print inspection. *Color Research and Application*, (to be published, available at http://onlinelibrary.wiley.com/journal/10.1002/%28ISSN%291520-6378/earlyview).

Zhang, W-F., P. Yang, D-Q. Dai, and A. Nehorai, 2011. Estimation of reflectance from camera responses by the regularized local linear model. *Optics Letters* 36, 3933-3935.

Address: Prof. Eva M. Valero, Department of Optics, University of Granada,
Facultad de Ciencias, Edificio Mecenas, Campus Fuentenueva, s/n 18071 SPAIN
E-mails: valerob@ugr.es ,timo.eckhard@gmx.com, javierha@ugr.es, jromero@ugr.es

Achromatic Adjustment Outdoors and Indoors using the Mirasol Reflective Display

Michal MACKIEWICZ,[1] Bradley PEARCE,[2] Stuart CRICHTON,[2]
Anya HURLBERT,[2] Graham FINLAYSON[1]
[1] School of Computing Sciences, University of East Anglia, UK
[2] Institute of Neuroscience, Newcastle University, UK

ABSTRACT

Achromatic adjustment (AA) in psychophysics refers to a procedure in which a participant is asked to adjust the colour of a surface so that it appears neutral. AA is typically used to measure colour constancy, or the degree to which object colours are perceived as stable under varying illumination conditions. To date, most such experiments have been confined to the lab environment. The emergence of new display technologies now offers the possibility to perform such experiments outdoors under natural illumination. Here, we report a series of experiments utilising the recent Qualcomm Mirasol display which uses interferometric modulation (IMOD) technology. Unlike other common display technologies (CRT, LCD), the IMOD display is purely reflective, i.e. it does not have its own light source. Therefore the IMOD display reflected light depends not only on the RGB setting, but also on the illumination spectrum. This feature allows for using the display outdoors as its screen radiance varies with the amount of incident light and thus tracks changes in brightness adaptation of the human visual system. The paper will compare the results of AA using this method for outdoor natural daylights and for indoor artificial lights with typical and atypical spectra.

1. INTRODUCTION

Humans possess colour constancy, the ability to perceive that object colours as largely unchanging when seen under different illuminations. The extent to which colour constancy holds under different illumination conditions is often measured using an achromatic adjustment paradigm (Werner and Walraven 1982), in which the observer adjusts the colour of a patch to appear neutral. The patch is typically displayed on a monitor and incorporated into the scene, or, alternatively, may be a physical surface spot- illuminated by a projection colorimeter (Kraft and Brainard 1999). The former approach is limited because the patch is an emissive source, and therefore (1) is not necessarily perceived as being a surface in the scene (2) in bright illumination conditions cannot match the luminance of a neutral surface and (3) in dim illuminations may have a small and coarsely resolved chromaticity gamut at the matching luminance. These limitations affect the constancy estimates. The latter approach requires careful setup and extra space so that the subjects are unaware of the additional light source; it may also be limited in bright or dim illumination conditions.

To address these limitations, here we present a new method for achromatic adjustment which enables adjustment of the patch reflectance itself. We introduce the use of a purely reflective display (the Qualcomm Mirasol display) which is adjustable, convincingly constitutes a part of the scene and is effective with arbitrarily strong light sources including natural daylight.

2. MIRASOL REFLECTIVE DISPLAY

The technology underlying the Qualcomm Mirasol display (here incorporated into the Kyobo e-reader[1]) is based on the physical phenomenon of light interference. In nature, light interference in the air pockets of reflective materials produces the colour, e.g. of butterfly wings and peacock feathers.

In the Mirasol display, a micromechanical system (MEMS) manipulates the size of an optical resonant cavity, which in turn alters the spectrum of the reflected light. With the cavity fully collapsed, no light is reflected and the corresponding area of the screen appears black. Each pixel of the display is subdivided into a grid of red, green and blue colour subpixels which are further divided into many addressable elements, to enable both colour mixing and spatial dithering for maximal grey level resolution. The reported contrast ratio of the display is 10:1, with a maximum 50% reflectivity, similar to a B&W newspaper; its reported refresh rate if 30 fps. The e-reader device has a 1024×768 pixel 5.7” screen and runs on the Android 2.3 OS. The device has an additional light source for use in low light conditions, which was kept off in the following experiments.

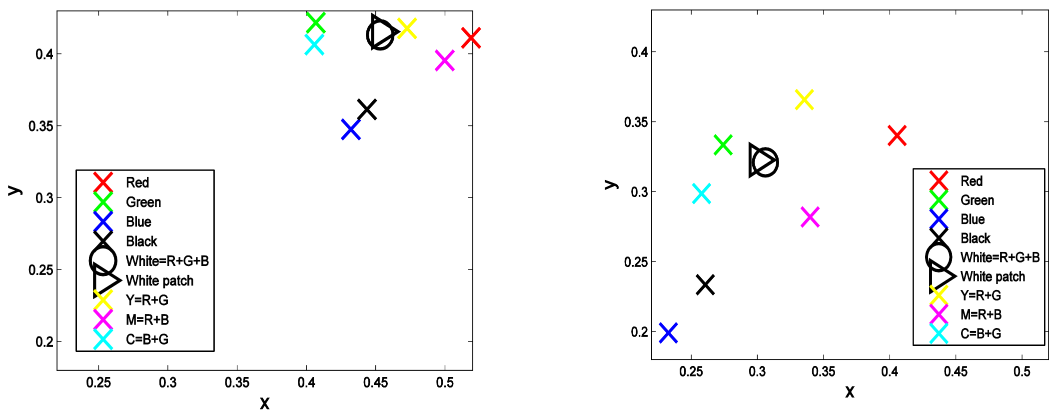


Figure 1: The location of primaries, main mixtures, black and white points in the CIE xy chromaticity diagram under A (left) and D75 (right) illuminants.

The reflective properties of the screen change with the viewing angle and illumination direction making colour calibration of the display challenging. Figure 1 shows the extent of the display gamut measured under illuminants A and D75 in the VeriVide light cabinet. In contrast to the standard LCD or CRT displays, the shape of the gamut is not strictly triangular (particularly visible for the D75 illuminant). The colour gamut is also limited to a range of chromaticities around the illumination chromaticity of the illuminant, and will be even more so when the screen luminance is held constant as in our experiments. Nonetheless, the experiments described below demonstrate that the colour gamut is sufficient to allow observers effectively free range of achromatic adjustment under a variety of illuminations.

3. EXPERIMENTS

The experimental setup comprises a viewing box with a porthole and the reflective display (interfaced with MATLAB) partially occluded by the cover identical to the wall lining for the particular condition. For the outdoor experiment, five conditions were tested: Mondrian, Grey and Black backgrounds, Black background with Fruits and Black background with 3-D shapes of the same colours as fruits. For the indoor experiment, eight conditions

1 http://www.qualcomm.com/mirasol

were tested: Mondrian and Grey backgrounds, each under four different lights: blue, yellow, green and magenta. The outdoor experiment was carried out on a roof at UEA. The box was illuminated by natural daylight through a glass covered opened ceiling. Part of the ceiling was covered by the diffusion sheet to minimise the screen specular reflection effects. The indoor experiment was carried out inside the lab. The illumination was provided by two photographic lights with 500W tungsten bulbs equipped with a diffuser. The four chromatic illuminants were created by placing Lee filter sheets (200, 602, 241 and 344 respectively) on top of the box. A dimmer was used to correct for the different filter transmittances and keep the luminance constant. The white points for each illumination where computed from the spectrum of a white calibration tile placed on top of the reflective display before each session, measured by a PR-650 spectroradiometer. The same device also measured the reflective display once the adjustments had been completed. For the outdoor experiment, given the inherently changeable nature of the illumination, illumination conditions were measured before and after the experiment and the mean of the two measurements was used. Where the distance between the two measurements was above a certain threshold, the session was rejected.

Twenty observers participated in the outdoor experiment (5 females; age range 24-47 years) and 8 (2 females; age range 24-34 years) in the indoor experiment. All tested normal (by error score and pattern) on the Farnsworth-Munsell 100-hue test. Seventeen were naïve to the purpose of the experiment. For the outdoor experiment, due to absence or excluded results, only 8 observers completed all 5 sessions (conditions); data from these only contributed to the analysis. For the indoor experiment, all 8 participants completed 8 sessions. A multiple staircase paradigm in a 2D colour-opponent space, similar to (Xiao et al. 2012), was used to determine the subject's achromatic point. On each trial, participants were presented with a stimulus, and were asked one of the two questions: "Does the surface appear more reddish than greenish" or "- yellowish than bluish". The type of question was indicated to the subjects using the two letters R and G or B and Y. Participants were asked to signal their response by pressing "left" for R and "right" for G or "up" for B and "down" for Y on the gaming controller (interfaced with MATLAB). The task was self-paced, and consisted of 3 double (2-D) staircases i.e. 6 individual opponent channel staircases, containing 40 trials each, totalling 240 trials. The completion time was usually around 15 mins.

3. RESULTS AND DISCUSSION

We measured the adjusted achromatic points and calculated the distances between them and the measured white points in the CIELUV space. There was no significant difference between conditions (one-way ANOVA p=0.7). As the illumination conditions for each subject were different, a non-parametric Wilcoxon signed rank test may be more appropriate for analysing each subject's pairs of different conditions. This test returns a significant difference between only one pair, Mondrian-Fruits (p=0.04), providing weak evidence that AA adjustment was better for the latter. While the natural illumination varies over an order of magnitude in overall irradiance, it varies little in terms of chromaticity, unlike earlier laboratory based studies where the targeted illuminations were very chromatic. The majority of natural illuminations cluster around 6700 K, making it difficult to test the effects of varying illumination chromaticity in this particular experiment.

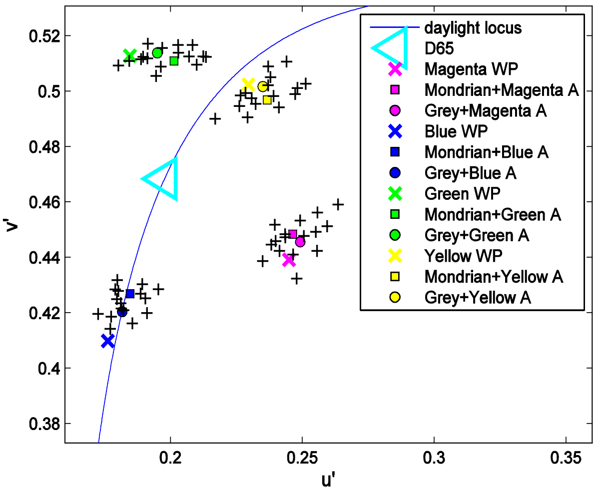


Figure 2: Indoor results. Illuminant chromaticities in the CIELUV space for 4 filters – x; means of grey and mondrian background condition AAs for each filter – circles and squares respectively; all individual AAs - +.

For the indoor experiment, there was no significant difference in AA between the 4 filter conditions (one-way ANOVA p=0.18). With regard to the 2 background conditions, the same test returns p=0.01 suggesting better colour constancy in the grey background condition. The mean constancy index was 0.70 and 0.78 for the mondrian and grey background conditions respectively (p=0.01 one-way ANOVA), comparable to previous results using standard displays under limited illuminations (Foster 2011). Most of the variance in the results was the between-subject variance.

The reflective display therefore is sufficient for achromatic adjustment, and presents advantages over luminance-limited emissive displays. We expect that further advantages will emerge for non-standard illuminations, such as very narrow-band lights, that are beyond the gamut of standard displays.

ACKNOWLEDGEMENTS

We thank EPSRC for supporting this research (grants: EP/H022236/1 and EP/H022325/1).

REFERENCES

Werner, J. S., and J. Walraven, 1982. Effect of chromatic adaptation on the achromatic locus: The role of contrast, luminance and background color. *Vis. Res.*, 22:929-943.

Kraft, J. M. and D.H. Brainard, 1999. Mechansisms of color constancy under nearly natural viewing, In *Proc. Natl Acad. Sci. USA* 96:307-312.

Xiao, B., B. Hurst, L. MacIntyre and D.H. Brainard, 2012. The color constancy of three-dimensional objects. *Journal of Vision*, 12(4):6, 1-15.

Foster, D.H., 2011. Color constancy. *Vis. Res.*, 51:674-700.

Address: Dr Michal Mackiewicz, School of Computing Sciences,
University of East Anglia, Norwich Research Park, Norwich, NR4 7TJ, UK
E-mails: m.mackiewicz@uea.ac.uk, anya.hurlbert@newcastle.ac.uk

Observer Variability Experiment using a Four-primary Display

Yuta ASANO,[1,2] Mark D. FAIRCHILD,[1] Laurent BLONDÉ[2]
[1] Munsell Color Science Laboratory, Rochester Institute of Technology
[2] Technicolor

ABSTRACT

We conducted a paired comparison experiment involving color difference judgments using four nearly-metameric spectra pairs to see the observer variability and the performance of CIEPO06 and Sarkar's observers. At least two different observer groups were found. The field size had a significant effect on the prediction.

1. INTRODUCTION

The CIE 1931 and 1964 standard colorimetric observer, also known as 2° and 10° (standard) observers, have satisfied industries for many decades. The use of a standard observer is based on the assumption that a single set of color matching functions (CMFs) can reasonably represent a whole population of people with normal color vision, which would often break especially for narrowband stimuli and thus possibly reduce the color reproduction accuracy (Fairchild and Wyble 2007, Ramanath 2009). Most of the observer variability experiments in the past involve colors appearing as unrelated colors, comparison of ajoining stimuli, a single bipartite field, and/or monocular view, which might be different from practical viewing conditions. Thus, our goal in this study was to conduct an experiment under the condition close to practical applications, to see how much observer variability we would obtain and to see if observer functions proposed by CIE TC 1-36 (CIEPO06, CIE 2006) and Sarkar›s observers (Sarkar 2011) cover the variability of human observers.

2. EXPERIMENT AND ANALYSIS

We designed a paired comparison experiment using SHARP Quattron display. Quattron is a display having four primsaries, R, G, B, and Y(Yellow) with 10-bit assignment that enables us to produce metameric spectra on a single display. Four nearly-metameric spectra are used in the paired comparison with 16 repeated judgments. By applying Case V of Thurstone's law of comparative judgments, it is possible to extract z-score values (Engeldrum 2000). Each pair consists of two color patches: One patch made from R, G, B primaries and the other patch made from B and Y primaries.

From measurements, we can compute color difference values (ΔE_{00}) of the four spectral power distribution (SPD) pairs for a given observer function. This could be done transforming a given set of CMFs into 10° standard observer space by linear regression, computing the CIEXYZ, CIELAB, and finally ΔE_{00}.

We can plot i-th SPD pair as x-axis and either z-score or ΔE_{00} as y-axis. One human observer or one observer function forms a connected line in the plot. Normalization is performed to the lines such that each line has the mean value of zero, and the standard deviation of unity. Then, we can compare the normalized z-score and the normalized ΔE_{00} directly, and we can investigate which observer function correlates with a given human observer.

2.1 Experiment Procedure, Conditions, and Subjects

The image that subjects observe during the experiment is illustrated in Figure 1. Two SPD pairs (left and right circles) were shown side by side on a gray background. The two circles were separated by a 2° gap and each circle subtends 4.5° in visual angle. The letters and the cross at the center were drawn in white, which is considered as reference white. Both the background and the reference white had D65 white point. The background had L^* of 50. The luminance of the reference white was 319 [cd/m^2]. The calculations here were done using 10° standard observer. There were eight stimuli (two patches for four pairs) used in this experiment. The eight stimuli were all very similar colors (bluish purple) but had slightly different SPDs. The display was temporally and spatially stable enough for the purpose of our study. In addition, the order and the location of the stimuli were randomized.

Subjects sat on a chair, aligned themselves to the center of the display. Then, they were asked to judge which color difference appears greater than the other by pressing Left/Right button on keyboard. Subjects were instructed to fixate their view to the fixation cross in Figure 1 during judgments.

58 color-normal subjects participated in this experiment. The youngest observer was 18 year-old and the oldest was 69 year-old. The number of males and females is 42 and 16, the number of naive and expert observers is 28 and 30, respectively.

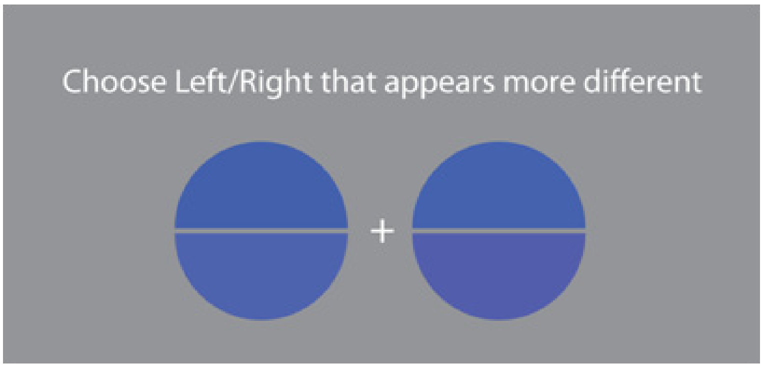


Figure 1: Experiment view.

3. RESULTS AND DISCUSSION

3.1 Results obtained from Human Observers

Figure 2(a)(b) shows the paired comparison results color-coded for different age groups. The line colors correspond to the colors in the bar chart. The majority of people have higher z-score values for pair 2 and 3, lower z-score values for pair 1 and 4, and thus form n-shape curves in the results. This means that, for the majority of people, pair 2 and 3 appears more different than pair 1 and 4. The second most popular type would be the opposite of the majority; higher z-score values for pair 1 and 4 and lower z-score values for pair 2 and 3, thus forming u-shape curves. The results obtained from age group 20 year-old and 30 year-old are distributed widely. The age groups 40 year-old or more always form n-shape curves.

3.2 Assessment of Different Observer Functions

Figure 3 (a) shows the prediction of CIEPO06 using the actual ages of human observers who participated in the experiment. Field size was set to 10°. 2° and 10° standard observers are also shown as reference. As age increases, the curve shape changes from u-shape to n-shape. This agrees well with our observation that higher age groups always form n-shape curves. However, the age factor does not explain why the majority of people (even young observers) form n-shape curves.

(a) Obtained z-scores *(b) Age distribution*

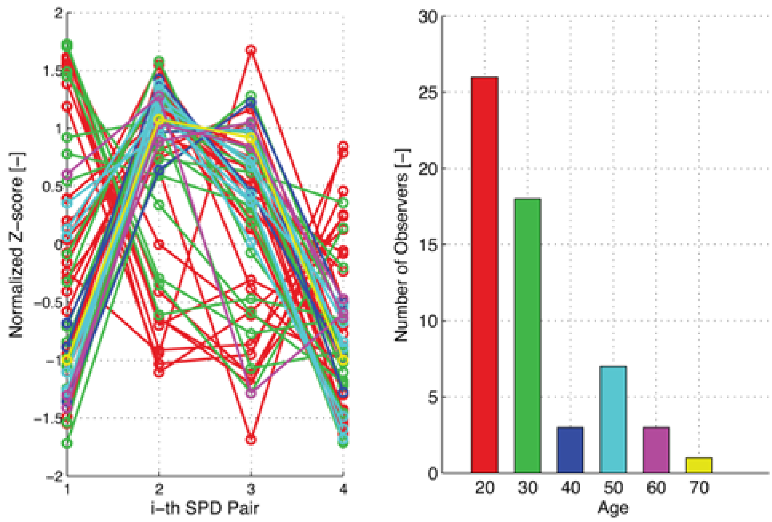


Figure 2: Obtained results for different age group.

(a) CIEPO06 with real observers' age *(b) Sarkar's eight categorical observers* *c) CIEPO06 with different field sizes*

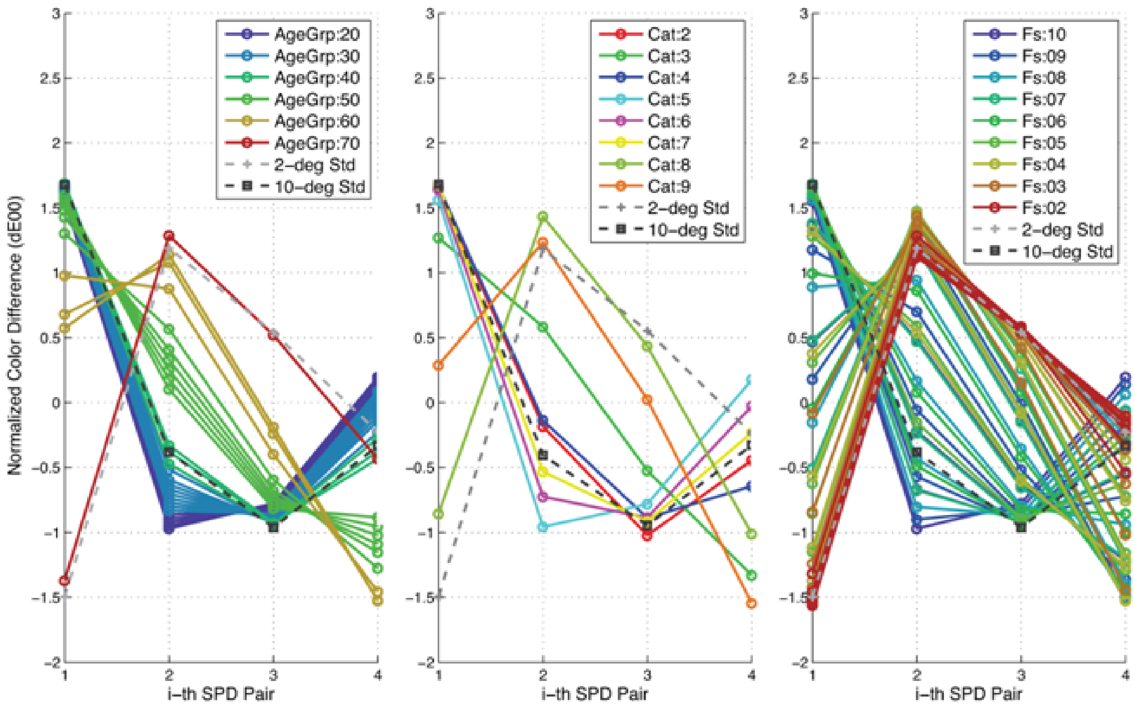


Figure 3: Normalized color differences for different observer functions.

Figure 3 (b) shows the prediction of Sarkar's eight observers. In legend, Cat:2, 3, ..., 9 refers to Sarkar's i-th categorical observer. Sarkar reported that the categories 8 and 9 are dominated by elderly people (Sarkar 2011), which form n-shape curves. Categories

2, 4, 5, 6 and 7, regroupping a majority of Sarkar's observers, are similar to CIE 1964 – 10° curve, itself representative of an average population behavior in this experiment.

The effect of the change in field size is investigated using CIEPO06 shown in Figure 3 (c). CIEPO06 functions were generated with the field size ranging from 2° to 10° at every 1° step. For each field size, ages were varied from 20 to 70 year-old at every 10 year-old step. Each line is color-coded based on its field size (Fs in legend). As we can see, lines only for higher age group form n-shape when field size is 10°. However, as the field size decreases from 10° to 2°, more lines change their shapes from u-shape to n-shape. Although the experiment was meant to be 10° match, it is highly possible that the judgments were made with the field size somewhere between 2° and 10°, and this would depend on each observer. This effect would happen in many practical situations since the field size, and observer gaze would not be well-controlled, and therefore, we might need to take field size into consideration for observer metamerism evaluation.

4. CONCLUSIONS

A paired comparison experiment involving color difference judgments was designed and conducted for 58 color-normal human observers. Observer variability was evaluated using CIEPO06 and Sarkar's observers. We found at least two different groups in our results: (1) those with high z-score values for pair 2 and 3 and low z-score values for pair 1 and 4, which forms n-shape curves, and (2) those who form u-shape curves. The first group can be explained by decreasing field size or increasing age in CIEPO06. The second group can be explained by CIEPO06 with large field size and young age. We found that the field size in CIEPO06 has a significant effect on the prediction.

ACKNOWLEDGEMENTS

The research was supported by Technicolor. The modified Quattron display was loaned by SHARP for this research.

REFERENCES

CIE, 2006. *Fundamental Chromaticity Diagram with Physiological Axes - Part 1*, CIE Pub. No. 170.

Engeldrum, P., 2000. *Psychometric scaling: a toolkit for imaging systems development*. Massachusetts: Imcotek Press.

Fairchild, D.M., D. Wyble, 2007. Mean observer metamerism and the selection of display primaries. In *Proc. 15th IS&T/SID Color Imaging Conference*. 151-156.

Ramanath, R., 2009. Minimizing observer metamerism in display systems. *Color Research and Application* 34 (5): 391-398.

Sarkar, A., Ph.D. Thesis, 2011. Available online, http://www.abhijitsarkar.com/.

Address: Yuta Asano, Munsell Color Science Laboratory,
Rochester Institute of Technology, 54 Lomb Memorial Drive,
Rochester NY 14623, USA
E-mail: yxa8513@rit.edu

Display Image Brightness Matching across Dark and Average Surround Condition

Ye Seul BAEK,[1] Youngshin KWAK,[1] Jiyong PARK,[2] Sangkyun IM[2]
[1] School of Design and Human Engineering, UNIST
[2] Visual Display Division, Samsung Electronics

ABSTRACT

The brightness of image is changed by surround condition. The phychophysical experiment was performed to find the correponding luminance between dark and average surround conditions using ten test images displayed on LCD monitor. Based on 20 observers' reponses, it is found that images with 150 cd/m^2 peak white in a dark room look similar to the images with 170 cd/m^2 peak white in a room lighting condition when the measured illuminance on a monitor surface is 540 lux. Performance of CIECAM02 is evaluated and found that CIECAM02 over-predicts the brightness changes between dark and average surround condition. This study implies that the further color appearance researches are required for display industries to display the images under wide range of surround conditions without color distortion or image quality deterioration.

1. INTRODUCTION

The color appearance of display is affected by viewing condition. When an image is displayed on a monitor with ambient light, in many cases, the image appears darker than that shown in a dark room. Therefore higher luminance setting is required for average or bright surround condition to reproduce the same brightness of the image shown in a dark surround condition. Even though CIECAM02 predicts brightness changes by surround condition (CIE 2004), experimental data sets used to develop CIECAM02 were quite limited. The several studies (Fairchild 1995, Park et al. 2007, Choi et al. 2010) have been studied to predict the color appearance under different surround conditions. Latest color appearance studies found that CIECAM02 predicts poorly under bright surround (Park et al. 2007, Choi et al. 2010).

In this study, the corresponding luminance pair appeared as the same brightness between average and dark surround is investigated using memory-matching technique. Then the accuracy of CIECAM02 is evaluated.

2. EXPERIMENTS

A 24-inch sRGB monitor (EIZO-CG242W) was used for psychophysical experiment. The surround conditions were divided into two groups, dark condition and ambient lighting condition. The latter was the conventional office lighting condition. The illuminance level measured on the monitor surface was around 540 lux. Figure 1 shows the test images used in this study. Ten images on LCD monitor in a dark room were used as references images. In a dark room, the peak white of the monitor was set to 150cd/m^2 and the color gamut was set to sRGB. Then each image was rendered to simulate various peak white luminances varying from 140cd/m^2 to 185cd/m^2 with 5cd/m^2 interval. Therefore total number of test image was 100 (10 reference images x 10 rendered images). The rendered images were shown on the same display in the lighting condition. Since there was no white surface around the display, monitor white was the brightest color in that condition.

Memory matching experiment was conducted to find the rendered image having the same brightness appearance of the reference image in the dark room. Firstly, observers were fully adapted to the dark viewing conditions for 20 minutes. During that time, they memorized the brightness of reference images. Reference images were shown over and over again.

When they fully memorized the brightness of the images, surround condition was changed to ambient light condition. After 3 minutes adaptation time, the main experiment was conducted. The rendered images were shown one by one in a random order and the observers were asked to judge whether the images shown to them were brighter (1), the same (0), or darker (-1) than the memorized reference image. Twenty observers with normal color vision were participated. There were 10 female observers and 10 male observers.

Figure 1: Test images.

3. RESULTS

3.1 Corresponding Luminance Pair

From the visual data, the average and standard deviation of the relative brightness difference for each rendered image were calculated.

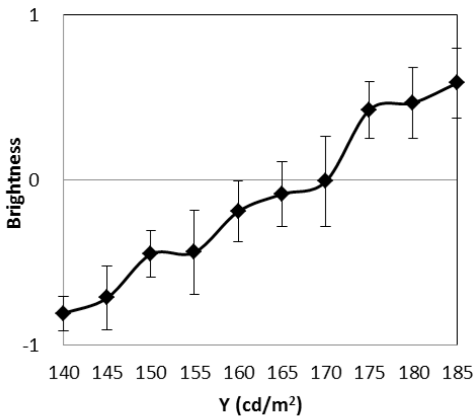


Figure 2: Relation between the average relative brightness difference and luminance of rendered images.

Figure 2 shows the average data against the luminance of the rendered images. The x-axis is the luminance of the images and the y-axis is the relative brightness difference. The relative brightness difference ranges between 1 and -1, where 0 indicates the same brightness. The error-bars represent the standard deviation. On the average, the corresponding luminance is around 165 to 170 cd/m^2, which was higher than the luminance of original image (150 cd/m^2) in the dark surround. This suggests that the displayed images under ambient lighting surround should be increased by an average of 11.5% in order to achieve the same brightness as the one in the dark surround.

Figure 3 shows the CIELAB L* histogram and the relative bightness difference of each test image. All the graphs show similar trend except 2nd and 5th test images, which show higher corresponding luminance than others. Many observers reported that 2nd and 5th test images were difficult to estimate the brightness than others and looked darker than the other test images. This result suggests that there might be a content dependency.

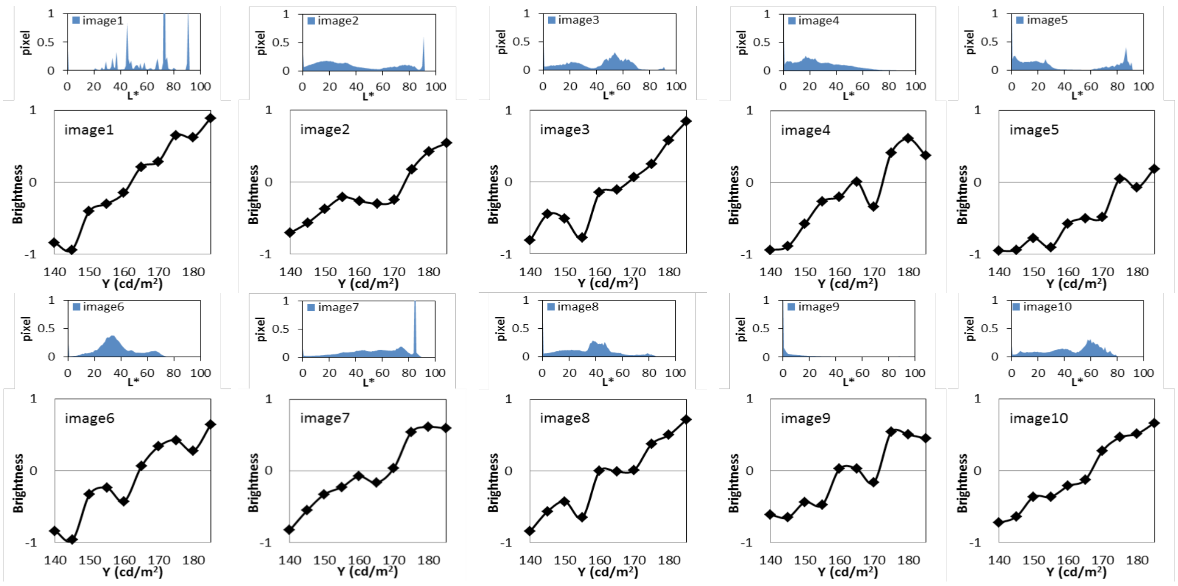


Figure 3: Lightness histogram (top) and Relative Brightness difference (bottom) of each test image.

3.3 Comparison of the Estimated Brightness and CIECAM02 Brightness

The experimental data was compared with CIECAM02 brightness predictor, Q. Table 1 summarise the changes of the Q of monitor whites, 150 cd/m^2 and 170 cd/m^2, under various surround condition.

Table 1: CIECAM02 Brightness (Q) for each surround conditions.

Luminance of the monitor white	150 cd/m^2			170 cd/m^2		
Surroud conditions	Dark	Dim	Average	Dark	Dim	Average
CIECAM02 Q	**244**	217	186	250	**223**	**191**

The predicted Q of 150 cd/m^2 in a dark room is 244, while the predicted Q values in an average surround condition is 186. CIECAM02 predicts the low brightness under the average surround conditon than dark. From visual results, the average matching luminance was 170 cd/m^2 in the ambient lighting condition. The lighting condition can be divided into two conditions; dim and average condition. In general, the office condition can be categorized as average surround condition. Therefore according to the visual data, 170 cd/m^2 color shown in average surround should look like 150 cd/m^2 color in a dark room. However, Q value of 170 cd/m^2 for average surround condition is only 191, which is much lower than 244. It disagrees with visual results. It can be concluded that CIECAM02 over-predict brightness change by surround change. For dim surround condition, Q is also over-predicted.

4. CONCLUSIONS

The image brightness was matched between dark and average surround condition using various test images displayed on LCD monitor. The results showed that the observers estimated the lower brightness under average surround condition than that in a dark room. Also experimental results suggest the possibility of a content dependency for brightness matching. Even though, CIECAM02 can predict the brightness changes by surround condition changes, performance of CIECAM02 was not good enough.

Since, nowadays many display images are shown under various surround condition including bright daylight because of the wide use of smart phones, further researches on color appearance model are required especially to predict display color appearance changes under wide range of surround conditions.

ACKNOWLEDGEMENTS

This project was funded by Samsung Electronics Co., Ltd.

REFERENCES

Choi, S.Y., M.R. Luo, M.R. Pointer, C. Li, and P.A. Rhodes, 2010. Changes in Colour Appearance of a Large Display in Various Surround Ambient Conditions. *Color Res. Appl*. 35, 200-212.

CIE, 2004. *A color appearance model for color management systems: CIECAM02.* CIE publication.

Fairchild, M.D., 1995. Considering the surround in device independent color imaging. Color Res. Appl. 20, 352-363.

Park, Y., C. Li, and M.R. Luo, 2007. Applying CIECAM02 for mobile display viewing conditions. CIC 15th. 169-173.

Address: Prof. Youngshin Kwak, School of Design and Human Engineering, UNIST, UNIST-gil 50,Eonyang-eup, Ulju-gun, Ulsan, Korea, 689-798
E-mails: yeseul@unist.ac.kr, yskwak@unist.ac.kr, jiyong.park@samsung.com, sky.im@samsung.com

Image Quality Assessment using a High Dynamic Range Display

Iris SPROW,[1] Dennis KUEPPER,[1] Zofia BARANCZUK,[1] Peter ZOLLIKER[1,2]
[1] Laboratory for Media Technology,
[2] Laboratory for Electronics/Metrology/Reliability,
Swiss Federal Laboratories for Materials Science and Technology (Empa), Switzerland

ABSTRACT

In High Dynamic Range imaging (HDR), a remarkable range of compression algorithms has been provided in recent years. With the emergence of new HDR display technology, HDR content can now be displayed directly. We develop a colorimetrically calibrated viewing environment to evaluate the perceived quality of HDR and compressed LDR images. The goal is to use an HDR display instead of the original scenes. Our results give judgment agreement between the original scene and its HDR image version on a HDR display. Furthermore, we investigate whether visual comparisons of simultaneously displayed HDR and LDR content are feasible. We confirm that this set-up is of great use in the development of Tone Mapping Operators on the basis of an applied visual experiment.

1. INTRODUCTION

HDR data stores real-world luminance information and corresponds to what the human visual system is capable of seeing simultaneously within a scene. Within the HDR imaging pipeline, displays are still cutting-edge technology. Until displays are more widely available, HDR data must be adapted to low dynamic range (LDR) displays in a process called Tone Mapping to approximate the appearance of HDR images. Such Tone Mapping Operators (TMOs) have widely been studied in recent years but rigorous evaluations of their visual performance in regard to the original scene are rare. This stems from the difficulty of setting up a controlled environment for the comparison of an LDR rendering with the original scene, or a faithful reproduction thereof. Ledda (Ledda et al. 2005) presented one of the first studies using an HDR monitor for TMO evaluation. This study used a pairwise comparison methodology by means of employing HDR and LDR displays to evaluate subjective preferences.

We present an experimental setup using a single HDR display for the controlled and simultaneous side-by-side comparison of LDR and HDR content. Our HDR content preserves absolute luminance data originating from scene reconstructions via multiple exposure technique (Debevec and Malik 1997) captured with a calibrated camera. We calibrate the workflow from original scene, via a camera, to the HDR monitor using a spectrophotometer, and verify that the original scene is faithfully reproduced. Our setup also allows to display HDR content from other sources and to play short HDR movie sequences simultaneously, which is especially useful for the visualization of gloss effect. For LDR simulations images are tone mapped to LDR images towards a limited dynamic range with peak intensity of 300 cd/m^2. We use a SIM2 HDR Monitor with a peak intensity of 4,000 cd/m^2 and a simultaneous contrast of up to 1:100,000.

2. TESTING SETUP

2.1 Design

The experimental design consisted of a moveable miniature HDR scene inside a light booth, resulting HDR images and movies thereof, and a visual test on the HDR display to view HDR and LDR content. Here's the equipment we used: DSLR Canon 1D Mark IV for capturing HDR images, X-Rite SpectraLight QC booth with 2 Dedo DLH4 halogen lamps for real-world lighting environment, Newport URS50BCC stepper rotation stage for moving samples inside light booth, SIM2 HDR47 display for visual test, Minolta CS2000 spectral measurement device.

2.2 HDR imaging workflow

The test image set consisted of nine photographs (6 outdoor, 4 indoor/lab), two computer rendered images and two movie sequences. We created HDR still images and HDR movies via the multi exposure technique and stop-motion technique. All images were recorded in the 14-bit raw file format. Five to seven single images at 1 or 2 EV steps respectively were captured to cover the lightness range. The camera was colorimetrically characterized to recover the camera's response curve and color transform matrix. The scene luminances in the light booth were measured by using an X-Rite ColorChecker and a spectrophotometer. This data was used to reproduce physically correct luminances. Lacking absolute measurements, outdoor photographs were adjusted in exposure for optimum display with a peak luminance of 2000 cd/m^2. Short videos from the stop-motion sequence were pre-processed and transferred directly to the display during evaluation.

2.3 Psychovisual Setup

All psychophysical experiments were carried out in a dark surround. Observers evaluated real scenes inside the light booth with a viewing distance of 70 cm. They also evaluated an HDR and LDR image thereof on the HDR display. The monitor viewing environment was separated through a black curtain from the rest of the lab to eliminate unwanted reflections. Observers sat approximately 250 cm from the display. The monitor had a resolution of 1920×1080 pixels; the two pair comparison images were displayed on the bottom and one original image above with a length dimension of approximately 700 px. The same applies to movie files, which were displayed at a frame rate of 10 fps. The background was black and choices were submitted by clicking on the preferred image or movie, respectively.

Figure 1: left - judging rotational scene in light booth, middle - judging HDR representation on HDR display, right - judging HDR and LDR images on HDR display.

3. EXPERIMENTS

With the presented test infrastructure three psychometric experiments with the following goals were performed: (1) to test the validity of using an HDR display for judging quality of scene reproduction, (2) to evaluate the use of judging videos compared to still images and (3) to evaluate tone- and gamut mapping aspects for the optimal presentation of gloss effect in scenes, see Figure 1 for illustrations.

For the first experiment we have chosen a color matching-task method, consisting of attributing the closest color of a test strip to that of a sample material. 9 observers performed this task under 5 illumination types for three types of tests: judging the scene directly, judging the scene in HDR on the HDR display and judging the scene in LDR-quality on the HDR display. Observers were asked to select one out of six possible colors that best match the color of the sample material. An evaluation of the influence of the involved variables (observer, illumination, test type) showed a higher variance among observers and among illuminations than among test types. This result indicates that it is suitable to use simulated scenes on a HDR display for psycho-visual tests and that for the chosen task (attributing a color patch to a sample) even an LDR representation is sufficient to fulfill that specific task.

For the following two tests, choice-task methods were used to investigate two aspects of global tone mapping algorithms for scenes containing gloss. For the first test both video and still images of the same scene were used. Tone mapping was implemented in two steps:

1) Lightness mapping (tone mapping)
2) Subsequent mapping of points outside of gamut (gamut mapping)

Both steps were conducted in xyY color space. We used the following formula to map the lightness:

$$Y_{map} = ((Y \cdot 10^{d})^{-1/b} + 1)^{-b}$$

The parameter d denotes the log of the exposure and the parameter b is a measure how smooth the tone mapping curve saturates. In addition to the lightness mapping, we have to handle points outside target gamut for which we assumed sRGB. If we restrict ourselves to hue preserving clipping all candidate points lay on a line segment on the gamut border between a point P_c with the best color preservation and the point P_L with the best lightness preservation. The clipping is parameterized with the following parameter $a \in [0, 1]$:

$$P_{\mathrm{clip}} = a \cdot P_L + (1 - a) \cdot P_c$$

In the first experiment four levels of parameter d in the range of [0, 0.7] were tested with two levels of b (0.1, 0.5). In the second experiment three d parameter settings (0.1, 0.3, 0.5), were tested with five levels of color mapping: a custom designed ICC profile, sRGB clipping, and hue preserving clipping with a = (0, 0.6, 0.8).

The results of the test can be summarized as follows: For the judgment of gloss effects the presentation of the scene as videos does not lead to more reliable results compared to judging still images extracted randomly from that video. Within the statistical limit the data show no difference for preferences if videos or still images are used in the test (Figure 2 left). The time to perform the selection using videos (median selection time 16 s) was even significantly longer than for the still images (10 s).

Among the different tone- and gamut mapping parameters the exposure parameter is the most import parameter and has an optimum at an intermediate level (see Figure 2 left and right). A closer analysis showed that the optimal exposure parameter is strongly dependent on the image content. The second most important parameter is how the color mapping is performed. Here hue preserving concepts with a compromise between saturation and lightness conservation are optimal. Only of third importance is how smooth the tone mapping curve goes into saturation (parameter b in Equation 1). In fact, based on our tests we cannot see a significant improvement of an optimized tone mapping curve compared to a clipped LDR image with an optimized exposure setting.

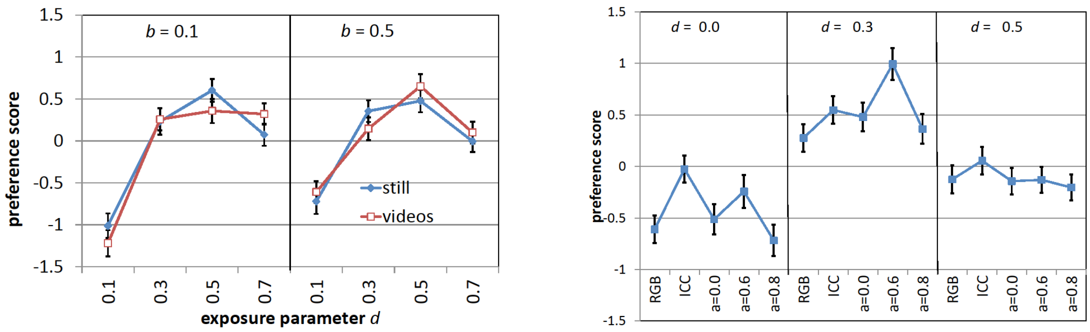


Figure 2: Results of the psychometric tests. Exposure and gloss parameters for still images and videos (left) and exposure and color mapping parameters (right).

4. CONCLUSIONS

The results of our experiments show that it is suitable to use simulated scenes on a HDR display for psycho-visual tests for image quality assessment of TMOs. Possibly neither the use of still images nor the simultaneous presentation of video content are the most appropriate methods for judging glossy materials. Interactive methods where observers can adjust angular position themselves may have a high potential.

The tone mapping experiments showed that the optimal exposure setting is a key factor and that the optimal color reproduction is not only a factor of the best TMO to the available dynamic lightness range but also of the gamut mapping to the display's available colors.

ACKNOWLEDGEMENTS

The project was partially funded by the Swiss Commission for Technology and Innovation (CTI) and supported by X-Rite Europe GmbH and the HDRi COST action IC1005.

REFERENCES

Ledda, P., A. Chalmers, T. Troscianko, and H. Seetzen, 2005. Evaluation of tone mapping operators using a high dynamic range display. *ACM SIGGRAPH '05*, 640-648.

Debevec, P.E., and J. Malik, 1997, Recovering High Dynamic Range Radiance Maps from Photographs, *ACM SIGGRAPH '97*, 396-378.

Address: Iris Sprow, Laboratory for Media Technology, Swiss Federal Laboratories for Materials Science and Technology (Empa), Switzerland. E-mails: iris.sprow@empa.ch, dennis.kuepper@empa.ch, zofia.baranczuk@empa.ch, peter.zolliker@empa.ch

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Datacolor is a global leader in colour management solutions and colour communication technology. The world's leading brands, manufacturers and creative professionals have been choosing Datacolor's innovative technology to consistently achieve the right colour for over 40 years. Industries served include textiles, paint, coatings, automotive, plastics, ink, print, photography and others.

Konica Minolta

Konica Minolta measuring instruments are widely used in product development, manufacturing and quality control. Konica Minolta spectrophotometers and colorimeters are used for essential colour management in a diverse range of industries. Our light and display products include spectroradiometers and Illuminance meters aimed at measuring the characteristics of light sources or displays.

Unison Colour

Unison Colour is a manufacturer of high quality Artists pastels. We are based in the Northumberland National park. We have been hand rolling our pastels for 25 years, and we sell all over the world. It was started by the Artist John Hersey, who strove for perfection in his pastels, and created over 400 vibrant and 'unified' colours. They will be available to buy.

Wiley

Wiley publishes scientific, technical, medical, and scholarly (STMS) journals, encyclopaedias, books, online products and services and are proud to publish books and a journal in partnership with the Society of Dyers and Colourists (SDC). In addition, Wiley publish professional/trade books, subscription products, training materials, online applications and websites; and educational materials for students and lifelong learners.

Spectral Edge

Spectral Edge delivers colour clarity for all. Our visual accessibility product enhances colours for the colourblind while producing images that are preferred by colourblind and colour-normal alike. Our image fusion product merges multispectral images seamlessly, naturally and without artefacts into a normal colour reproduction, revealing details otherwise invisible to the human eye. Spectral Edge makes the invisible visible.

Color Marketing Group

Color Marketing Group is the premier international association for color design professionals. Our mission is to create color forecast information for professionals who design and market color. CMG's Color Forecasting Workshops, held throughout the world, offer color design experts forecast colors that have not yet been applied to a particular product and are under consideration for future product introductions for all industries, manufactured products and services.

Lovibond Tintometer

Lovibond® innovation in colour measurement for the analysis of liquids and solids. The product range incorporates: visual and automated instruments; ISO 17025 certified reference materials and coloured glass standards; and precision fused cells. Lovibond® spectrophotometers for transmission and reflectance, colorimeters and colour comparators are used internationally in industries ranging from: edible, industrial and fuel oils; chemicals; petrochemical; pharmaceutical; medical; foodstuffs and beverages.

The Colour Group (GB)

The Colour Group (Great Britain), founded in 1940, is an interdisciplinary society that draws together people interested in all aspects of colour - its perception, measurement, reproduction and artistic expression. Monthly meetings are held from October to May and provide a unique forum for the exchange of information and contacts.

Mudpie

Mudpie is one of the world's leading trend forecasting services which continues to deliver accurate trends for creative professionals worldwide. Mudpie's three brands include Consultancy, which provides companies with bespoke design solutions, a range of Trendbooks providing ready-made ideas for complete garment ranges, and MPDClick, a leading commercial online fashion forecasting service.

Bentham Instruments

Bentham has been manufacturing instrumentation for the study and measurement of light and colour since 1975. We offer a comprehensive range of spectroradiometer and spectrophotometer systems and accessories including monochromators, integrating spheres, light sources, calibration standards, photometers and radiometers. The accurate measurement of LED products will be featured.

The Colour Ministry

The colour ministry offers insight into colour and light from a wellbeing perspective. This could be getting to know more about your own identity or the identity of others by colour profiling, or understanding the beneficial physical and psychological effects of colour and light to enhance your home, working environment and general everyday life.

AOD International Design Campus

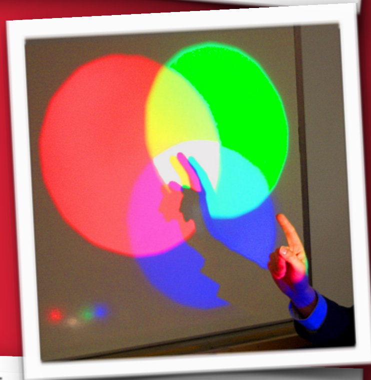
AOD International Design Campus provides award-winning degrees by Northumbria University Design UK, here in Sri Lanka. While training young minds to become global designers, AOD extends its mission beyond education to create a thriving design led economy in Sri Lanka. For this purpose, Design for Sustainable Development (DFSD) was conceptualized by AOD as part of its dedicated social mission. Sri Lanka Design festival (SLDF) and the Island Craft Project was also founded as part of its DFSD initiative.

The COLOUR GROUP (GB)

perception, measurement, reproduction, artistic expression

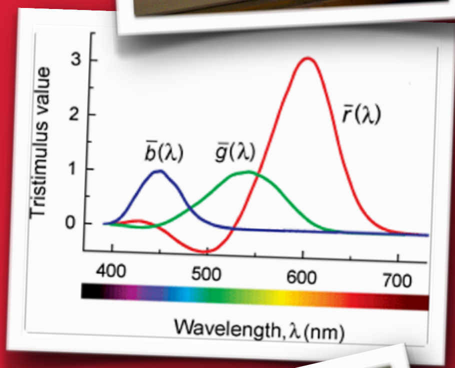
www.colour.org.uk

Since 1940 the Colour Group (GB) has promoted the study of colour in all its aspects and sought to disseminate colour knowledge and to provide opportunities for all those concerned with the various aspects of colour to meet and share ideas and insights.



It holds regular events ranging from discussions on the lastest ideas on how retinal photoreceptors work, the best ways to use indigo to make blue denim, what colours should be used for restful restaurants, the laws governing simultaneous colour contrast and what makes jewellery attractive and flowers pretty.

It makes awards to those early in their careers working in colour to help them spread details of their work. It has had teaching fellows lecturing in schools about colour and issues occasional publications on various aspects of colour.



Two medals, the Newton Medal and the Turner Medal, are awarded in alternate years to distinguished recipients in, respectively, the domains of Science and Art for contributions in the field of colour.

Every year, the Colour Group invites a distinguished vision expert to deliver the annual Palmer Lecture in January at its colour vision meeting.

JOIN TODAY AT:

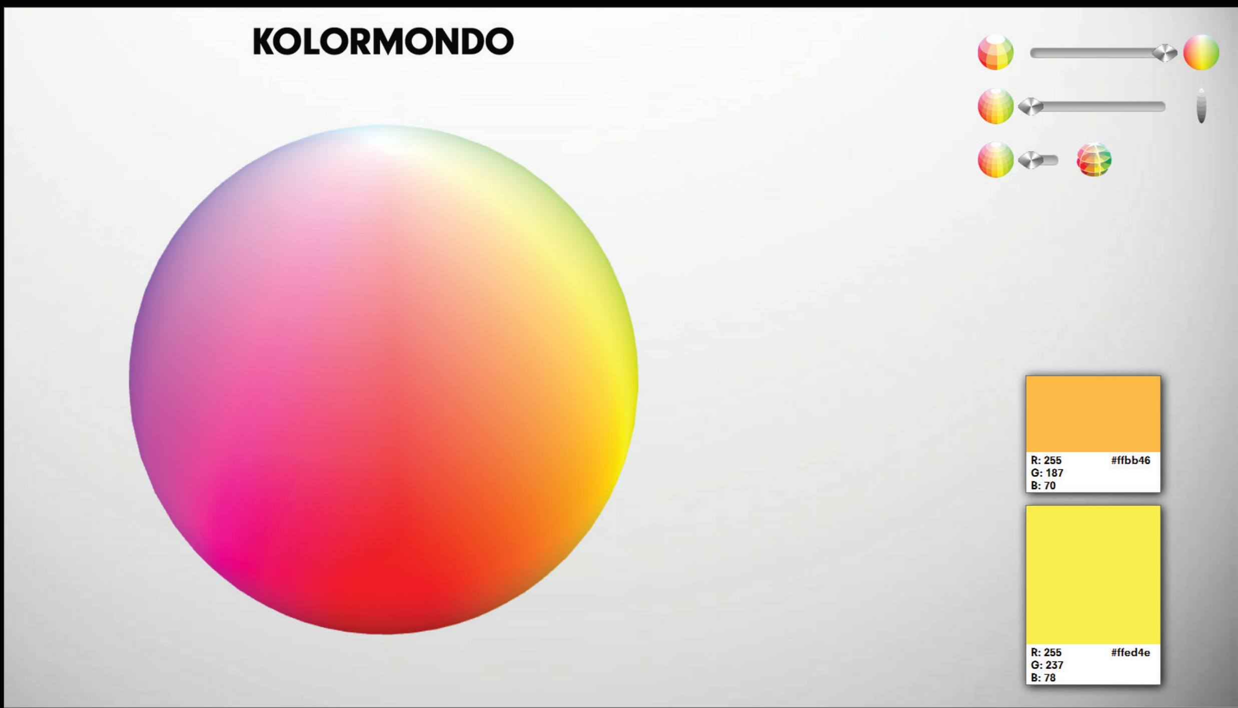
www.colour.org.uk/members.html

Dear Fellow Congress Participants,

The purpose of the Kolormondo concept is to open a door for beginners to the complex world of colours, and thereby inspire to a more advanced understanding.

We present the Kolormondo 3D Colour Puzzle, the Kolormondo App and the Kolormondo Colour Web Tool. The web tool is not yet official but is shown as a special courtesy during the AIC 2013 Congress.

Nicoline Kinch,
Founder and Award Winning Inventor of Kolormondo



THE KOLORMONDO 3D COLOUR WEB TOOL

In the Kolormondo 3D Colour Web Tool you can flip, zoom and travel into the Kolormondo 3D Colour Globe. It can be sliced horizontally and vertically. Any two colours can be seen in a mini-palette. You can also opt for a globe with very few colours, or, as illustrated here, with an endless amount of colours.

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WWW.KOLORMONDO.COM

society of dyers and colourists

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Come and visit us on our stand and join us at our **Sustainable Coloration symposium** (Tuesday afternoon)!

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ISBN 978-0901623027

Editors: Lindsay MacDonald, Stephen Westland and Sophie Wuerger