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aic SENSING COLOUR

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Sensing Colour

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This publication includes abstracts of the invited talks, and contributed oral and poster papers presented at the International Colour Association (AIC) Conference 2022. The theme of the conference was Sensing Colour. The conference, organized by the Colour Research Society of Canada (CRSC), was held online, from June 13th-16th, 2022 and should have been held in Toronto, Canada at OCAD University.

More information at: www.aic2022.org and www.colourresearch.org

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The International Colour Association (AIC) is a learned society whose aims are to encourage research in all aspects of color, to disseminate the knowledge gained from this research, and to promote its application to the solution of problems in the fields of science, art, design and industry on an international basis. The AIC also aims for a close cooperation with other international organizations, regarding issues concerned with color. In 2009 the AIC agreed on the creation of an International Colour Day, which is celebrated in many countries around the world.

https://www.aic-color.org/

COLOUR RESEARCH SOCIETY OF CANADA
SOCIÉTÉ CANADIENNE DE RECHERCHE SUR LA COULEUR

The Colour Research Society of Canada is Canada's only colour-focused, not-for-profit organization. We are a community of interpreters, knowledge seekers and experts, and colour – whether material or ephemeral – is our common focus. The CRSC is a non-profit organisation for colour research, focused on fostering a cross-disciplinary sharing of colour knowledge. We seek to develop and support a national, cross-disciplinary network of artists and designers, scholars and practitioners, with an interest in engagements with colour, and to encourage discourse between arts, sciences and industry related to colour research and knowledge.

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Welcome from the AIC 2022 Organizing Committee

Welcome to AIC 2022 Sensing Colour!



We were both pleased to welcome you (virtually) to Toronto, Canada, and saddened that we were not able to meet you all face to face at OCAD University and the Art Gallery of Ontario. 2022 was a year that held the promise of a renewed capacity to travel, to gather together in a particular place in the world, and to share our joint interests and experiences of colour. We had hoped to use a hybrid approach, with both in-person and online attendance, to share our knowledge and allow more participation from across the globe. But in the end we found that the world was not yet ready for the in-person component. However our shift to a fully online gathering successfully engaged many diverse contributors from many countries, with over 250 attendees from around the world.

Sensing Colour, our AIC 2022 theme, was chosen as a cross-disciplinary framework, to push and pull at any perceived or implicit boundaries that might confine our understandings of colour. Certainly, one implication of this theme is the inclusion of diverse senses. Another is the sharing of diverse means of sensing, perceiving, and understanding colour. Yet another is the historical and contemporary awareness of colour as a social and racial construct. So we thank all who opened up viewpoints and ways of knowing color that added new dimensions to our understanding of colour experience. We would particularly like to thank our two Special invited speakers, whose talks were co-sponsored by the Art Gallery of Ontario, and open to the general public. Anong Migwans Beam, of the M'Chigeeng First Nation on Manitoulin Island, shared her experiences and approaches to painting and making pigments in her lecture on *Gathering colour.* Award winning photographer Angélica Dass spoke about her Humanae Project in *Celebrating how colourful we are,* and promoted dialogue that challenged how we think about skin colour and ethnic identity.

We would also like to thank our invited speakers: Anya Hurlbert, Rob DeSalle, Anna Franklin, Michael Murdoch and Joseph Ingoldsby for their illuminating contributions which helped enrich our conference theme. In addition we would like to thank Tom Butters for arranging a fascinating panel on the role of colour and light in the lighting industry.

We thank members of the AIC Executive Committee for their guidance and support throughout our planning process. We also thank the 12 members of our Program Review Committee for their help in shaping AIC 2022, and our team of 70 Reviewers who helped hone the contributions. We had 68 oral presentations and 35 posters; thanks to all contributors for making AIC 2022 a success.

In our planning, we aspired to offer students and those with limited finances or mobility ways to participate. We were delighted that we had many contributions from young researchers from diverse locales, and that we could provide funding for individuals in need. We were happy to give experience and exposure to a large number of student presenters, with 30 oral student papers and 20 student posters. The best student papers and posters were honored with the AIC Student Paper Awards and the Colour Group (Great Britain)'s Robert W. G. Hunt Poster Awards.

We'd like to thank all of our sponsors for their steadfast support: OCAD University and the Canada Council, Haft2, the Art Gallery of Ontario, the CNC-CIE, and Lighting Agora each played a strong role in our success. In particular, the strong team at Haft2 designed and organized our website, our social media presence and provided invaluable guidance for our conference management program. We could not have managed the conference without them! The CNC-CIE sponsored an award for best student paper in the lighting industry, and the CRSC sponsored the Sensing Colour Award.

And finally, we would like to thank each and every participant in the conference for your dedication and generosity in sharing your colour studies. There are many attendees who have known each other over years of AIC gatherings. And many who are new to the community. It is a vibrant community, and the Colour Research Society of Canada and its members are pleased to be a part of it, and to have hosted the AIC Midterm Meeting in Toronto and online. We all look forward to AIC 2023!

Sincerely,
Doreen Balabanoff, Robin Kingsburgh, Brian Funt
AIC 2022 Organizing Committee

Welcome from the AIC President

Leslie Harrington, AIC President

Welcome to AIC 2022. It is that time again to get together for our annual colour event. First and foremost, I would like to express my sincere gratitude to the Colour Research Society of Canada for organizing committees and the tremendous help and support from the team at Haft2 for our online conference management program. I remember talking to Doreen several years ago to see if CRSC would be interested in hosting their first AIC Meeting. She was not sure they would have the resources to pull it off, but I am sure we can all agree that they have done a superb job. It is a shame that they had to make a tough last-minute decision to be an online format only.

As a Canadian growing up in Toronto, I can attest to how beautiful their selected venues are. We all missed a great experience, but I know that AIC 2022, while being virtual, will still meet all our expectations.

Some of the conference highlights include the special talks: Gathering Colour with Canadian Indiginous artist Anong Migwans Beam, Humanae; Celebrating how colourful we are with Angélica Dass, the Special-session Panel on Light, Colour, and … , and the opening Plenary on Illuminating colour: Do people see the light? with Anya Hurlbert.

This year marks the 3rd AIC Student Award, issued every two years. Its goal is to encourage students to present their work at the AIC meetings and support their interaction with the international colour community.

Also, 2022 ushered in a new Executive Committee, and we have been busier than ever...

2022 is an essential year for AIC as we will be finalizing the registration of AIC in Vienna, a move necessitated by a change in Australian regulation. This process has been no small task, and I want to thank everyone for that as we continue to work to complete this process.

One of our annual initiatives, International Colour Day, continues to grow its awareness worldwide. Thank you once again to all our members that worked so hard to put on exceptional events to recognize this day. Participation is an important step toward our application for UNESCO to recognize ICD.

Finally, I would be remiss if I did not recognize all of those who have submitted papers and are attending AIC 2022, the Review Committee for their help with the review process, the session chairs, the AIC Study Group Chairs for hosting their workshops, and the sponsors of this event.

I know we will all enjoy AIC 2022.

Leslie Harrington
AIC President
June 14, 2022

Awards

AIC Student Paper Awards

The AIC Student Paper Awards are for final-year undergraduates and postgraduates (any stage of Masters or Doctoral degrees). Accepted abstracts with a student as first author are eligible for these Awards. Three prizes, agreed by the AIC Student Paper Awards Panel, are awarded to students on the basis of the quality of their full papers published in the AIC proceedings. The top, first runner-up and second runner-up prizes are a monetary prize. An extended version of the awarded papers are published in a special issue of the JAIC.

On Jun 16, 2022 Maurizio Rossi, AIC Vice President, presented the Student Paper Awards at the AIC 2022 Symposium in Toronto, Canada. Out of more than 50 entries AIC Executive Committee conducted two phases of evaluations to confirm the 6 finalist student papers:

First Prize – Cat Pattie, Newcastle University
Development of a questionnaire to assess the impact of congenital colour vision deficiencies on education
Co-authors: Harpreet Dlay, Sinéad Mullally, Gabriele Jordan

Second Prize – Lou Ricome, Architectural School of Lyon
Colour and care in space
Co-author: Chantal Dugave

Third Prize – Yulia Kovanova, The University of Edinburgh
Chroma Calls: Place attunement through colour intra-action in sculpture

Honorable Mention

Qiang Xu, Zhejiang University, China
A parametric colour difference study on the physical size effect

Mengyuan Chen, University of Leeds, UK
The effect of colour temperature of morning light exposure on wellbeing

Abigayle Weymouth, Rochester Institute of Technology, USA
Perceived speed in transitions between neutral and chromatic illumination

Robert W. G. Hunt Poster Awards

The Colour Group of Great Britain presented the Robert W. G. Hunt Poster awards, in the form of 3 x £150 cash prizes for the top 3 posters by students/young researchers at AIC 2022.

Yuka Akuzawa, Tokyo University of Science
Comparative study of the psychological effects of the spectral distribution of daylight and LEDs in office spaces
Co-authors: Chuanyi Liu, Yuki Oe, Yukie Miura, Nozomu Yoshizawa, Naoko Shinohara, Marie Nakaso, Koichi Kaiho

Hortense De La Codre, Université Bordeaux Montaigne
The impact of colours fading on our sense of 18th century tapestries
Co-authors: P. Bertrand, L. Servant, R. Chapoulie, P. Mora, A. Mounier

Zachary Manning, Amsterdam University of Applied Sciences
Emotional association of colours through participants delineation of their present state of mind paired with specific color tones
Co-authors: Aljoscha Gleser, Miriam Loos, Robin Tepe, Irene Maldini

CIE-CNC Student Award

Venkat Venkataramanan of the CIE/CNC presented the following awards for best student presentations related to the lighting industry:

Hao Xie, Rochester Institute of Technology
The Luther Condition for all: Evaluating colorimetric camera design for personalized color imaging
Co-Author: Mark Fairchild

Olivia Kuzio, Rochester Institute of Technology
Simulating the effect of camera and lens choice for color accurate spectral imaging of cultural heritage materials
Co-Author: Susan Farnand

CRSC/AIC 2022 Sensing Colour Award

Awarded by the CRSC, "For embodying relevance to the conference theme and encompassing design & aesthetic considerations". A monetary prize of CDN$200, and an invited talk to the CRSC Kaleidoscope lecture series.

CC Hart, The International Association of Synaesthetes, Artists, and Scientists
Fifty Shades of Grayscale: Orthopedic structures as perceived by a manual therapist with synaesthesia

Invited Lectures

Illuminating Colour: Do people see the light?

Anya Hurlbert, Newcastle University

We humans see colour because light interacts with particles and surfaces and then with the sensors in our eyes. But the meaning of colour comes about because we attribute colour to objects as an intrinsic property, and this conceptual operation requires unpicking the interaction between light and surfaces. Put another way, to perceive objects as having stable colours our visual systems must disentangle changes in illumination over time from changes in object properties. The yellowing of banana skin is meaningful when it comes about from ripening changes in pigment composition; less so, when it arises from changes in the light spectrum illuminating the banana. How does the human visual system distinguish temporal changes in illumination from changes in the material properties of objects? Does its ability to do so depend on the spectral properties of the illumination? Does the human visual system perceive temporal changes in illumination at all? These are questions that are closely tied to the question of how and to what extent the human visual system achieves colour constancy. Is colour constancy optimised for the types of illuminations and illumination changes under which the human visual system evolved? And can colour constancy survive the challenges posed by the varieties of artificial illumination spectra which now light people's lives?

To address these questions, I will explore the spectral dynamics of natural illumination, and discuss evidence that visual and non-visual responses are tuned to these characteristics. New measurements of natural illumination, together with analysis of existing spectral irradiance databases reveal a characteristic pattern: rapid changes in chromaticity at the start and end of the day, when illuminance is lowest, with relative stability in between; with a slower, smoother rise and fall in illuminance, following the change in solar elevation, interrupted by unsystematic spikes due to weather-related factors. Behavioural experiments in which people are required to detect temporal changes in artificial illumination – generated by spectrally tuneable lamps in an immersive environment and mimicking natural illumination – reveal that the visibility of natural changes in illumination is generally low, and depends on the chromatic direction of change as well as the adapting chromaticity. Temporal changes away from extreme chromaticities (very warm or very cool chromaticities) towards neutral are significantly harder to detect than changes in the opposite direction, when illuminance is held constant. This effect reverses when illuminance changes at the same time. The results suggest that the human visual system has evolved mechanisms to dampen sensitivity to natural changes in illumination, maintaining perceptual stability of object colour. Concurrently, the non-visual system, fed by the melanopsin-containing intrinsically photosensitive retinal ganglion cells, is well suited to follow the slow, smooth changes of natural daylight. It is likely that the non-visual responses contribute to the feelings aroused by naturally changing illumination, even when those changes are visually undetectable.

Changes in illumination that violate the natural pattern are, on the other hand, readily visible, and difficult to distinguish from changes in object colour. Although these pose a challenge to colour constancy, they may also be exploited to enhance material properties of artworks, for example, as well as the affective and aesthetic responses of the viewer.

Sensing Colour in Nature

Robert DeSalle, American Museum of Natural History

It should be obvious that color is a complex concept and dependent on a lot of *things*. There are four major themes that I have identified when considering the natural history of color. The first theme involves an examination of what color is on the physical level. The second major theme involves looking at the biochemical and neurobiological levels of light and light detection in organisms. The third major theme concerns color in nature and how color is used by organisms to expand the information they receive from their surroundings. How organisms on our planet diversified is partly a story of color. Adaptation and natural selection have shaped the way color is distributed in plants and animals on our planet and is very tightly complexed with our general impression of our planet. The final theme concerns the cultural/human context of color. Evolution by natural selection is a strong force on our planet, but cultural evolution can change the patterns of natural selection very rapidly and in some surprising and enlightening ways. I address each of these four themes with vignettes from the Natural History of Color (DeSalle and Bachor, 2021).

Vignette 1. How bright was the Big Bang

Cosmologists Christopher Andersen (2019), Charlotte A. Rosenstroem and Oleg Ruchayskiy ask this question in a recent article in the *American Journal of Physics*. They take a simple approach by placing a human eye as a proxy of the light detector at the beginning of the universe. Their thought experiment takes into account the various rapid epochs that are predicted for the first second of existence of the universe and beyond. They determine two important aspects of light in the early universe with respect to the sight our eyes accomplish: the limit of darkness and the limit of visible light. The limit of darkness is the point where complete darkness gives way to being able to see light and the limit of light is where light becomes blindingly intense.

Without going into too much detail, it is clear from cosmological studies that after the singular event that started the universe it cooled enough to form hydrogen atoms and also to allow photons to be released. Photons could move about in this transparent hydrogen soup and for long distances. We still detect them as radio waves as they are part of the cosmic microwave background (CMB) or Cosmic Radiation Background (CRB). They are very, very weak, coming from all around us in space. While the CMB is technically made up of photons, we cannot see them with our eyes. Our eyes can only detect photons in a small range of energies, or as we say colours.

Andersen and colleagues' human eye required in their thought experiment viewed the earliest stages of our universe in time lapse. That eye could only start to see anything when the universe was more than 1 million years old. As more cooling occurred over the next 5 million years or so the universe became less and less bright until it reached pitch blackness. That human eye would detect no light for over 150 million years, a period of the early universe called the Dark Ages. What happened? Stars started to form at this point in time, and enough of them formed for Andersen and colleagues' eyes to start to detect a little light. As the universe expanded more and more and more stars formed, more light was produced to get us to the current state of the universe where there is neither too much light that would fry our retinas nor too little light that we couldn't see.

Two very recent calculations become relevant to our understanding of light in the universe and how much of it reaches our eyes. The first concerns a calculation of the number of photons produced so far in the universe made in 2018. The details of how this was done involved blazars (galaxies with supermassive black holes), epochs (periods of time in the 13.7 billion years of evolution of the universe), the cosmic fog (that plasma we discussed earlier in this chapter) and NASA's Fermi Gamma-ray Space Telescope. The number turns out to be 4(1084), oh what the heck I'll just write it out - 4,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000, 000,000,000,000,000,000,000,000,000,000,000 photons. The second calculation was made in 2013, by scientists at the Max Planck Institute who calculated the minimum lifetime of a photon. Their estimate was an average of 1018 years or perhaps more easily written as a billion billion years (Oh what the heck, here it is again in full number glory 1,000,000,000,000,000,000). Remember the age of the universe calculated from the Big Bang is 13.7 billion years (13,700,000,000), and so most photons in our universe are nowhere near "dying". Because the universe cooled as it expanded (it is now only 2.7 degrees C above absolute zero) the amount of light reaching us as part of this cosmic radiation background (CRB) was also diluted. Of those non CRB photons reaching our eyes, the remainder do indeed come from our sun in the form of what is called blackbody radiation. Needless to say, the number of photons in the universe is an incredibly large number (4[1084]). Even though a large number of photons reach our eyes each day, the light we see is pretty dim compared to what it could be. But because photons are pretty resilient, it means that even with the vastness of the universe a large number of photons reach our eyes each day. It is those photons that produce color for our brains.

Two things are important for color from this first vignette about the early universe. First vision (and color in turn) is triggered by a physical phenomenon – photons. One thing that Anderson and colleagues built into their theoretical observing eye is that it is connected to a nervous system which can process a property of the photons that results in color – wavelength. Second, we cannot view the early universe without some device; in this case it is a human eye. As Galileo put it "Colors are not properties of bodies to the intuition of which they attach but are also only modifications of the sense of sight, which is affected in a certain manner by light." It is the light sensing organs of organisms that do the hard work of capturing the physical information that is at the heart of brightness and color. Without these organs there would be no brightness to observe the big bang or to view the brilliant variation of color which is one of the more important fuels for natural selection.

Vignette 2. Opsins: The linchpins of color

The evolution of light detection and structures that do the detecting is fascinating and, in some ways, convoluted with the gain and loss of light detecting organs over evolutionary time. While the genetic and molecular mechanisms that lead to light detection across the animal tree of life are diverse, a general theme developed in the early evolution of animal life on our planet with respect to light detection is one that includes stops and starts. Organisms with the capacity to detect light evolved systems that incorporated proteins and molecules that react to light. These unique proteins usually bind to a small molecule that are sensitive to light (commonly called chromophores) that can bind to a protein (usually a pigment protein called an opsin) to form a light sensitive entity. When light hits the chromophore it "jostles" the small molecule causing it to be released from its cozy protein and this causes some other response in the animal's cells. By looking at organisms with nervous systems very unlike our own and organisms with nervous systems that are a lot like the precursor to our nervous system we can learn a lot about how color vision works. The most prominent of these proteins that bind chromophores in organisms with eyes connected to a brain (or cerebral eyes) are as I said the opsins which are the linchpins of color perception on our planet.

If we say something like "light is perceived by a broad range of organisms'', what exactly do we mean? The perception of light by us humans is one thing, but do microbes perceive light? Do plants? Do things without eyes? The key word in the sentence above is "perceive". Perception is usually connected to things with brains and nervous systems. Although some plant biologists have made some noise about plants having nervous systems and point to behaviors that stem from such systems, animals are the only organisms with true nervous systems. So, it is important to look at light perception organs in animals. One such bizarre case is illuminating (pun not intended). Light detecting organs are scattered all over the bodies of some cnidarians and ctenophores. Cnidarians (jellyfish, corals, hydroids and box jellies) and ctenophores (common comb jellies) look somewhat alike, but it turns out they are not closely related to each other at all despite looking a lot alike. They are nearly as different from each other as we are to sponges. This paradox of looking alike, but not related is a repeated theme called convergence in evolutionary biology and one that was repeated over and over again with respect to color vision in animals.

There is a box-jelly *(Tripedalia cystophora)* that actually has fairly complex light detecting organs that very much resemble our complex eye. Because it has opsins too, researchers have determined that it can actually visualize shapes and shades. *Tripedalia* actually has 24 light detecting organs on its body, some of which are very simple. But there are four that are more complex light detecting organs that actually have lenses and as Bielecki (2014) and colleagues have shown are always pointing upwards to the surface (even when the animal is swimming upside down). Apparently, this box jelly uses these organs to detect changes in light indicative of shade and then navigates toward shady areas of the mangroves where it lives. It turns out that many of the genes used to make these eyes are also involved in controlling eye development in higher animals.

But since this box jelly doesn't have a brain (it has a neural network), and it appears to be an isolated appearance of a light detecting organ in this lineage, these light detectors that this box jelly has evolved are more than likely not the same thing as our eyes, or even an octopus eye or an insect eye. This pattern of gaining and losing light detecting organs in animals is peculiar and has a very important explanation. Research has shown that animal genomes carry an evolutionary toolbox, or a set of important developmental genes that remain a steady part of animal genomes that can be called upon to produce important structures in organisms. Because the combinations of the genes in this toolbox are limited and because development of tissues are produced in the way they are, there are a lot of structures that evolve that are repeats of previous evolutionary "experiments". Animal light and color detecting organs have evolved over 25 to 40 independent times. If independent evolution (convergence) of detecting light and color is this frequent on our planet it means that light and color are truly intense drivers of organismal change on Earth.

Vignette 3: Wallace, Darwin and Larsen

Both Charles Darwin and Alfred Russel Wallace traveled as young men to many exotic places. Darwin was included as a gentleman companion and natural historian on the second voyage of the HMS Beagle in its circumnavigation of the globe from 1831-1835. Wallace's journeys occurred during two periods of his early life. One trip to South America (1848-1852) and a second to the East Indies (1854-1862) mostly in the Malay Archipelago resulted in enormous collections of insects and vertebrates (some of which were lost when one of the ships he was sailing on caught fire). What they both had to say about color and how color helped each to develop their ideas about natural selection is most illuminating.

Wallace described as categories that invoked color in nature the following: 1) protective colors, 2) warning colors, 3) mimicry, 4) sexual colors, 5) 'typical colors' and 6) attractive colors in flowers and fruits. Of his six categories protective coloration, aposematism, mimicry and sexual colors have remained major focal points of modern research. Why make such a big deal out of Wallace constructing these categories? The answer is that Wallace invoked natural selection to delineate these categories, and this demonstrates not only his hold on the natural process of selection, but also that natural selection was real to him and an overarching way to understand diversity in nature. Wallace, like Darwin, was looking for universals. Color aided him in establishing that there was a universal force that generated the many phenomena he documented during his lifetime. Darwin's reference to color was also voluminous. Like Wallace he recognized many of the same major categories of the role of color in nature. For instance, he had this to say about one of the more versatile animals on the planet with respect to color – the cuttle-fish

This cuttle-fish displayed its chameleon-like power both during the act of swimming and whilst remaining stationary at the bottom. I was much amused by the various arts to escape detection used by one individual, which seemed fully aware that I was watching it. Remaining for a time motionless, it would then stealthily advance an inch or two, like a cat after a mouse; sometimes changing its color...

That color was susceptible to natural selection was a major theme of their writing on color. Darwin thought that because color was correlated with traits involved in survival that color itself would be subject to natural selection. To stamp in stone the color in nature research areas Innes C. Cuthill and Tim Caro (Cuthill, 2017) published a highly visible paper on color research in nature and concluded that the major areas in this area have settled on: aposematism -, camouflage, sexual selection, mimicry and self-producing light (bioluminescence, fluorescence and light shifting). The modern research program on color in nature is not too terribly different from the one Wallace described 150 years ago.

There is another figure in biology who has also touched on most of these topics. The cartoonist, Gary Larsen has been able over his illustrious career to add context to science with simple cartoons and has focused many of his creations on animal and plant traits that add to their success in nature. Without going into much detail of these often hilarious cartoons I will mention four that are of particular interest. If you are a Larsen fan, see if you can envision them, if not then simply google the terms I give after each, and you can view the mentioned cartoon.

For aposematism (warning coloration) we can turn to his "How nature says DO NOT TOUCH" (google Larsen nature DO NOT TOUCH). Mimicry usually involves coloration adaptations or some kind of anatomical or behavioral adaptation. The best example of the principle can be found in Larsen's "When animal mimicry breaks down" (google Larsen mimicry when mimicry breaks down). Natural selection is intense enough to maintain the color patterns needed for mimicry, but if there is change in selection pressure there is a breakdown. For sexual attraction, Larsen's "Hold it right there young lady!" (google Larsen hold it right there young lady) cartoon of a young female insect on her way out for a night on the town will suffice. While the cartoon is about sexual odorant attractants, visual attractants work in much the same way. For camouflage we can go to Larsen's famous "When the monster came, Lola, like the peppered moth and the arctic hare remained motionless and undetected. Harold, of course, was immediately devoured" (google Larsen When the monster came Lola like the peppered moth). This cartoon shows the adaptive advantage of blending in versus standing out. Finally, for fluorescence, bioluminescence and other light phenomena the relevant Larsen cartoon is his "Nik, the fireflies across the street – I think they are mooning us!" (google Larsen Nik the fireflies across the street). This cartoon shows the power of bioluminescent coloration in signaling as the subject homebody insects view two bright splotches in the front window of their neighbors.

Vignette 4: The color of humans

No treatment of color would be complete without a discussion of color variation of the parts of humans that do indeed vary in color. Skin, hair and eyes are the most obvious parts of our bodies with color variation because these are all on the visible outside of our bodies. Our skin is the largest organ in our bodies and the range of color of this organ is spectacular amongst humans. It is probably the single most variable organ with respect to color. Eye and hair color also vary widely. While color abounds in other parts of our bodies specifically on the inside of our bodies, in this vignette we will focus on skin color.

While skin, eye and hair color might ultimately be predictable from genome information, we humans have to resist the tendency that we have to accentuate the differences between people and not the similarities. Almost all racism starts with a misguided conception that there are significant differences between groups of people. While skin color of humans can be different from region to region of the globe there are three things that render it irrelevant to perceived differences between the so-called races of people we discussed at the beginning of this chapter when we brought up Linnaeus.

First, skin color is marginally if at all connected to other phenotypes (other than hair and eye color). While some of the genes involved in skin color might also be involved in other traits (and indeed they are to a big extent in eye and hair color) their involvement in other traits is so minimal as to be ignored. What this means is that the modern basis of racism - skin color - has little if anything to do with the traits that racists associate with groups other than their own who have different skin color, like intelligence, demeanor, athletic ability, responsibility, social involvement, crime and the like.

Second, skin color and its cousins, eye and hair color, have complex genetic architectures. There are many ways to make white skin and many ways to make black skin and these involve incredibly complex genetic interactions; ones that we may be able to decipher eventually, but ones that if given significance will simply split us into further and further smaller groups.

Finally, skin, eye and hair color are adaptive and hence have undergone rapid and fairly directed evolution enhancing those traits as visibly different. But other traits such as the ones that racists harp on are less prone to the directional and clinal selection that pigmentation has experienced, rendering racist arguments moot. On the other hand, the rapid process of cultural evolution might be more aligned with the rapid rise of skin, eye and hair color adaptation. It is well known that while the genetic biological context of race is fallacious (DeSalle and Tattersall, 2020), the cultural context is fully understandable and more significantly important. The importance lies in using culture to explore and explain our differences and not some underlying fallacious biological basis.

A Natural History of Color

In this somewhat meandering account of color here we have traversed a spectrum of topics on color phenomena. This spectrum has led us through the physics and chemistry of the early universe, where the photons responsible for our color perception started, to how color is perceived in nature, to how color helped to unlock one of the great mysteries of our planet (natural selection), to what color means to us as a species. Photons and their wavelengths are what initiate our perceptions of color. They are physical entities that our visual system collects and processes physically, biochemically, and neurologically. Our biology and the biology of most of the organisms on the planet have evolved to detect these wavelengths for a multitude of purposes. Plants, algae, and some bacteria use this stimulus for food. Animals use it for information. The evolutionary mechanisms that steadied our human visual system and color perception capacity are also very important to fully understanding a natural history of color.

We humans and indeed all living organisms are swimming in a world of information made up of small molecules, sound waves, gravity and - most importantly for color - light waves. Organisms on Earth have figured out how to use light in a wide range of ways. The broad range of uses that organisms on this planet have evolved is probably the result of the fact that there is a plethora, or a rainbow so to speak, of different wavelengths of light hitting our planet. All organisms use light to inform them of their surroundings, but some organisms use it as food for energy. Plants and some bacteria have evolved mechanisms to extract energy from light. For these mechanisms a broad range of light wavelengths are gobbled up and transformed via biochemical pathways to produce energy for the plant and certain kinds of bacteria. So, light to some organisms is food and to others a source of information. Color is a way that organisms have evolved to stretch the utility of light wave information that they are exposed to.

We humans have a stake in cutting through the information flooding us from the environment, but we have somewhat uniquely reduced the severity of consequences of faulty or slowed processing of this info. For instance, it is absolutely imperative that a small mammal in a forest process visual information nearly instantaneously and with great accuracy for its survival. Today for survival most humans simply need to know, for instance, that the white silhouette of a person on a traffic light means "walk" and an orange hand up means "don't walk". How this evolutionary give and take works in our species and in others is foundational to understanding color. Examples abound about how visual, auditory, olfactory, tactile and taste perception aid in the survival of species.

Color has grandly influenced our human behavior and sociality. We are a species driven by color in many ways, and our cultural evolution oftentimes involves color as a driving force or a cultural survival vehicle. The actual colors of human hair, eyes, and skin are wonderfully variable, but unfortunately, perverse unscientific ideas about this variation have led to some of the worst human tragedies and behavior we know of. We need to understand color in the context of what is all around us to grasp the complexity of the world we exist in.

The natural history view of how our senses, especially color vision, evolved indicates that we are in many ways very unique in how the sensory information is processed in our brains. It is also evident from Ian Tattersall's writing on human consciousness that language and all of the very human things we do around language are the most important developments in the emergence of the mind in our species. Color is a critical component of this way of communicating. As Tattersall (2014) so eloquently puts it, we are the only species on this planet that can think about thinking and in doing so create "mental constructs of alternative versions of the world." To extend the statement while we are then the only species on this planet that can see colors, we are the only one that creates mental constructs based on color. Color is a critical part of completing those alternate versions of the world that must be important to understanding our own consciousness.

References

Andersen, Christopher, Charlotte Amalie Rosenstroem, and Oleg Ruchayskiy. 2019. "How bright was the Big Bang?." *American Journal of Physics* 87, no. 5: 395-400.

Bielecki, Jan, Alexander K. Zaharoff, Nicole Y. Leung, Anders Garm, and Todd H. Oakley. 2014. "Ocular and extraocular expression of opsins in the rhopalium of Tripedalia cystophora (Cnidaria: Cubozoa)." *PLoS One* 9, no. 6: e98870.

Cuthill, Innes C., William L. Allen, Kevin Arbuckle, Barbara Caspers, George Chaplin, Mark E. Hauber, Geoffrey E. Hill et al. 2017. "The biology of color." *Science* 357, no. 6350: eaan0221.

DeSalle, Rob and Hans Bachor, 2020. *A natural history of color*. Pegasus Press (New York, NY, USA).

DeSalle, Rob and Ian Tattersall, 2023. *Understanding Race*. Cambridge University Press (Cambridge, UK).

Piccolino, Marco and Nicholas J. Wade, 2008. Galileo Galilei's vision of the senses *Trends in Neurosciences*, 31 (11)

Tattersall, Ian. 2014. "Language as a Critical Factor in the Emergence of Human Cognition." *Humana. Mente Journal of Philosophical Studies* 7, no. 27: 181-195.

How do infants and children see and think about colour?

Anna Franklin, University of Sussex

Colour is a ubiquitous feature of human perceptual experience. Colour provides cues for perceiving and understanding objects and scenes, we talk about colour, have an emotional response to colour, colour is symbolic and has a role in aesthetics. The question of how humans perceive colour is the focus of ongoing research from across many disciplines, involving a broad range of questions, from understanding the neurobiological basis of colour to the use of colour in art. Much of this research focuses on adults' perception and experience of colour. A parallel stream of research from developmental science is asking questions about colour perception in infants and children. Infants and children have both immature visual systems and less perceptual experience than adults. Investigating their colour perception has potential to provide insight into the mechanisms that underpin human colour perception, as well as the processes that drive perceptual development. Investigating colour perception in infants and children also has potential for informing infant and child centred design, and for understanding how infants and children interact and respond to the world around them.

In this talk I will review what is known about how infants and children see colour. I will identify the main take home messages from the last few decades of research, and I will also discuss recent studies from our own baby lab. I will tackle 5 main questions. First, when does trichromatic colour vision develop and how does experience shape the development of colour discrimination? Second, when do humans start to develop the ability to use colour cues to perceive and think about objects and their scenes? Third, when and how does colour categorisation develop and what are the challenges for children learning colour terms? Fourth, at what age do colour preferences appear and what influences their development? Finally, on the topic of neurodiversity, how do children with neurodevelopmental disorders perceive colour, and what impact does colour vision deficiency have on children's wellbeing and educational engagement? I will outline research that has tackled these questions, explain the methods used, and identify the issues on which further research is needed.

The overall message of the talk is that even young infants have the ability to perceive and think about colour, yet their perception of colour is rudimentary and it takes many years, even as late as adolescence, for many aspects of colour perception to mature. I show how this protracted maturation provides an opportunity to understand the relative contributions of biology, culture and environment to human colour perception. I also provide examples of how this research can be applied to the Arts and Industry, for example to ensure that products for infants and children, such as toys, books and art, are designed with their immature colour perception in mind.

Color in Layers: From Pepper's Ghost to Augmented Reality

Michael J. Murdoch, Munsell Color Science Laboratory, Rochester Institute of Technology

Abstract

Optical see-through AR presents virtual objects to a user through a transparent display that blends them with the real-world environment. This is simultaneously novel and familiar: beam splitters have been used for ghostly visual effects, and yet the mechanism is exactly the same as the reflections in an everyday window. The history of theatrical visual effects leads through a series of vision science experiments and now to research on the perception of transparent AR systems. Still, there is a tension in the perception of AR stimuli: users of AR seem to be able to separate, or scission, the layers of virtual and real, depending on their understanding of the scene and its visual characteristics.

Keywords: *AR, Color Appearance, Simultaneous Contrast, Transparency, Scission*

Introduction

Augmented reality (AR) is a tantalizing, developing technology that promises to seamlessly blend virtual, computer-generated objects into the real world. AR is already being used in industrial and medical applications, has enjoyed its first hype cycle with gaming, and will likely impact education and retail applications, among others. One type of AR, optical see-through AR (OST-AR), is implemented in a goggle- or glasses-like headset using an optical combiner such as a beam splitter to create a transparent display where virtual content can be overlaid on the real world visible behind it. Because the transparent display is unable to block out the real-world background, the appearance of AR content can vary, from apparently solid to transparent or ghostly.

Ghostly images via glass beam splitters have an interesting history in theatre, popularized in the mid-nineteenth century in London during the era of phantasmagoria. Attributed to John Henry Pepper, Pepper's Ghost is the reflected image of an off-stage, spotlighted actor who appears glowing and transparent, able to interact with and even physically pass through the other actors on the stage. The ethereal effect was a sensation at the time, offering a surprising visual experience that seemed inexplicable except by magic.

Outside the theatre, however, transparent reflections are actually no surprise at all, as they accompany everyday windows and other transparent, glass-like objects. Reflections are so ubiquitous that we usually ignore them. Transparency and alpha matting are so familiar that image manipulation software is architected around the metaphor. So, what do we expect with AR? Is it magical or familiar? Confusing or natural? In practice there is a tension between these extremes that depends strongly on the viewing situation.

Key Concepts

Transparency & Brightness

Transparency is of course a physical, material property, but it is also a percept that can be engendered by reasonable simulations of transparent layer structures, as explained by Metelli and Anderson et al. In OST-AR, the physical transparency of the display is fixed; however, the perceived transparency of presented stimuli depends on their brightness as well as the luminance contrast of the background behind. Zhang and Murdoch found that in general, the brighter the AR stimulus and the lower-contrast the background, the less transparent (equivalently: more opaque) the AR appears. The brightness dependence causes the practical limitation that it is difficult to reproduce black in AR, as darker colors become more transparent and eventually invisible. In the creation of theatre illusions, selective illumination uses invisibility to great advantage, eliminating visual cues that would expose the optical trickery. Silvia Pont et al. used illumination differences to create optical blends of transparent and opaque materials, which can be interpreted as blended meta-materials. In 2011, Kingdom reviewed the history of literature on percepts of lightness, brightness, and transparency, emphasizing the complexity of the topic and disagreement between researchers. Unfortunately, much of the relevant research questions remain unresolved.

Scission & Visual Discounting

Part of the reason that reflections in windows go unnoticed is that the layering caused by a window is usually obvious due to a range of cues including luminance differences, depth difference, motion parallax, and cognitive understanding. The resulting visual separation of layers is known as scission, and one response to scission is visual discounting, wherein the perceptual or cognitive contribution of one layer or the other is minimized to focus on the other. Gilchrist and Jacobsen showed that people have no trouble interpreting the lightness of scene objects when a layer of reflected light (or “veiling luminance”) distorts their view. Grace Moore Heider studied the visual interrelationships between veiling luminance, transparency, and scission in the 1930s, and her work has been cited by many of the researchers already mentioned.

Scission can be induced in AR by some of the same visual cues, and the result is partial-to-complete visual discounting of the background. In color perception, this means that the background color, which physically distorts the transparent AR stimulus, is nonetheless partially ignored when interpreting and matching the AR foreground color (see Hassani and Murdoch). Murdoch (2020) also found that the AR layer can be partially discounted when matching the brightness of real-world objects behind, and Zhang (2022) showed complete discounting for brightness matching tasks, meaning a textured background could be entirely ignored, despite its physical effect.

Scission and discounting may sound like excellent news, as it seems to imply that the physical limitations of transparent AR could be overcome by the power of visual perception. However, it is not so simple, and the degree of visual discounting varies immensely over different visual stimuli and experimental tasks (see Downs and Murdoch, Hassani and Murdoch). The AR research cited so far has primarily focused on understanding the variables that affect perception and scission; moving forward, one goal is a color appearance model for AR, and another goal is guidelines for AR content creators to ensure visibility, transparency, and other attributes are rendered as desired.

Simultaneous Contrast

Color perception is always contextual, and the immediate surrounding of a color stimulus has an enormous effect on its appearance known as simultaneous contrast (see Fairchild). An AR stimulus, transparent or not, may appear visually surrounded by another AR color and/or the background behind. Models of simultaneous contrast, especially chromatic simultaneous contrast, on color appearance are surprisingly rare; yet, in several of the mentioned AR studies, an accounting for simultaneous contrast has been made, but the visual effects are not fully explained, showing that the AR appearance and discounting effects are separate from simultaneous contrast (see Hassani and Murdoch, Murdoch 2020, Downs and Murdoch).

Both Kingdom and Anderson have pointed out the visual similarities between transparent-appearing stimuli, such as those discussed by Metelli, and typical examples of simultaneous contrast. In future research and model development, the similarities between these types of stimuli should be explored and modeled. It may be that a generalized visual interpretation of colors in layers helps explain both transparency and simultaneous contrast perception.

Conclusion

Layers of colors and other stimuli are ubiquitous, seen via optical reflections as well as common software implementations such as alpha matting. Spatial arrangements of color can be interpreted as stacked, transparent layers in some situations, or as single layers in other situations. In some situations, configurations of layers and transparency can be difficult to interpret, and may appear magical. Visual interpretation of AR stimuli is similarly varied: AR is compelling in part because it is novel and seems magical, yet in some cases the transparent AR stimuli are interpreted independently of the background and they appear very natural. Ongoing research aims to measure the sources and results of visual discounting effects in layered transparent AR environments that contribute to the natural or ghostly interpretations. A robust model of these results will enable proper accounting for perceptual effects, which will help ensure that AR content can be reliably, naturally, and comfortably delivered as intended to viewers in a variety of situations.

Acknowledgment

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References & Further Reading

Anderson, B. L., M. Singh, and J. Meng 2006. The perceived transmittance of inhomogeneous surfaces and media. Vision Research 46(12): 1982–1995. doi: 10.1016/j.visres.2005.11.024.

Downs, T. and M. J. Murdoch 2021. Color Layer Scissioning in See-Through Augmented Reality. *In IS&T 29th Color & Imaging Conference*.

Fairchild, M. D. 2013. *Color Appearance Models*. John Wiley & Sons.

Hassani, N. and M. J. Murdoch 2019. Investigating color appearance in optical see-through augmented reality. *Color Research & Application* 44: 492–507.

Hassani, N. 2019. *Modeling color appearance in augmented reality*. Ph.D. dissertation, Rochester Institute of Technology.

Heider, G. M. 1933. New studies in transparency, form, and color. *Psychologische Forschungen* 77, 13-55.

Kingdom, F. A. A. 2011. Lightness, brightness and transparency: a quarter century of new ideas, captivating demonstrations and unrelenting controversy. *Vision Research* 51: 652–673.

Metelli, F. 1974. The Perception of Transparency. Scientific American 230(4): 90–98. doi: 10.1038/scientificamerican0474-90.

Murdoch, M. J. 2020. Brightness matching in optical see-through augmented reality. *Journal of the Optical Society of America A* 37: 1927-1936.

Pepper, J. H. 1890. *The True History of THE GHOST; and All About Metempsychosis*. London: Cassell & Company.

Pont, S. C., J. J. Koenderink, A. J. van Doorn, M. W. A. Wijntjes, and S. F. te Pas 2012. Mixing material modes. In: *Human Vision and Electronic Imaging XVII, Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol. 8291, 82910D*. doi: 10.1117/12.916450

Zhang, L. and M. J. Murdoch 2021. Perceived Transparency in Optical See-Through Augmented Reality. In: 2021 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct): Bari, 115—120. doi: 10.1109/ISMAR-Adjunct54149.2021.00033

Zhang, L. 2022. *Lightness, Brightness, and Transparency in Optical See-Through Augmented Reality*. Ph.D. dissertation, Rochester Institute of Technology.

Requiem for a Drowning Landscape

Creative Director, J.E. Ingoldsby, ASLA, Landscape Mosaics

Abstract:

The author's work involves research, scientific collaboration, examination, documentation, analysis and synthesis using art, science, and technology for environmental advocacy. Trained in art and landscape architecture, the observation of nature and culture has been a central focus of Joseph Ingoldsby over the years. Works include Requiem for a Drowning Landscape, Spartina Winter Ice, and the Landscape Mosaics series including Leaves in Grass, and Coastal Color Palettes Installations.

Landscape Mosaics looks at the color and pattern of the Atlantic salt marsh landscape from satellite imagery to the ground plane, the study of the palette of plants within each ecosystem, and the conflicts of climate change, development, and fragmentation. Drawings and color studies developed into site installations for highlighting concerns for vanishing landscapes and endangered species. Requiem for a Drowning Landscape traces the life and death of the Atlantic salt marsh from dormancy, growth, maturation, reproduction, senescence, to death. The gallery space becomes a place for remembrance, recollection, and retelling through portraits, projections, and narration that describe the life and slow death of the coastal landscape to the rising seas. Anadromous Awakening traces out the return of anadromous fish to spawn in a cyclical celebration of life, death, and rebirth.

Keywords: *Climate Change, Ecological Art, Color*

Elegy for Coasts and Estuaries in a Changing World: The Atlantic Salt Marsh

This elegy for coasts and estuaries in a changing world must be told. There is an urgency to the storytelling. By 2100, at current rates of warming, the seas are projected to rise 24 inches along most of the U.S. coasts [1]. The increase in air temperature caused by a rise in CO_2 concentrations and other greenhouse gases will increase the snow and ice melt [2]. If the polar ice caps were to disappear, the sea level is estimated to rise 60 to 70 m higher than at present [3]. Mountain glaciers make up 1% of the volume of land ice. Their potential contribution to sea level rise is about 1 m, should their melt-water flow to the sea [4].

The rising seas will impact the salt marsh, which rings the shore and transitions and arbitrates between the land and the sea. The salt marsh of an estuary is one of the most productive zones on earth. The mixing of the tidal and fresh waters and the input of nutrients feeds a host of species, which depend on it for food and cover. The salt marsh is tough, yet fragile. It stands extremes of temperature, freezing, thawing, saturation, and drought. The plants of the salt marsh are uniquely adapted to life on the edge of the sea.

Salt marshes can be differentiated into distinct zones, which correspond to increasing elevation and decreasing durations of submergence. The lowest zone is vegetated by a variety of drifting or attached algae and eelgrass, Zostera marina. Above, a tall form of Spartina alterniflora may be found growing along the edges of channels, creek banks, and ditches.

The next highest zone is the intertidal area from mean low tide to mean high tide. This is the Low Marsh or Spartina alterniflora zone. Spartina alterniflora dominates the low marsh, where it forms dense, continuous stands.

The High Marsh is the uppermost zone of the salt marsh and is usually only centimeters higher than the Low Marsh. However, this elevation difference is enough to restrict the tidal intrusion to spring flood tides and storm tides. The lower edge of this zone may include the short form of Spartina alterniflora mixed with Spartina patens. Spartina patens (salt hay) dominate the High Marsh, where it mixes with other grasses, including Distichilis spicata (spike grass). Juncus geraldi (black rush) often indicating fresh water intrusion into the salt marsh marks the next increase in elevation, with high marsh forbs to the Iva frutescens zone. Above, in New England, is generally a forested terrestrial edge that demarcates the saltwater zones from the fresh water zone. Each zone's plant palette represents an adaptation to degrees of salinity, submersion, and elevation. The rising seas will impact the salt marsh, which rings the shore, transitions and arbitrates between land and the sea.

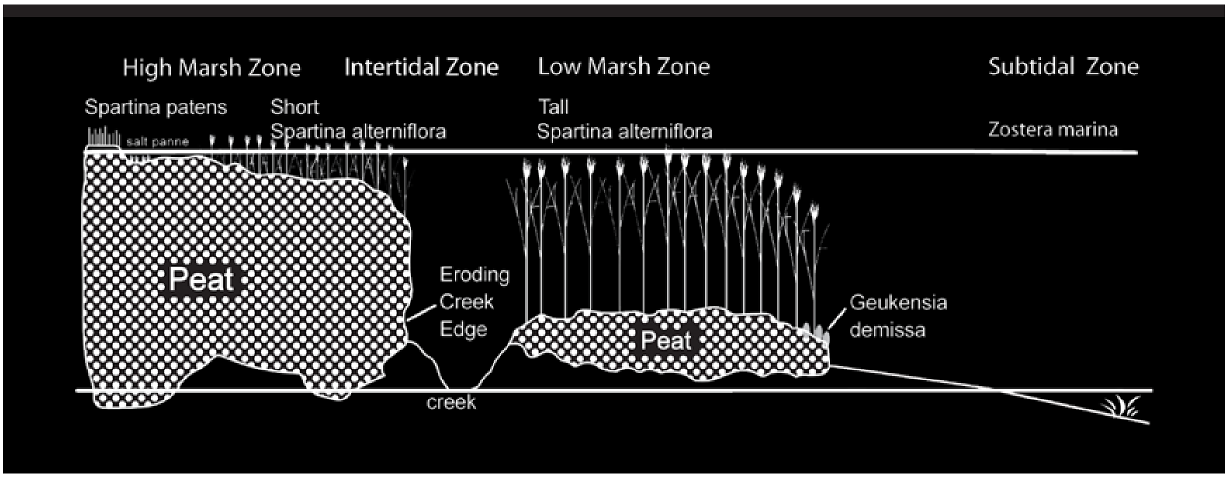


Figure 1. *Schematic cross-sectional view of salt marsh zonation with creeks, Illustration by J. E. Ingoldsby*

That narrow ribbon of marsh between land and sea is dying. What is killing the salt marsh is still not fully known. The stress of climate change, sea level rise, warming trends, drought, salinity change, with coastal development, pollution, and a constricted growing area, may develop stress related pathogens and opportunistic predation, which infect, attack and kill the salt marsh grass. The Spartina marsh is stripped bare, leaving the hollowed out memory of the marsh grass roots, which erode with each high tide as the rising tides move steadily inland inundating the high marsh. Spartina patens and Distichilis spicata of the High Marsh cannot adapt or migrate quickly enough to counter the effects of sea level rise and so the high marsh of the Atlantic coast is slowly drowning.

Climate change also affects species composition. There is scientific documentation that the southern Sasarma crab has established a beach-head at Wellfleet Bay, Massachusetts, where the crab is eating the low marsh Spartina alterniflora to bare mud, slowly stunting and killing the marsh grasses. The trophic cascade of predator and prey is out of balance. Salt marsh dieback has many causes, such as sea level rise, climate change, drought, stress pathogens, invasive species, and trophic imbalance. This is not a local problem. Scientists report salt marsh dieback from Maine to Louisiana. The end result is a loss of coastal protection, habitat, biodiversity, estuarine landscape resilience, and sustainable fishery.

Figure 2. *Salt Marsh Dieback-Trophic Cascade, Cape Cod, MA, Photographic Panel - J. E. Ingoldsby*

Art and the Environment

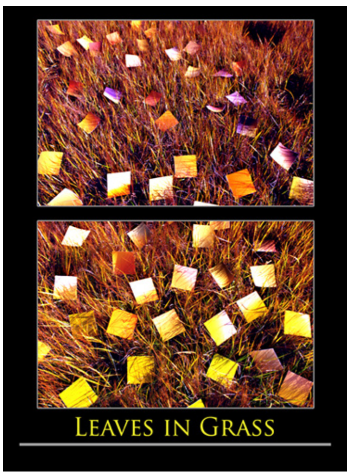
The public seems oblivious to the impending, incremental changes that reflect an imbalance in nature. Art can be used to arbitrate and communicate concerns of climate change and environmental degradation to the general public outside the confines of the gallery or museum. Often my art installations involve collaboration with scientists, governmental agencies, environmental organizations, and the community.

Spartina Winter Ice is the first in a series of environmental advocacy works I created that focus on the vulnerability of the U.S. Atlantic coastline to sea level rise. The installation documents the melting of winter ice from the Spartina patens marsh and the rising tide washing over the salt marsh on the last day of winter. Spartina Winter Ice is an animation of gridded projections, which capture images of the sunrise on the marsh and the sea level rise, from first light to high noon. The work is projected onto a corresponding grid of handmade salt marsh fiber sheets fixed to a scrim of sheer linen. The wall behind the scrim is set with a corresponding grid of coarse salt marsh fiber panels flanked by salt marsh grasses gathered from the site. The projections are sequenced to project from the top panels down and are synchronized with the recorded sound of the waves washing over the shore. Spartina Winter Ice presents a microcosm of global concerns as rising temperature, polar ice cap melting, and global sea level rise accelerate with each passing year.

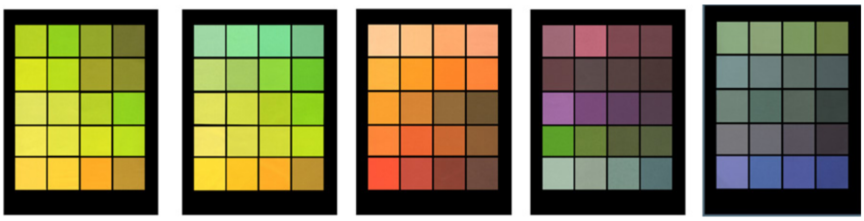
For all of its utility, few see the beauty of the salt marsh. Remember it. Soon it will be gone. For many years, I have visited the marsh and relished in its seasonal change of color and pattern. My work Landscape Mosaics has charted that change over time.

Figure 3: *Late Summer Spartina Patens Marsh*

Figure 4: *Leaves in Grass, J. E. Ingoldsby*



Through methodically charted color palettes, the work traces the growth of the marsh through the seasons using color change. This change is based on a number of scientific principles and plant physiology, including the quality, intensity, and duration of light allowing for photosynthesis. I installed hundreds of color panels, which I called pixel panels, representing the color projection of the marsh below. The colors were charted using Pantone colors held directly to the plants at fixed times of the day to reflect the altering of color with the degree of light and the span of time. The Pantone colors were then matched to custom-mixed acrylic paints applied to primed panels set into the salt marsh on thin, neutral-colored stakes. The color panels appeared to float above the sea of grass. I added additional color panels as the seasons progressed until the landscape was pixelated with hundreds of colored squares representing the mosaic of the salt marsh landscape through the seasons. Leaves in Grass is an ephemeral installation of handmade Spartina grass paper palettes embedded in an autumnal Spartina patens high marsh. With the lunar high tides, the paper palettes floated free and returned to the sea, hovering in the moonlit waters before dissolving.



Figures 5–9. *Spartina Patens Color Palettes, Spring, Summer Seeding, Autumn, Winter, J. E. Ingoldsby*

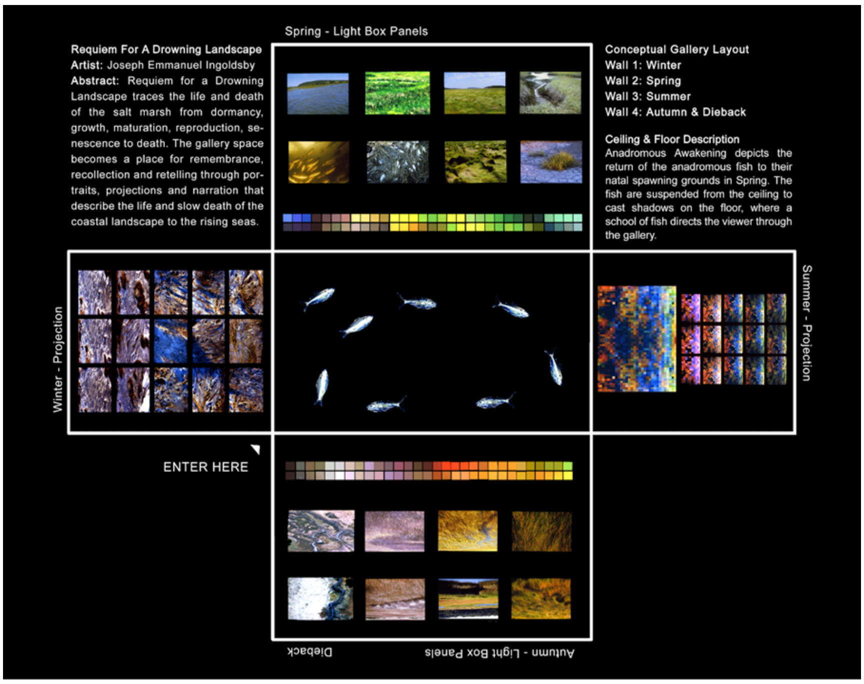


Figure 10. *Requiem for a Drowning Landscape: Remembrance, J. E. Ingoldsby, Immersive Environment*

Requiem for a Drowning Landscape

Light Box Panels: Remembrance

The projected Spartina Winter Ice is followed with a series of light box panels, tracing the seasonal progression of the salt marsh within a darkened gallery. Each panel is set with iconic photographs of color transformation in the salt marsh, representing seasonal change. Each panel is set with its corresponding color palette, representing a seasonal time expressed in colored light. Imagery and text explain and illustrate the process from dormancy, emergence, growth, reproduction, senescence, to death.

Projections: Recollection

The color timeline with staggered intervals of growth and decline is to be projected to create the colors of each season in an experiential way. Illuminated glass rods are set in a meander pattern.

Presentation: Retelling

Projection of an animated Spartina marsh summer color mosaic in a Flash format with audio

Anadromous Awakening:

Illuminated anadromous fish are suspended from the ceiling to cast shadows on the gallery floor.

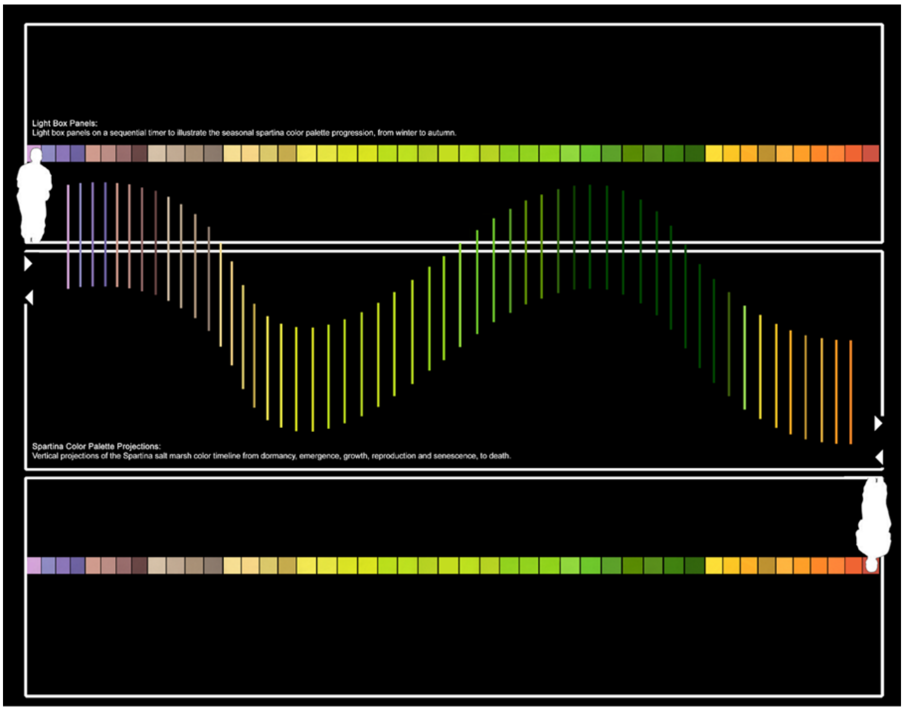


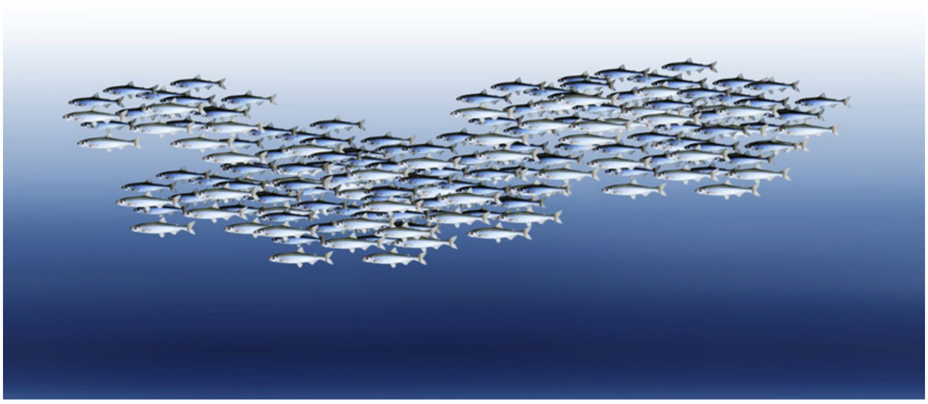
Figure 11. *Requiem for a Drowning Landscape: Recollection, J. E. Ingoldsby, Salt Marsh Color Immersive Environmental Installation with light panels and illuminated glass rods*

Recollection

Interprets the seasonal progression of the salt marsh using projected colored light in a color meander representing the staggered intervals of seasonal growth and decline in an experiential way. The installation traces out the color change from the slow breaking of dormancy in spring with the lengthening of daylight hours to a rapid state of pure luminous, green chlorophyll. By summer, the maturation of growth deepens the color. Seeding occurs in late summer into autumn and with it, the marsh transforms into a kaleidoscope of colors. The colors become muted with the shortening of daylight and the cooler night temperatures as the plants become dormant with the onset of winter.

These color projections were installed along a creek meander of the tidal North River in Scituate, Massachusetts as part of a Cyber Arts Festival in Boston. Fifteen hundred vertical posts were primed and painted with custom mixed acrylic paints with the help of students and installed into the high marsh after community and environmental reviews and permitting. The colored posts marked the seasonal progression of color and time in the salt marsh and were reflected in the waters of the rising spring lunar tides, which inundated the high marsh. There is a science to the transformation and adaptation to light.

Figure 12: *Anadromous Awakening: Fish swim over former fields, Artwork by J. E. Ingoldsby*



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References

Union of Concerned Scientists, Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions, (NECIA)

Union of Concerned Scientists, The Changing Northeast Climate, Our Choices, Our Legacy. Massachusetts, Rhode Island

New England Climate Coalition, Global Warming in the New England States

National Academy Press, Sea Level Change, Commission on Geosciences, Environment

Panel: Light, Colour, and...

Moderator: Tom Butters, Lighting Agora

Light, Colour and the Importance of Modern Lighting Metrics

Tony Esposito, Founder and Head Research Scientist of Lighting Research Solutions, Philadelphia, PA, USA

Abstract: Architectural lighting has many impacts on human visual and non-visual functioning. One important impact, driven by light's intensity and spectrum, is the color rendering of objects. In this brief talk, I will attempt to convince you that good light source color rendition is critically important in the built environment. IES TM-30, a color rendering system from the Illuminating Engineering Society, will be briefly discussed.

Light, Colour and Health

Mariana G. Figueiro, Director of the Light and Health Research Center at Mount Sinai and Professor in the Department of Population Health Science and Policy at the Icahn School of Medicine, New York, NY, USA.

Abstract: In addition to its well-known visual effects, light can also elicit a direct (acute) and a phase shifting (alter the timing of the biological clock) effect on humans. These are typically referred to as the "non-visual effects of light". This presentation will provide an overview of the impact of light color on the direct and phase shifting effects of light and demystify the notion that all we need is blue or "blue-enriched" lights to elicit these non-visual effects on humans.

Light, Colour and Design

Deborah Gottesman, Principal, Gottesman Associates

Abstract: How do humans sense colour? Seeing colour accurately is intricately related to the light source. Deborah will discuss how humans perceive colour, introduce some colour metrics, and what is required to sense colour accurately. The discussion will be rounded out by showing how colour can be leveraged to advantage in design.

Light, Colour and Application Strategies from Classrooms to Patient Rooms

Patricia Rizzo, Healthcare Segment Manager at Axis Lighting

Abstract: The colour of light can play a more important role than we realize in our everyday lives – not only for overall circadian health and wellbeing, but for safety as well. When we weave colour purposefully into the design of a space, we can positively affect a child's classroom experience, and we can minimize the risk of falls for patients or older adults as they navigate from bed to bathroom across a range of healthcare facilities. We will look at these two very different environments, and also see how research and real-life conditions have influenced product design to enable these applications.

Special Invited Lectures

Gathering Colour

Anong Migwans Beam, Independent Artist

Many of my earliest memories are encountering colour with my parents, both practicing artists, and learning to know them as forces, personas with emotions and powers all their own. At three years old, I remember standing on a black paved driveway with my mother standing adult-tall above me. We were both looking up into a canopy of spring green maple leaves, the sun gleaming through them. I asked, "What colour is that?" and she said, "Chartreuse." I stood feeling full of the gleaming gold colour, smelling the spring green scent of evaporating rain from pavement and leaves. I wanted to know the colour and there, sitting at the base of the tree, I ate the sprouts of budding spring maple and knew the taste of green.

I learned how to collect pigment with my father in the La Cloche mountain range close to home. He taught me how our ancestors made paint to make "mizzins" designs on rock faces with hematite to share their histories, proud moments, and cautions. Now in my adult life I have returned to this practice with children of my own, experiencing making paint and colour with them. I have given myself the authority of my experience, and as a paint maker I have decided to name all my colours in my own language. The act of printmaking has continued to be a powerful shamanic act for myself as I learned it from my father, and now I share it with other artists. Giving names to the colours is claiming an experience of the world, saying that it is not just the purview of European colour men and that tradition but also my own, which includes them and encompasses more, giving back to all creative people an experience of colour that grounds them in this land and all the stories it holds.

LECTURE JUNE 13 Gathering Colour: Anong Migwans Beam

(in-person and live-streamed)

The CRSC thanks the AGO, Canada Council and OCADU Research and Special Events for supporting this Keynote public lecture that opened AIC 2022. the evening before the conference started.

Event archive :https://ago.ca/events/gathering-colour-anong-migwans-beam

Humanae: Celebrating How Colourful We Are

Angélica Dass, Independent Artist

Humanæ is a photographic work in progress by artist Angélica Dass, an unusually direct reflection on the color of the skin, attempting to document humanity's true colors rather than the untrue labels "white", "red", "black" and "yellow" associated with race. It's a project in constant evolution seeking to demonstrate that what defines the human being is its inescapably uniqueness and, therefore, its diversity. The background for each portrait is tinted with a color tone identical to a sample of 11 x 11 pixels taken from the nose of the subject and matched with the industrial palette Pantone®, which, in its neutrality, calls into question the contradictions and stereotypes related to the race issue. More than just faces and colors in the project there are almost 4,000 volunteers, with portraits made in 20 different countries and 36 different cities around the world, thanks to the support of cultural institutions, political subjects, governmental organizations and non-governmental organizations. The direct and personal dialogue with the public and the absolute spontaneity of participation are fundamental values of the project and connote it with a strong vein of activism. The project does not select participants and there is no date set for its completion. From someone included in the Forbes list, to refugees who crossed the Mediterranean Sea by boat, or students both in Switzerland and the favelas in Rio de Janeiro. At the UNESCO Headquarters, or at a shelter. All kinds of beliefs, gender identities or physical impairments, a newborn or terminally ill, all together build Humanae. All of us, without labels.

Currently more than 4000 images exist in the project. They have been taken in 36 cities, in 20 different countries: Arteixo, Madrid, Barcelona, Getxo, Bilbao and Valencia (Spain), Paris (France), Bergen (Norway), Winterthur, Chiasso (Switzerland), Groningen, The Hague (Netherlands), Dublin (Ireland), London (UK), Tyumen (Russia), Gibellina and Vita (Italy), Vancouver, Montreal (Canada), New York, San Francisco, Gambier, Pittsburgh and Chicago (USA), Quito (Ecuador), Valparaíso (Chile), Sao Paulo and Rio de Janeiro (Brazil), Córdoba (Argentina), New Delhi (India), Daegu (South Korea) Wenzhou and Shanghai (China), Ciudad de México, Oaxaca (Mexico) and Addis Abeba (Ethiopia).

LECTURE JUNE 16 Angélica Dass: Humanæ: Celebrating How Colourful We Are

WORKSHOP JUNE 18 Angélica Dass: Flesh Colour: The Colors We Share

The CRSC thanks the Art Gallery of Ontario, the Canada Council and OCADU Research and Special Events for supporting Angelica's participation in AIC 2022.

Events Archive at AGO https://ago.ca/events/archive?search=angelica%20dass&field_agoc_year_filter_target_id=3751&field_agoc_event_category_target_id=All&media_type=All

Oral Papers

Session 1
Colour Science 1

Color Materials and Techniques in John Gould's "Folio Bird Books"; A Comparison with R.P. Lesson's "Histoire Naturelle des Oiseaux Mouches"

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Abstract

English naturalist John Gould (1804-1881) produced a number of "Folio Bird Books" between 1831 and 1888. "Folio Bird Books" depicts the ecology of birds in hand-colored lithographs based on scientific research. Tamagawa University Museum of Education has a main collection of Gould's "Folio Bird Books." Gould collected bird specimens and made observations of them in producing "Folio Bird Books." Therefore, he might select color materials and techniques to precisely depict the characteristics of the birds. However, the color materials and techniques used in their production are still unclear. In this study, we investigated color materials and techniques for "Purple-throated Carib" and "Purple-backed Thornbill" in "A Monograph of the Trochilidae, or Family of Humming-birds" using a two-dimensional spectroradiometer, an X-ray fluorescence (XRF), and a digital microscope. In the "Purple-backed Thornbill," the digital microscopy and the XRF revealed the use of gold. The results of the Spectral reflectance and XRF analysis show that the green color materials used in the "Purple-throated Carib" and "Purple-backed Thornbill" can be classified into three types. We also conducted research on René Primevère Lesson's "Histoire Naturelle des Oiseaux Mouches," which preceded Gould's "Folio Bird Books," and compared the color materials and techniques.

Keywords: *color materials, two-dimensional spectroradiometer, X-ray fluorescence, John Gould's "Folio Bird Books"*

Introduction

The British naturalist John Gould (1804-1881) produced a number of "Folio Bird Books" published between 1831 and 1888, which are known as one of the most representative natural history books of the 19th century. The highly praised books of natural history combined artistry and science with their precise depiction of birds and sensitive color expression. These hand-colored works were produced using lithographic techniques developed at the time. The total number of illustrations in the 40 volumes is about 3,000, and most of them were produced in a large format called Imperial Folio Prints. “A Monograph of the Trochilidae, or Family of Humming-birds,” which contains natural history drawings on the theme of hummingbirds, is a large-scale natural history illustrated book consisting of five volumes and one supplementary volume, with a total of 400 illustrations. Gould was fascinated by hummingbirds and collected many specimens.

Tamagawa University Museum of Education in Japan has a collection of the main volumes of Gould's “Folio Bird Books,” and Kakizaki and Kuroda have been investigating these works from the perspective of art history and ornithology (Norinomiya (2005), Hasegawa and Kuroda (2017)). However, the coloration of these works has not yet been researched from the view of color science. Since “Folio Bird Books” were produced as academic natural history catalogues, Gould made careful observations of specimens and actual birds during their production. Gould’s “Folio Bird Books” were drafted by Gould, and the original drawings were done by artists in his atelier under his direction. It is highly probable that Gould made his choice of color materials and techniques from the perspective of precisely reproducing the characteristics of each bird, such as the color and luster of the feathers.

The purpose of this study is to clarify the color materials and techniques used in the painting of Gould's “Folio Bird Books.” The color materials and techniques used for “Purple-throated Carib” in volume 2 and “Purple-backed Thornbill” in volume 3 of “A Monograph of the Trochilidae, or Family of Humming-birds” will be reported. Some of the results were compared with the “Histoire Naturelle des Oiseaux Mouches” produced in 1830 - 1832 by René Primevère Lesson (1794-1849) in the collection of the Tamagawa University Museum of Education. “Histoire Naturelle des Oiseaux Mouches” is the world's first monograph on hummingbirds, preceded by Gould's Folio Bird Books. It contains 110 illustrations of hummingbirds, printed using copperplate engraving techniques and hand-colored. The results of this study prompt a re-evaluation of the significance of Gould's “Folio Bird Books” and 19th century natural history.

Materials and Methods

We conducted research on “Purple-throated Carib” (length 53.7 cm, width 36.0 cm) and “Purple-backed Thornbill” (length 56.0 cm, width 38.5 cm) from John Gould's “A Monograph of the Trochilidae, or Family of Humming-birds”. The survey was also carried out on “Oiseau-mouche Rivoli” (length 22.7 cm, width 14.7 cm) and “Oiseau-mouche Anna” (length 22.7 cm, width 14.7 cm) from the “Histoire Naturelle des Oiseaux Mouches” produced by Lesson. These works are from the collection of the Tamagawa University Museum of Education. Figure 1 shows images of the works.

The spectral reflectance ratios of the color materials were measured using two-dimensional spectroradiometers (SR-5000 and SR-5100, TOPCON). The compositions of the materials were determined by X-ray fluorescence (XRF, XL3t-900S-M, Thermo-Niton). In addition, the works were observed with a digital microscope (VHX-970F, KEYENCE).

Figure 1. The images of the works, (1) “Purple-backed Thornbill,” (2) “Purple-throated Carib,” (3) “Oiseau-mouche Rivoli,” and (4) “Oiseau-mouche Anna.”

Results and Discussion

In “A Monograph of the Trochilidae, or Family of Humming-birds,” it has been pointed out that some pictures might be colored with gold to depict the metallic luster of the hummingbird's feathers. However, the materials and techniques used have not been clarified. In “Purple-backed Thornbill,” metallic luster was observed in an area shown in Figure 2 (A). Observation using the digital microscope of areas showing luster confirmed the use of a material that appeared to be gold foil. In the XRF spectrum of the measurement point (A), Au was detected. On the other hand, metallic luster was also visually confirmed at the point (B) of “Purple-throated Carib” shown in Figure 2 (B), but no metal-derived element was detected. Digital microscopic observation of point (B) revealed that the green and yellow color materials were used to produce a metal-like texture.

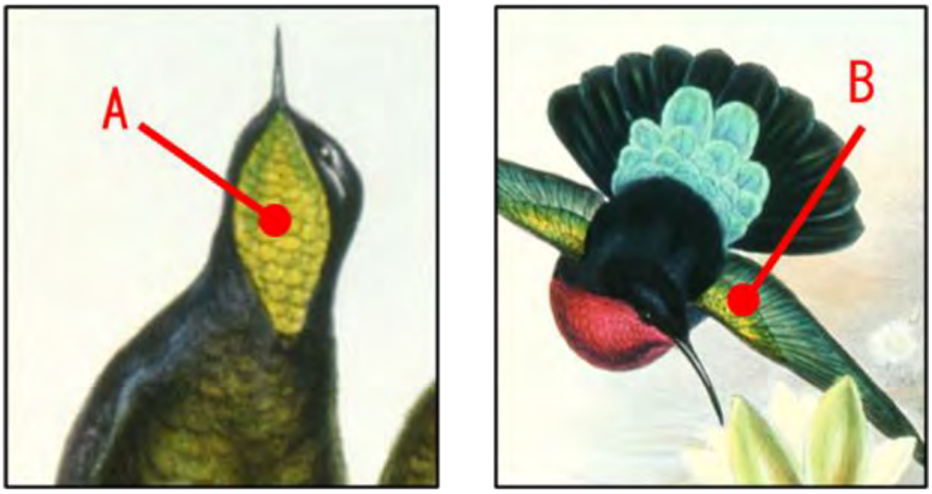

Figure 2. Areas where metallic luster can be observed, (A) “Purple-backed Thornbill,” (B) “Purple-throated Carib.”

Figure 3 (a)-(c) shows the spectral reflectance ratios and the measurement points in “Purple-backed Thornbill” and “Purple-throated Carib” where a green color material was used; (a) upper tail covert of Purple-throated Carib, (b) wing-coverts and wings of Purple-throated Carib, (c) head of Purple-backed Thornbill. The measurement revealed that the point (a) has a peak of the spectral reflectance ratio around 510 nm, the point (b) has a peak around 520 nm and the point (c) has a peak around 540 nm. Cu and As were detected using XRF measurement in the point (a), but no element derived from color material was detected in the points of (b) and (c), probably due to the use of dyes. These results indicate that Gould used different color materials and different techniques in the production of the “A Monograph of the Trochilidae, or Family of Humming-birds.” Since the green color might be mixed with blue or yellow color materials, we plan to identify the color materials using analytical methods such as X-ray diffraction.

On the other hand, digital microscopy and XRF measurements of Lesson’s “Oiseau-mouche Anna” and “Oiseau-mouche Rivoli” revealed that no gold foil was used. Digital microscope observations were also used to measure the differences in outlines by Gould and Lesson. Gould's “Folio Bird Books” were produced using lithography whereas Lesson's “Histoire Naturelle des Oiseaux Mouches” was produced using copperplate engraving. Kakizaki conducted research on the sketches, original drawings and lithographs used by Gould's atelier to create the “Folio Bird Books” in the collection of the Kenneth Spencer Research Library at the University of Kansas, and restored the lithographic technique based on the results. In the process of reconstruction, he found that Gould may have chosen the lithographic technique to depict the softness of the feathers. In addition, the optical microscopic and spectral colorimetric observations show a possibility that Gould chose the lithographic technique for his faithful depiction of birds.

Figure 3(d)-(f) shows the results of the spectral reflectance measurements of the green areas of “Oiseau-mouche Anna” and “Oiseau-mouche Rivoli”; (d) throat of Oiseau-mouche Rivoli, (e) wings of Oiseau-mouche Rivoli, and (f) head of Oiseau-mouche Anna. The spectral distribution of the (d) is similar to (a), and that of (e) is similar to (c). The spectral reflectance ratio showed a flat shape in (f). These results suggest that Lesson, as well as Gould, selected color materials depending on the characteristics of the birds.

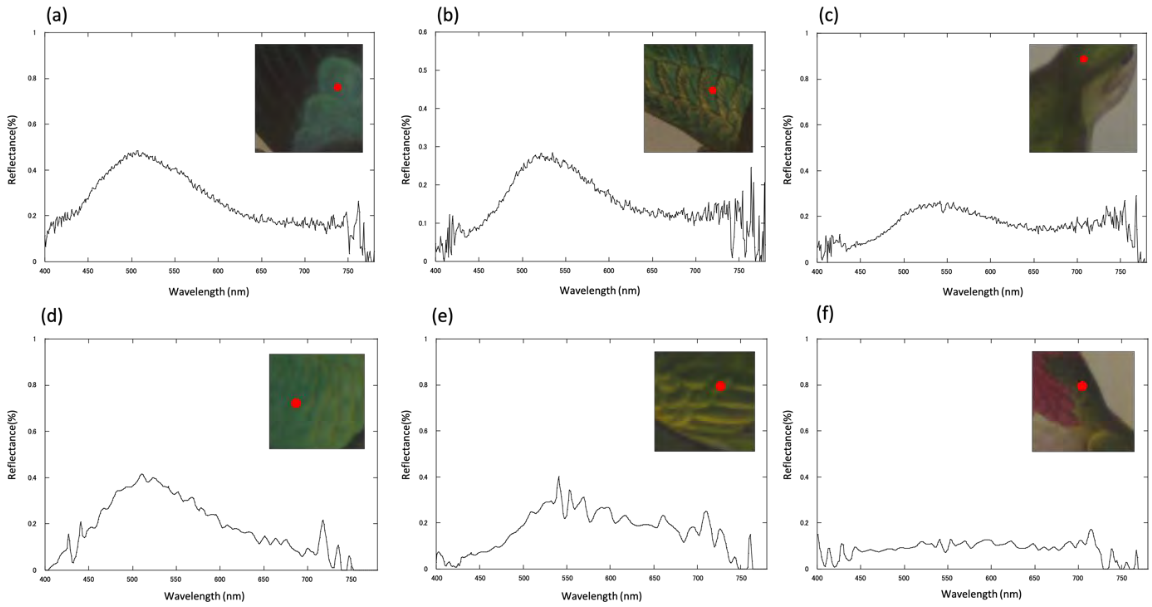

Figure 3. Spectral reflectance ratios of the areas where green color material was used, (a) upper tail covert of Purple-throated Carib, (b) wing-coverts and wings of Purple-throated Carib, (c) head of Purple-backed Thornbill, (d) throat of Oiseau-mouche Rivoli, (e) wings of Oiseau-mouche Rivoli, and (f) head of Oiseau-mouche Anna.

Conclusions

X-ray fluorescence analysis and spectral reflectance measurement revealed that Gould used different color materials to depict the bird's features. In addition, the lithographic technique and use of gold leaf were thought to contribute to Gould's lively depiction of birds. We will continue our research on color materials and techniques for other illustrations in “A Monograph of the Trochilidae, or Family of Humming-birds.”

Acknowledgements

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References

Hasegawa, M. and S. Kuroda. 2017. Phylogeny mandalas of birds using the lithographs of John Gould's folio bird books. *Mol Phylogenet Evol*. 117: 141-149.

Norinomiya, S., ed. 2005. *Catalogue of the birds in John Gould's folio bird books*. Tokyo: Tamagawa Daigaku Shuppanbu.

Tamagawa University Museum of Education. 2011. *The birds were drawn on stones: John Gould's folio bird books.* Tokyo: Tamagawa University Museum of Education.

Tamagawa University Museum of Education. 2019. *John Gould's folio bird books: illustrated birds of the world in the 19th century.* Tokyo: Tamagawa University Museum of Education.

Texture Management for Glossy Objects Using Tone Mapping

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Abstract

In this paper, we proposed a method for matching the color and glossiness of an object between different displays by using tone mapping. Since displays have their own characteristics, such as maximum luminance and gamma characteristics, the color and glossiness of an object when displayed differs from one display to another. The color can be corrected by conventional color matching methods, but the glossiness, which changes the impression of an object, needs to be corrected. Our practical challenge was to use tone mapping to correct the high-luminance part, also referred to as the glossy part, which cannot be fully corrected by color matching. Therefore, we performed color matching and tone mapping using high dynamic range images, which can record a wider range of luminance information as input. In addition, we varied the parameters of the tone- mapping function and the threshold at which the function was applied to study the effect on the object's appearance. We conducted a subjective evaluation experiment using the series category method on glossy-corrected images generated by applying various functions to each display. As a result, we found that the differences in glossiness between displays could be corrected by selecting the optimal function for each display.

Keywords: *Tone Mapping, Color Matching, Glossy, High Dynamic Range*

Introduction

In recent years, the use of video communication has increased rapidly due to the spread of new coronavirus infections. Video communication systems are being introduced by many companies because they can be easily implemented using familiar devices without the need for new specialized devices or systems. Currently, online business negotiations are also used in automobile purchases, where users check the condition of a car through images and videos without seeing the actual car, and in some cases, make purchases. However, current video communication systems may give different impressions from actual colors and textures, depending on the user's environment. In particular, the color and texture of objects play a very important role in telemedicine, online business negotiations, and meetings conducted through video communication, so it is necessary to accurately convey information about patients and products. If the color or texture of an object is different from that viewed by the other party, it may lead to serious problems such as cancellation of the transaction or misdiagnosis. In video communication, one of the possible causes for differences in color and texture is the effect of differences in displays. Since each display has different characteristics, such as maximum luminance, gamma, and color gamut, it is not always the same—even if the same image is displayed.

In this study, we propose a method for matching the color and texture of objects between different displays by using tone mapping. In addition, we focused on glossiness among the different textures. Since glossiness is mainly affected by changes in the maximum luminance of the display showing the object, a display method that does not depend on changes in the viewing environment is required for products for which visibility of color and gloss is important, and for human skin in telemedicine. We analyzed the perception of texture and implemented a method for correcting the glossiness of a real object with gloss. For display-independent color reproduction, Takahashi et al. proposed a color reproduction method using a color chart to improve the color quality of telemedicine systems. In their study, based on the color chart, the images sent from the patient side were color corrected and displayed on the doctor's display to enable accurate diagnosis in telemedicine. The flow of such a system is shown in Figure 1.

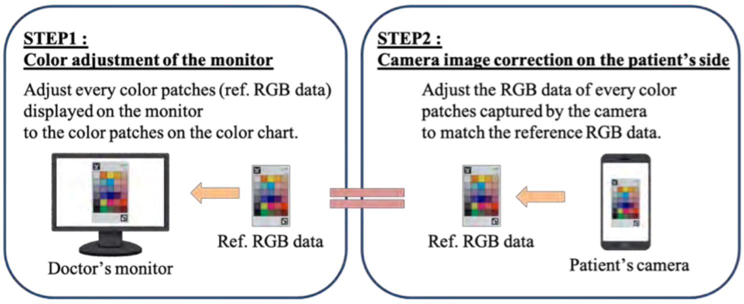

Figure 1. Overview of the automatic color correction method.

Materials and Methods

Correction Procedure

In this study, we aim to correct the color reproduction and glossiness of objects between different displays. As a method for reproducing the color of objects, we use color matching, using the color chart. In conventional color matching, processing is based on the color gamut of the color chart; therefore, if saturated areas exist in the image, then processing cannot be performed appropriately. In this case, information from high-luminance areas may be lost and the glossiness may change. Therefore, to achieve a representation that is similar to the real object, we used high-dynamic range (HDR) images, which can retain a wide range of luminance information and glossy information without degradation. As an HDR image cannot be displayed on a normal low-dynamic range (LDR) display, it is compressed to a dynamic range that can be displayed on an LDR display by applying tone mapping. Many methods of tone mapping have been proposed in the past. By applying a tone mapping function to the entire image, the luminance of high-luminance areas is reduced and that of low-luminance areas is increased, thus allowing the entire image to be represented without losing any information. However, when correcting the glossiness of an image, reducing the luminance of the high-luminance areas may result in loss of the glossiness of the image. Therefore, the proposed method performs color matching on the HDR image to accurately reproduce colors, and then applies tone mapping only to the glossy areas of the subject to correct the glossiness across different displays. The reference display is the iPhone7, and the target displays to be matched are the Xperia1 and FireHD8. The object is a decorative bell with a glossy surface.

Color Matching for HDR Images

An HDR image is an image that can represent the entire luminance range and color gamut of a real scene as perceived by the human eye. Since it can handle images with a high contrast ratio as the naked eye does, color matching using HDR images as input can reproduce colors while retaining the glossy information of the object in the image.

First, to create a HDR image, we performed HDR synthesis, which is a technique for creating a HDR image by combining the best dynamic range of multiple images taken at different exposure times. In this paper, we used exposure fusion. This method extracts information such as luminance, saturation, and contrast from each image, and combines them according to the weight assigned to each pixel in each image so that only the best part is retained. The images used for HDR synthesis were taken with a digital single-lens camera (SONY ILCE-5100, resolution 6000×4000 px, Sony, Minato City, Tokyo, Japan) under the same shooting conditions, except for the exposure time. The object and the color chart were photographed at the same time to perform color matching. The color chart used is a special color chart that does not bend under normal use and is printed on a special matte paper using an industrial inkjet printer. The three images taken are shown in Figure 2 and the HDR image based on them is shown in Figure 3. The exposure time was 1/8 s, 1/60 s and 1/125 s, respectively, and the images with a relatively short exposure time and without saturated glossy areas were used. The resulting HDR image can hold a wider range of luminance than a normal LDR image, so it is believed that the information in the glossy areas was recorded.

Color matching was performed on each target display using the generated HDR image as input. We used a color luminance meter CS-100A from KONICA MINOLTA to measure the color of the color charts and displays. The color matching results for the iPhone7, Xperia1, and FireHD8 are shown in Figure 4.

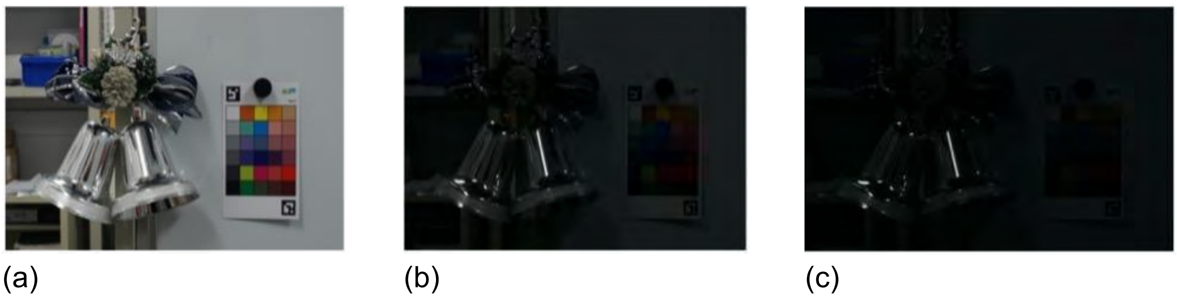

Figure 2. Images with different exposure times. (a) 1/8 s; (b) 1/60 s; (c) 1/125 s.

Figure 3. Generated high dynamic range image.

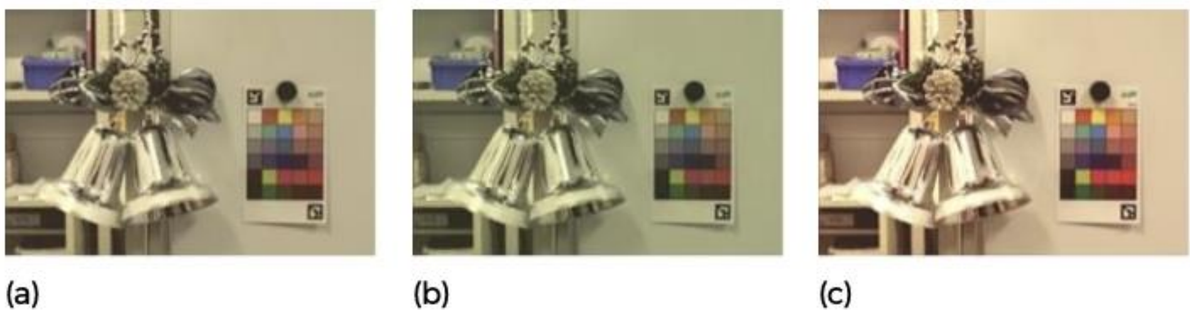

Figure 4. Color matching images. (a) iPhone7; (b) Xperia1; (c) FireHD8.

Figure 5 shows the color matching images displayed on each display, and Figures 6(a)-(c) compares the actual color chart with the color chart on each display. Comparing Figures 6(a)-(c), we can see that the colors appear to vary with the different displays, but when these images are displayed on each display, as shown in Figure 5, the color differences between the displays almost disappear visually, indicating that the color matching is executed accurately. In addition, as shown in Figure 6, the accuracy of the color matching is sufficient when compared with the actual color chart.

Figure 5. Color matching images displayed on each display.

(a) (b) (c)

Figure 6. Comparison of the actual color chart and that on each display. (a) iPhone7; (b) Xperia1; (c)FireHD8.

Generation of Glossy-Corrected Images

In the tone mapping process, since the dynamic range in a color image mainly affects the luminance information, it is necessary to keep the chromaticity information consistent to create a visually natural image. Therefore, we converted images from the RGB color space to the YUV color space to separate luminance and chromaticity information. Studies based on cone responses have shown that the human eye is sensitive to changes in luminance but insensitive to changes in color, since contrast sensitivity involves a higher resolution than color contrast sensitivity. Hence, in the YUV color space, chromaticity is suppressed, and a wide bandwidth as well as the number of bits are allocated to luminance. By processing only luminance component Y in the YUV color space, we can adjust the dynamic range without affecting the chromaticity information.

If the conventional tone mapping function shown in Figure 7(a) is applied, then non-linear processing is also applied to the area where colors are corrected (i.e., the area that corresponds to the color gamut of the color chart), and changes may occur in the area where colors are corrected by color matching. Therefore, to compress the dynamic range while preserving the results of the color correction by color matching, we use a tone mapping function, as shown in Figure 7(b). The color-corrected portion is compressed linearly, and an arbitrary tone curve is applied only to the glossy portion, which is outside the gamut of the color chart, i.e., where white blur occurs, to correct the glossiness of the object. Since the color matching method used in this study is based on a color chart, the color correction can be applied only within the color gamut of the color chart used. However, the glossy part of the object was very bright and did not fit within the color gamut of the color chart, so this method was effective. For the arbitrary functions in the tone curve, we applied the gamma function and the logarithmic function, which are also used in general tone mapping. By varying the parameters in the function and the threshold for applying the function to the luminance component, multiple glossy corrected images are generated for each display.

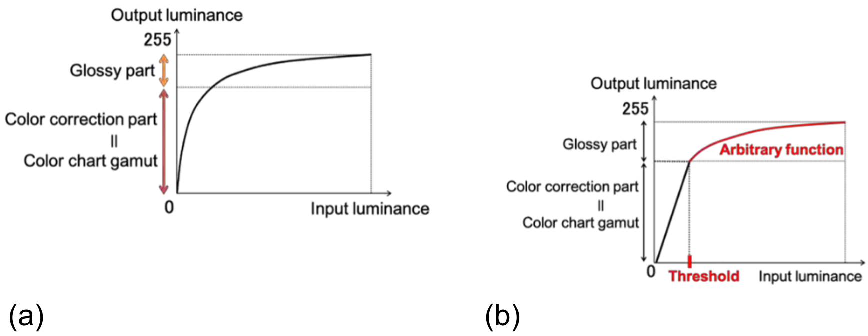

Figure 7. Tone mapping function. (a) Conventional tone mapping function; (b) Proposed tone mapping function.

Results

Procedure of Subjective Evaluation Experiment

To select the best tone mapping function for each display and to verify the effectiveness of the proposed method, we conducted a subjective evaluation experiment. In the method for this experiment, images are displayed on two displays and presented to the subject simultaneously. Then, images with only color matching applied to the reference display, as well as images with color matching and tone mapping applied to the target display, are displayed, and evaluated. As mentioned above, the reference display is an iPhone7 and the target displays are an Xperia1 and FireHD8. The evaluation item is the consistency of glossiness compared to the reference, and the evaluation scale is shown in

Figure 8; o indicates images where the glossiness of the object displayed on the target display is consistent with the reference display, +1, +2, +3 indicates images where the glossiness is stronger than the reference, and -1, -2, -3 indicates images where the glossiness is weaker than the reference. The observers were asked to rate the glossiness of an object displayed on a target display with respect to a reference display on a scale of -3 to 3. We asked the observers to focus on a certain object in the image by instructing them to focus on the bell in the image and evaluate its glossiness. Moreover, we did not ask the observers to disregard the color differences remaining after color matching; however, we asked the observer to focus on the appearance of the gloss. This experiment was conducted in the environment shown in Figure 9, with the distance between the subject and the display set at 70 cm. The experimental environment was set to be the same as that used for measuring the brightness of the color chart and the display. The subjects were seven male and female students in their 20 s, and the evaluation time was unlimited. The evaluation targets were 38 images for Xperia1 and 39 images for FireHD8. Regarding the characteristics of the three devices, the maximum luminance was 624, 391, and 534 cd/m^2 for the iPhone7, Xperia1, and FireHD8 displays, respectively.

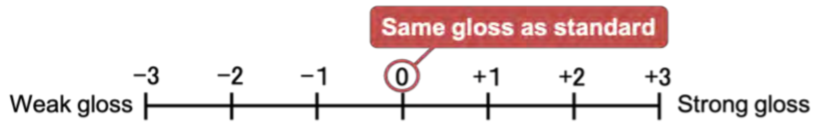

Figure 8. Rating scales.

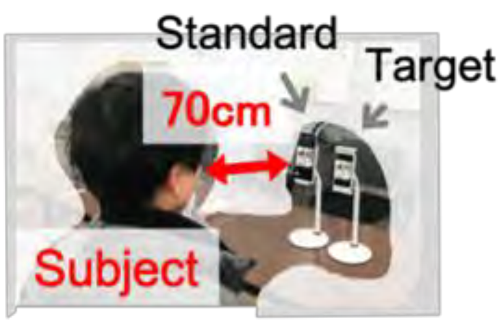

Figure 9. Experimental condition.

Results of Evaluation Experiment

Figure 10 shows the results of the six images with the best evaluation among all images. For the glossiness evaluation in this study, the image with the mean evaluation value closest to 0, without any positive or negative variation among subjects, is the best. The image with logarithmic function processed with a parameter of 3.0 and a threshold of 0.9 was the one with the mean value closest to 0 on the Xperia1. In this case, the evaluation mean value was 0.186. On the other hand, the image processed with the gamma function with a parameter of 0.5 and a threshold value of 0.85 had a mean value of 0.279, which was the closest to 0 on the FireHD8. The images are shown in Figures 11(a) and (b). The experimental results show that it is possible to correct for glossiness by selecting the optimal tone mapping function that differs for each display.

(a) (b)

Figure 10. Results of the evaluation experiment. (a) Xperia1; (b)FireHD8.

(a) (b)

Figure 11. Gloss-corrected images with the best evaluation. (a) Xperia1; (b) FireHD8.

Discussion

The effect of tone mapping depends on the parameters of the function, the threshold value, the reflection characteristics of the object, and the characteristics of the display. Therefore, it is necessary to select an appropriate tone mapping function for each object and each display. In this study, we applied several functions to specific objects and selected the best function based on the results obtained from subjective evaluation experiments, but it is impossible to select the best function for other objects or displays. Therefore, it is necessary to develop a method that can automatically select the function that outputs the optimal image according to the object and display and adjust these parameters. In the future, we will conduct experiments with more objects and displays to increase the data and then apply the method to machine learning. We will analyze the correlation between the glossiness evaluation and characteristics such as the maximum luminance of each display, and aim to automatically select the optimal function. In this study, the white point and gamma values, except for the maximum luminance of the display, could not be obtained. Therefore, characteristics associated with the abovementioned values should be obtained and described in the future to present more comprehensive results.

In this subjective evaluation experiment, we assumed that the iPhone7, which is the reference display, had the same glossiness as the real object, and compared it with the target display. However, the glossiness of the actual object and the object on the display must match, so it is necessary to evaluate the actual agreed to the comparison in the future.

References

BCC Research, Global Markets for Telemedicine Technologies.

Online: https://www.bccresearch.com/market-research/ healthcare/global-markets-for-telemedicine-technologies.html

Nishibori, M. 2000. Problems and solutions in medical color imaging. In Proceedings of the Second International Symposium on Multispectral Imaging and High Accurate Color Reproduction: 9-17

John, P., A. B. Paul, and D. S. Jolene. 2014. Color error in the digital camera image capture process. *Journal of Digit. Imaging* 27: 182-191.

Takahashi , M., R. Takahashi, Y. Marihara et al. 2020. Development of a camera-based remote diagnostic system focused on color reproduction using color charts. *Artif. Life Robotics* 25: 370-376.

Imai, H. I., N. Tsumura, H. Haneishi, and Y. Miyake. 1996. Principal Component Analysis of Skin Color and Its Application to Colormetric Color Reproduction on CRT Display and Hardcopy. *J. Imaging Sci*. Technol 40: 422-430.

Philips , J. B., J. A. Ferwerda, and S. Luka. 2009. Effects of image dynamic range on apparent surface gloss. In *Proceedings of the Color and Imaging Conference. Society for Imaging Science and Technology* 17: 193-197.

Mertens, T., J. Kautz, and F. Van Reeth. 2009. Exposure Fusion: A Simple and Practical Alternative to High Dynamic Range Photography. *Comput. Graph. Forum* 28: 161-171.

Image Based Measurement of Augmented Reality Displays and Stimuli

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Abstract

Perceptual research of see-through augmented reality (AR) displays faces many challenges in the design of display stimulus and viewing conditions for effective psychophysics experiments due to the many known and unknown factors that can affect the appearance of transparent stimuli. The decisions made about the stimulus presentation may be very difficult to document in a simple or intuitive way and very few tools for describing and designing experiments for AR displays exist. In this paper we describe an application specific imaging technique for documenting visual experiments for AR displays. Imaging these stimuli presentations simplifies the recording of the known stimulus presentation factors, as well as recording factors that may become relevant for future comparative studies.

This imaging technique borrows inspiration from other multi-channel imaging approaches. Besides the application needed in AR, the design of this imaging technique might be applied to many other areas of imaging where only a specific application is required, and color accuracy must be as high as possible. The approach used here, with the particular application factors described, resulted in an imaging system capable of imaging AR stimulus presentations with an accuracy of around 1 ΔE 2000.

Keywords: *Multichannel Imaging, Augmented Reality, Experiment Design, Image Based Color Measurement, Color Science*

Introduction

Vision science research of augmented reality (AR) displays often requires careful measurement of several properties including spectral or colorimetric measurements of an emissive display, background elements and their spatial arrangement. The authors demonstrate that image-based multispectral measurement techniques commonly used in cultural heritage imaging can successfully be used to measure the colorimetric and spatial properties of AR displays, with an average color accuracy of 1 ΔE2000. This technique is appropriate for experiments studying larger effect sizes and can be easily combined with spectroradiometer measurements for studying smaller effect sizes.

Augmented reality refers to the usage of a transparent display device to overlay information, images, or other visual stimuli on the real world. Because the display is transparent, the observer can see both the background colors present in real reality and the colors presented on the transparent display. The light that reaches the eye, the proximal color, is the additive combination of these two sources. However, research has shown that the perceived color is quite different from this physical / proximal color in augmented reality contexts, Downs (2021), Zhang (2021), Murdoch (2021). Perceived color of AR displays is an important area of study, and as such tools are needed for characterizing, verifying, and recording the stimuli used in visual experiments.

The stimuli used in an AR study may take several forms including interactive virtual objects, simple virtual color patches, textures, or full images. The shape and form of the virtual stimuli as well as the colors and textures of the background stimuli all play a role in creating the perception of transparency, "realness", or color scissioning / layer decomposition, Zhang (2021), Murdoch (2021). Therefore, not only are the tristimulus or spectral measurements of the stimuli important, capturing the spatial detail is vital to this field of color science research.

Leveraging techniques commonly used in cultural heritage for spectral imaging, we can create highly accurate color and spatial measurements of these displays. One method for spectral estimation imaging uses a commercially available RGB camera and two color-filters, one yellow and one cyan, to create a 6-channel image array, Berns (2005), Kuzio (2021). As detailed later, the particular camera used here has been modified to remove the IR filter. This does have some impact on the final color accuracy, it is not believed to be paramount to this method and normal cameras, with an IR filter in place, should work as well. Differing spectral sensitivity functions will provide different results, but the effect of these differences is not evaluated in this paper.

These 6 channels can then be multiplied by a 6x3 or $6xN_\lambda$ matrix to produce an estimation of either tristimulus values or spectral information about the stimuli. For the purposes of this research, the possibilities of spectral imaging are not explored, but would be a short extension of this technique.

Imaging Workflow Design

Calculating the 6x3 transformation matrix to convert from the RGB-yellow filtered and RGB-cyan filtered values to CIE XYZ tristimulus values or a $\rho\gamma\beta$ cone-like color space requires calibration images with known tristimulus values. In cultural heritage imaging, typically a color checker or other calibration target is included in the images, Berns (2019). However, because the spectral emission of the transparent display may be quite different from the typical reflectance of real color patches, it is important to additionally create a virtual color checker on the display (Figure 1).

Figure 1. The targets used for camera calibration. A virtual color checker using 5 key display gamut stimuli and 5 experimentally relevant test patches (top left). A selection of Munsell patches (right). A common color target used in cultural heritage imaging (bottom). Because the display is transparent, the virtual patches are shown on two backgrounds, a dark and light grey. All patches were measured by a Konica Minolta CS-2000 spectroradiometer.

The choice of color patches will vary by application, but for our imaging of AR stimuli we chose a selection of Munsell patches relevant to the Munsell patches used in a previous experiment as well as a selection of virtual patches that A) matched the hue of the virtual patches in the previous experiment and B) were the primaries and native white point of the display, Downs (2021). Lastly a third target was placed in the scene to provide yet another set of reference patches for matrix optimization.

To create the calibration images the real and virtual patches were displayed at the same time. The real patches were placed in the scene behind the transparent display and the virtual patches were displayed on the emissive transparent AR display against a relevant background. Next a Konica Minolta CS-2000 spectroradiometer was used to measure each color patch. This measurement provides the ground truth XYZ for later camera matrix development. In the case that the imaging system will be used to produce a spectral estimation of the scene, these measurements will provide the ground truth spectra.

After the ground truth measurements are made, the initial calibration images must be taken. The camera is set up from the viewer position. It is important to note the distance and FOV of the camera lens in order to quantify spatial organization of the scene in units of visual angle or Euclidian units later. Next a calibration image is taken using each color filter. In this case a cyan and yellow filter are used, Berns (2005). It's very important to try not to move the camera in between each filter image exposure, however in practice it is very hard to change filters without at least some camera movement. Later, during image processing, the two images will undergo image registration to align their edges as closely as possible.

In the development of this paper, MATLAB 2022a Computer Vision Toolkit was used to register the two filter images with the MSER algorithm. Other algorithms have worked similarly well in testing, including the open source ORB algorithm. Despite a very careful filter changing operation, the camera was still shifted approximately 11px, resulting in the requirement for image registration. Figure 2 (below) shows the approximate magnitude of the image shift and resulting registration quality.

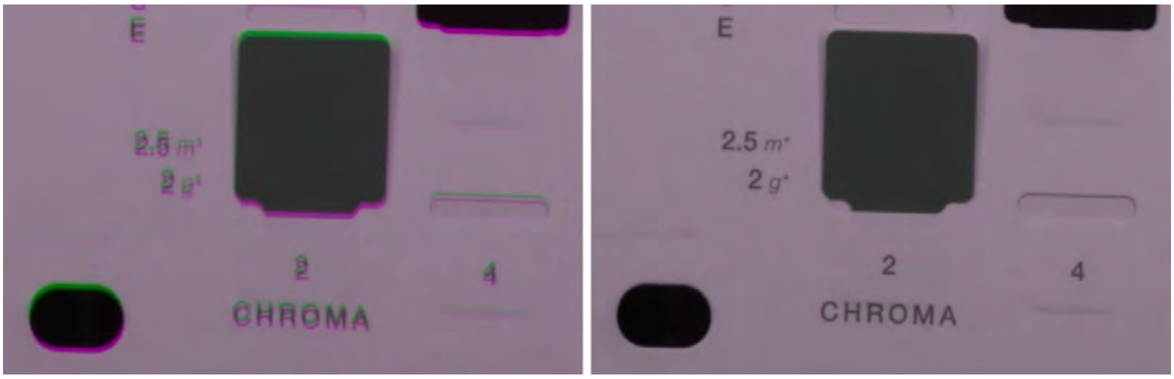

Figure 2 SEQ Figure * ARABIC 2 Results of Image Registration. The registration operation required to correct minor camera movements during the filter change operation between captures. Images shown here are false colored to highlight registration errors. Pink and Green differences demonstrate the difference in relative position of the two image layers. Other image processing operations such as darkfield and flat field correction are not shown.

After imaging the calibration targets, the image data and known colorimetry values are used to calculate the 6x3 transformation matrix. The process is similar to calculating a color correction matrix for a normal 3 channel camera, described in, Rowlands (2020), Zhu (Ukn.). For each color patch an average camera RAW RGB value is computed from the cyan and yellow images. These raw values are set up as a Nx6 matrix (signal matrix) on the right side of Eq. 1. A Nx3 matrix of XYZ values computed from the CS-2000 data (ground truth matrix) is used on the right side of Eq. 1. N represents the number of patches. Lastly, a matrix M (6x3) is used to convert the 6 channel value from each patch into the corresponding 3 channel value. A linear algebra solver is used to estimate M.

After estimating the M matrix with the calibration / ground truth targets. The same matrix can then theoretically be used to estimate the transparent AR scene for any stimuli. This approach will be used in future work on AR image appearance models to provide a detailed record of the spatial and color characteristics of a see-through augmented reality scene.

$$[X_1 \; \dots \; X_n \; Y_1 \; \dots \; Y_n \; Z_1 \; \dots \; Z_n] = M_{6x3}[R_{c1} \; \dots \; R_{cn} \; G_{c1} \; \dots \; G_{cn} \; B_{c1} \; \dots \; B_{cn} \; R_{y1} \; \dots \; R_{yn} \; G_{y1} \; \dots \; G_{yn} \; B_{y1} \; \dots \; B_{yn}]$$

Eq. 1 The governing equation for calculating the color correction matrix M for the 2-filter imaging system. On the left side of the equation are the XYZ ground truth data for each color patch, virtual and real. On the right side are the matrix M and the 6 RGB values for each color patch (signal matrix). The 6 colors come from the RGB pixel values in each cyan and yellow image, denoted with the subscripts c and y respectively.

Image Processing and Matrix Optimization

While the basic process above may be suitable for many applications, some image processing steps and matrix optimization may further improve performance for certain design goals. The linear algebra solver used to estimate M will produce a least squares estimate that minimizes ΔXYZ, but the relationship to ΔXYZ and visual noise or appearance error is known to be non-linear. Other metrics such as ΔE 2000 are used to evaluate visual performance. A numerical optimization routine such as MATLAB's patternsearch or ga (genetic algorithm) functions can be used to modify the initial estimate of the M matrix and minimize any design criteria.

For this manuscript RMSE ΔE 2000 was selected as the basis of matrix optimization. Previous authors on this topic have suggested a balanced criteria of noise performance and ΔE Berns (2005), Zhu (Ukn.). If applying this method to spectral ground truth data, RMSE spectral error or spectral error weighted by some sensitivity function, such as the spectral similarity index sometimes used in studio lighting evaluation, may be used, Academy (Ukn.).

Furthermore, aside from the normal error metrics applied to single pixels, there is often some desire to improve image data for other reasons. For the purposes of archiving scientific visual stimuli, none of the following methods should be

employed. However, recognizing the generality of the "application specific image-based measurement" topic, they are mentioned briefly.
For noise reduction some image convolution or filtering may be employed, such as non-local-means, bilateral filtering, or gaussian blur, all of which may reduce noise at either the RAW input stage, or in the final output. Additionally, if the purpose of imaging is balanced between scientific color preservation, and the production of images aesthetic enjoyment, a non-linear tone reproduction curve or sharpness enhancement might be employed.

Evaluating Matrix Performance

Normally matrix performance would be evaluated using independent data, for example by photographing a different evaluation target. Unfortunately for the work leading up to this manuscript no such comparison has been made. Still, there are several evaluation metrics using the target data that provide some insight on the application and the future of similar image-based measurement solutions. The RMSE ΔE 2000 across all 70 color patches used for this manuscript was 1.13.

To evaluate the matrix noise performance, first the mean estimated CIELAB value for each patch in the test target was computed. Then the estimated CIELAB values of each pixel in that region of interest were compared to the target mean value. The standard deviation of these comparisons was computed with all 70 target patches. For the particular target and imaging system used for this manuscript the noise correlates (CIELAB std. dev) was 3.5.
For our specific application, the RMSE ΔE2000 among the AR patches was 1.45. For the remaining real / non AR patches the RMSE ΔE2000 was 0.98, suggesting that this imaging system has a higher accuracy for real / non-AR color patches. A larger independent dataset with more AR patches is desirable for further development. The ΔE2000 error for each patch is shown in Figure 3.

Conclusions

The resulting application specific 6x3 matrix can be used with filtered imaging to record the stimuli used in an experiment. This enables researchers to easily collect high resolution tristimulus images. Besides the uniqueness of imaging transparent displays, this technique can be used anywhere where an imaging colorimeter would be useful but is either unavailable, not high enough resolution, or too expensive.

Using this two-filter approach, we measured 3 calibration targets: a selection of Munsell chips from a 2019 edition of the Munsell Book of Color, a typical calibration target from cultural heritage imaging, and a virtual calibration target which displayed 10 colors on two background objects. The virtual calibration target included the display's maximum red, green, blue, and white colors as well as black and 5 colors selected from a recent visual experiment.   Across all calibration patches the RMSE color error was 1.13 ΔE2000, with a slightly higher mean for the virtual color patches, ΔE 2000: 1.45.

Figure 3: ΔE2000 error shown for each image patch used in this manuscript. The 20 upper left patches are each an AR color patch overlayed against some real-world background object. In this case, black and grey construction paper. The Munsell target and Linear target are shown to the right and lower portions of the image. The linear target included a glossy greyscale, which was not included in this analysis due to the presence of the specular glare. The circle patch in the center of the linear target was also selected for analysis.

Thus, this technique is useful for providing spatial and color information for studies where small color differences within 1 or 2 JNDs are much smaller than the effect size in question. In AR studies, the color perception of transparent stimuli can differ from the perception suggested by traditional color models by several orders of magnitude larger than this measurement technique can resolve, therefore the image-based approach by itself may be useful for studying AR color perception. If higher accuracy measurements are needed, spot measurements with a typical spectroradiometer, which is the most common approach to quantifying AR stimuli.

References

Academy of Motion Picture Arts and Sciences (AMPAS). Spectral Similarity Index (SSI).Oscars.org. https://www.oscars.org/science-technology/projects/spectral-similarity-index-ssi (accessed May 19, 2022)

Berns, R. S., L. A. Taplin, M. Nezamabadi, M. Mohammadi, and Y. Zhao. 2005. Spectral Imaging Using a Commercial Colour-Filter Array Digital Camera. In *The Fourteenth Triennial ICOM-CC Meeting*, 743–50.

Berns, R. S. 2019. Digital Color Reconstructions of Cultural Heritage Using Color-Managed Imaging and Small-Aperture Spectrophotometry. *Color Research and Application* 44 (4): 531–46.

Downs, T., Murdoch, M. Color Layer Scissioning in See-Through Augmented Reality. 2021. *29th CIC Final Program and Proceedings*, pp. 60-65(6). Virtual.

Kuzio, O. and Farnand, S. LED-Based versus Filter-Based Multispectral Imaging Methods for Museum Studio Photography. In *Proceedings of the International Colour Association (AIC) Conference 2021,* pp. 639–644.

Murdoch, M. J, Brightness matching in optical see-through augmented reality. 2021. JOSA-A 37, 1927-1936.

Rowlands, D. A. (2020) Color conversion matrices in digital cameras: a tutorial, *Optical Engineering*, 59(11), pp. 1–36. doi: 10.1117/1.oe.59.11.110801.

Zhang, L. and Murdoch, M. J. Perceived Transparency in Optical See-Through Augmented Reality,.2021 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), 2021, pp. 115-120, doi: 10.1109/ISMAR-Adjunct54149.2021.00033.

Zhu, Y. Exploring Camera Color Space and Color Correction. https://www.cs.rochester.edu/courses/572/fall2021/colorvis/camcolor.html (accessed May 10, 2022)

Study of measurement of 3D shape and spectral reflectance by Multi-View Stereo

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Abstract

Recently, many methods of measuring spectral images and 3D shapes have been proposed because they are more realistic than 2D RGB images. However, there are many that integrate spectrum and 3D shape. Especially our previous system to measure 3D shape and spectral reflectance targeted only small objects. It did not work well for large objects and outdoor environments. Therefore, we propose a measurement method of 3D shape and spectral reflectance using Multi-View Stereo, enabling large and dense measurement. In our method, the past method generates the spectral intensity image, and the point cloud is generated by using the spectral intensity image. Furthermore, we aim to improve the accuracy compared to single point cloud generation by integrating multiple point clouds, including spectral intensity, into one point cloud. In addition, we realize more complex color expressions than RGB measurement based on the spectral information acquired by the integrated point cloud. In the future, we will construct a system based on the proposed method and evaluate the spectral information and the shape of the 3D point cloud. Our method contributes to improving the quality of digital archives.

Keywords: *Spectrum, 3D data, Multi-View Stereo*

Introduction

Recently, digital archives have been promoted mainly for cultural properties. However, most of them use RGB images. The colors may differ when we see the actual object with the naked eye. It is because how the actual objects look depends on the spectral distribution of the light source and the object's spectral reflectance, so the object's color cannot be reproduced entirely with only RGB information. Also, if the target object is a 3D object, we cannot see from various angles with the image. Therefore, we aim to develop a method for measuring spectral information and 3D shapes.

We have studied spectral images with high dynamic range (HDR) to measure colors closer to the actual object than RGB images. Tsuruta et al.(2019) proposed an HDR spectral video measurement system using an RGB camera and filters.

Figure 1 shows the structure of the system. We acquired four types of RGB images through four different filters, and the 12-bands information can estimate HDR and spectral images. Ishida et al.(2019) measured the 3D spectral shape by using HDR spectral video measurement system and the gray code patterns. Due to the area of patterned light, this method allowed small objects but did not measure large objects or spaces such as walls and floors. Horimoto et al.(2020) use the HDR spectral video measurement system and SLAM to measure objects and spaces' 3D shape and spectral reflectance. However, this method could hardly recover the shape because SLAM is a sparse method. Therefore, we use Multi-View Stereo (MVS) instead of SLAM and study a method that enables the accurate measurement of the 3D shape and the spectral information of an object/space.

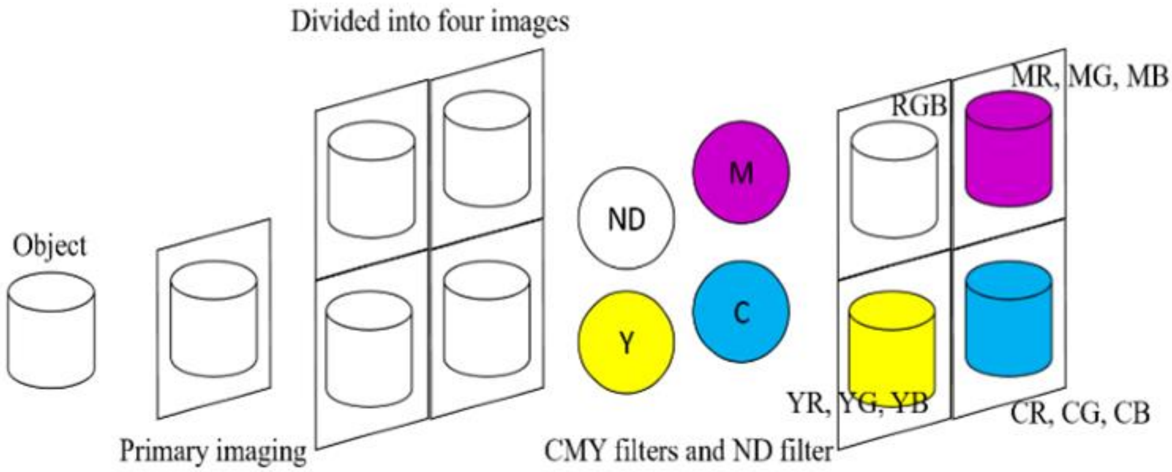

Figure 1. HDR Spectral Video Measurement System overview. By shooting an object through four filters, we can get four RGB images and 12 bands of information.

Proposed Method

Cernea and Dan (2020) proposed a multi-view stereo (MVS) as a 3D measurement method. MVS detects features from images and matches them with features between images and estimates 3D shape. This method can measure even in spaces such as walls and floors. MVS can be operated with a monocular camera like the ORB-SLAM (Artal and Montiel 2015) used in the previous research. Although real-time measurement is not possible, dense measurement is possible. Figure 2 shows an example of shape measurement by MVS.

MVS is often used in combination with a method that can estimate the camera position. Moulon et al.(2016) proposed Structure from Motion (SfM) as a camera position estimation method. SfM is a method that uses multiple images of an object taken from various positions and angles. Then, it can estimate the relative position by detecting the feature points for each image and matching them between the images.

Figure 2. An example of a 3D point cloud by MVS (left) and parts of used images (right). The results are dense enough to recognize cups and balls.

We use the input images, and the camera positions estimated by SfM and then estimate the 3D shape by MVS. HDR spectral video measurement system calculates the spectral intensity of each wavelength for each pixel and produces an image with that as the pixel value. Moreover, we use it to form a spectral intensity point cloud, which is a point cloud including the intensity of a single spectral wavelength. By integrating all the spectral intensity point clouds, it is expected that the accuracy of the 3D shape will be improved compared to standard 3D measurement.

HDR Spectral Video Measurement System

This system acquires spectral information from the pixel values of four images. If the transformation matrix is X, the spectral information is r, and the RGB value is g, the relationship is expressed as Eq. (1). The transformation matrix X can be obtained using the pseudo-inverse matrix as shown in Eq. (2).

$$r = Xg \quad (1)$$

$$X = rg^T(gg^T)^{-1} \quad (2)$$

The spectral information r and signal value g in Eq. (2) are obtained from the color chart in Figure 3.

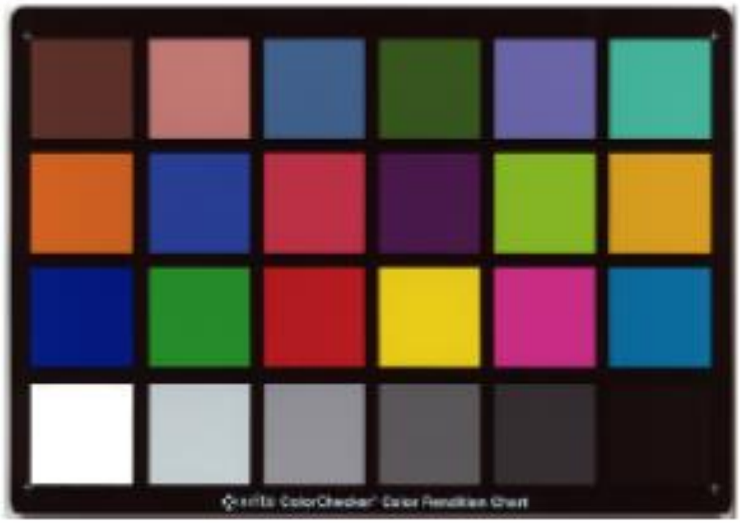

Figure 3. Color chart. It contains 24 different colors. We take this with the HDR Spectral Video Measurement System and a spectroradiometer and use it for calculations of the spectrum.

3D Shape Measurement

We applied SfM for the spectral intensity image to get the spectral intensity point cloud, but we could not get the camera position. The spectral intensity image has a lower pixel value than the RGB image, and it is not easy to detect feature points (Figure 4). We can acquire RGB images and spectral intensity images using the HDR spectral video measurement system. Since RGB and spectral intensity images are generated from images taken simultaneously, they have the same camera position. So, we perform SfM and MVS with different images. The camera position is estimated by SfM using RGB images, and the 3D shape is measured by MVS using the camera position estimated by SfM and spectral intensity image. As a result, we can acquire 3D point clouds with spectral information of a certain wavelength. By integrating these 3D point clouds with spectral information of different wavelengths, we can expect higher quality measurement than a 3D measurement generated by only one set of images.

Spectral Information of Point Clouds

Please note that the generated spectral intensity point cloud has light source information. In our method, the spectral reflectance and the light source information are included in the point cloud. We expect that this realizes the representation in the environment where the actual object exists. This information is suitable for digital archiving of spaces such as walls and floors, which is one of the purposes of our method.

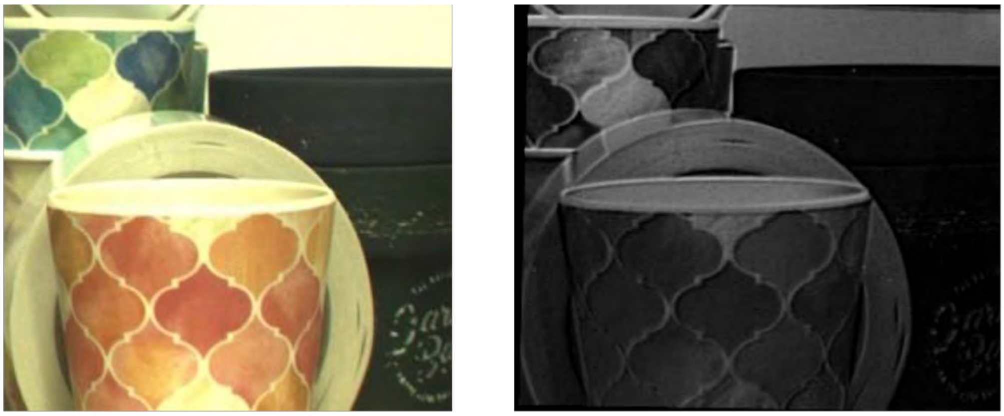

Figure 4. One of the spectral intensity images (770nm) (right) and RGB image (left).

Estimation of Spectral Information

The position of the spectral intensity point cloud may be significantly shifted. We solve this with the Iterative Closest Point (ICP) algorithm (Rusinkiewicz and Levoy, 2001). This algorithm overlaps two point clouds with very similar shapes: First, we overlap the spectral intensity point cloud of each wavelength with the point cloud generated from the RGB image to generate a transformation matrix. Next, we overlay the spectral intensity point cloud transformed by the matrix. Finally, we obtain the spectral intensity of each wavelength from the neighboring points of the integrated point cloud, and then generate a point cloud with spectral information of all wavelengths.

Results & Discussion

The spectral intensity point clouds were generated by our method, as shown in Figure 5. Figure 5 shows a point cloud at 430 nm. We could not get the camera position in SfM and spectral intensity images, so this result shows that our method is effective for images where it is challenging to detect feature points. Figure 2 shows that the spectral intensity point cloud can be obtained in an area almost the same as the point cloud by the RGB images.

Figure 5. One of the spectral intensities point clouds (left: 430nm, right: 625nm). Compared to the RGB point cloud (Fig. 2), this can represent a 3D point cloud in almost the same range.

Figure 6 shows the integrated spectral intensity point cloud. Most of the spectral intensity point clouds are overlapped. This point cloud contains spectral information in the visible domain every 5nm, as shown in Figure 5. It is shown that our method measured the spectral intensity point cloud.

Figure 6. The integrated spectral intensity point cloud by our method. This point cloud contains spectral information of visible domain Sampled to 5nm.

However, some of the point clouds are not in the correct position. For example, the two point clouds are greatly shifted at the RGB point cloud and 405nm point cloud, shown in Figure 7. We need to consider the cause of this phenomenon in the future.

Figure 7. Addition of RGB point cloud and 405nm point cloud. We can see that the RGB point cloud positions the green rectangle, and the 405nm point cloud positions the red rectangle in Figure 6.

Conclusion

As digital archiving progresses, there are many improvements in that method of digital archiving. We proposed a method that can acquire spectral information and 3D shape using an RGB monocular camera and some simple tools. Our method has the potential to perform spectral 3D measurements efficiently. However, the method needs some improvement, especially in calculating spectral information. In the future, we will improve and evaluate the method to realize a better measurement of spectral information and 3D shape.

References

Takayuki T., Y. Manabe, and N. Yata. 2019. *HDR Spectral Video Measurement System*, Proc. of 7th Computational Color Imaging Workshop, LNCS11418, pp.89-101

Ishida, Y., Manabe, Y., and N. Yata. 2019. *Measurement of Object Shape and Spectral Reflectance and its AR Application*, The Institute of Image Information and Television Engineers 2019 Winter Annual Convention Proceedings, 12C-1

Horimoto, T., Manabe, Y., and N. Yata. 2020. *Study of measurement of 3D shape and spectral reflectance by SLAM*, The Institute of Image Information and Television Engineers 70th Anniversary Convention Proceedings, 21E-3

Cernea, D. 2020. *OpenMVS: Multi-View Stereo Reconstruction Library*, access https://cdcseacave.github.io/openMVS

Artal, R.M. and J. M. M. Montiel. 2015. *ORB SLAM: A Versatile and Accurate Monocular SLAM System*, IEEE TRANSACTIONS ON ROBOTICS, VOL. 31, NO. 5

Moulon, P., P. Monasse, R. Perrot, and R. Market. 2016. *OpenMVG: Open multiple view geometry,* International Workshop on Reproducible Research in Pattern Recognition, pp. 60-74

S. Rusinkiewicz and M. Levoy. 2001. *Efficient variants of the ICP algorithm*, Proceedings Third International Conference on 3-D Digital Imaging and Modeling

Session 2
Design

Color Marketing Group™: Six Decades of Color Forecasting

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Abstract

This article aims to examine the motives that preempted Color Marketing Group®, since its inception in 1962, to concentrate its endeavors on color marketing and color forecasting. The investigation focuses on the evolution of color forecasting as a process and as a tool in product marketing over the last six decades as CMG celebrates its 60th anniversary in November 2022. The article also intends to discover the influence of CMG Color Forecast on so many industries around the world to realize the importance of color in product marketing and adopt the process. The research performed the examination of CMG's own property archived material including internal and Board of Directors (BoD) meetings notes, speeches scripts, membership directories, member-only CMG *ColorChip* publications, member-only color cards and Report Back Reports. CMG archives are not available to the public.

Keywords: *color forecast, color forecasting, color marketing, CMG, Color Marketing Group.*

Introduction

The inception of Color Marketing Group® (CMG) is attributed to individuals who in the 1950s and early 1960s worked toward solving technical and merchandising color problems within an inter-industry environment. The concern with color was reflected by the organization of associations to serve the area of color as a science. Color was considered as a specialized field of study in physics, chemistry, physiology, and psychology. Commercially, the color industry was limited to the manufacture of colorants. There was no organization to serve the marketing interest in color. It was in that atmosphere that CMG was founded.

In May of 1962, as a separate outgrowth of meetings of the Inter Society Color Council (ISCC) subcommittee for Problem #23 on *Expression of Historical Color Usage*, Mr. Everett R. Call of the National Paint, Varnish and Lacquer Association (NPVLA), Mr. Robert Eppinger, Vice Chairman of Baumritter Corporation, and Mr. Louis A. Graham of American Viscose Corporation issued invitations to business professionals proposing a meeting among various industries for mutual non-competitive cooperation. The invitations were accepted by individuals who met to review inter-industry color merchandising problems of mutual interest. As a direct result of the meeting in New York City, NY, in June, a steering committee was formed. It met and planned for another meeting in the fall of 1962 in New York

City. They chose NYC because it represented the commercial hub of the most interesting industries.

Fifty-five persons participated in the meeting, which took place on November 15, 1962. They were prompted to bring samples from textiles to advertisements to demonstrate the possibilities envisioned and discuss how the samples looked to the buying public in stores and at home. Ms. Kaye A. Leighton of the General Electric Company and Dr. Forrest L. Dimmick of the American Psychological Association, and the U.S. Naval Submarine Base at New London, CT, spoke about "Lighting and Color" and "Color Psychology" and helped to sort color fact from color fiction in everyday problems. The group then voted into existence the Color Marketing Group.

Elected to the first Board of Governors were Mrs. Beatrice West of Beatrice West Studios Inc.; Mrs. Ruth L. Strauss of Ruth L. Strauss, Inc.; Mrs. Ouida M. Wessmann of Scott Paper Company, Mr. Howard Haskel of Seneca Textiles, Mr. Dwight L. Wardell of Sandoz, Inc., Mr. Paul Olive of American Telephone and Telegraph Company; Mr. Joseph Roby of the Wallpaper Council, Mr. Everett R. Call of NPVLA, Mr. Robert Eppinger of Baumritter Corporation, and Mr. Louis A. Graham of American Viscose Corporation and then with Burlington Industries. Messrs. Graham (Figure 1), Eppinger and Call were subsequently elected by the Board to the respective offices of Chairman, Vice Chairman/Treasurer, and Secretary. The annual membership dues set at $5.00 were collected by Mr. Call in a cigar box.

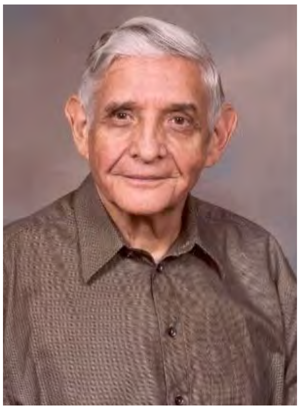

Figure 1. Mr. Louis A. Graham, first Chairman of Color Marketing Group.

In the following months, CMG selected its first logo and attracted its first hundred Charter members. CMG meetings continued in the spring and fall of the following years. The efforts of the members manifested in a rapid increase in individual memberships, legal incorporation as a non-profit organization, and acceptance of CMG's application to become a member body of the ISCC.

Evolution of Color Forecast

As a body, CMG was not meant to make color forecasts or predict color trends, stated Mr. Graham in an address to the first Congress of the Association International de la Couleur (AIC) in Stockholm, Sweden. From its inception, CMG members' prime interest was to promote more knowledgeable use of color in marketing, to provide a forum for the exchange of ideas and the solving of color problems, and to offer education and training in the complete application of color. This was formalized during CMG's May 1963 meeting, when an idea - put forward by Ms. Elisabeth Burris-Meyer, a consultant with the House & Garden Magazine, developed to collect and exhibit colored swatches of members' sold products and organize them on a color basis rather than by usage, industry, or type. The exhibit then became the COLORFAIR™. Colors were organized in 29 groups using the Universal Color Language. The COLORFAIR showed the color availability of products from the industries represented. The exhibit was featured at each CMG fall meeting.

The biannual meetings, called conferences, enabled CMG to serve the fluid aspect of marketing. Manufacturing was expected to react to color styling and design to be profitable. CMG effectiveness resulted in its presentation of both innovative ideas and tools, and older items of usefulness. The areas and fields discussed at panels and workshops during the meetings covered problematic topics and sought to provide scientific solutions. These included topics such as *Color action in communication - Photography & television*, *Color action in transportation - The colored planes*, *The color explosion in fabrics, fashions & furnishings*, *How has the use of color as a marketing tool changed in the past ten years?*, *How do changing color preferences broaden marketing opportunities?*, *How do advances in chemistry and physics affect consumer color trends?*, *Changing demands for color in durable and disposable goods*, *Problems of disposing of obsolete color inventories*, *What advance color information would be useful for future planning?* and *Overcoming field problems of color variation from production run to production run*.

During the conferences, participants broke into small discussion teams, each one reporting back to the general assembly their results on assigned topics. The positive reaction to those small discussions' teams led CMG to hold its first color/marketing workshops in 1967. The participants were divided into groups, each tackled the same assignment. The assignment involved selecting an industry and product then developing a marketing plan, which included target market, price point determination, product styling, color line development, sampling/sales ads, advertising, and POP, with special attention given to the importance of color use wherever applicable. Members used paper, pens, or markers to illustrate their ideas, which group leaders used for the final report back presentations.
Studying the current colors was not enough. Color decision makers needed more direction. CMG was in a unique position because it brought together the color

decision-makers from every imaginable industry: furniture, wallcoverings, floorcoverings, fashion, paper, appliances, cars, cosmetics and beyond.
In 1969, CMG introduced changes to the COLORFAIR™, requiring participants to submit their current best 10-15 sold colors in various lines and an annual color forecast of what they believed the next wave of colors would be. This was the first time the idea of a forecast had been stated. The forecasts were compiled and issued in the form of a *ColorCard*. The *ColorCard Program* was a tool exclusive to members who attended meetings.

In 1970, CMG introduced Regional Meetings across the USA to allow for greater contribution among members from the same region and to invite potential members. Later, these meetings were also taking place in Montreal and Toronto, in Canada.

At its 1972 Fall Conference, in Las Vegas, NV, CMG launched a new program called *Color Directions™* (Figure 2). It was designed to become an annual consensus of members' feeling as to what the best color sellers were liable to be one to two years out. The first *Color Directions™* was a forecast for 1973-1974. *Color Directions™* were not a color promotion, nor did they push any company's colors. Its purpose was to show a direction for color in the future as a working tool for CMG members. They represented a full spectrum of the multi-billion-dollar color dependent industries represented in CMG. In preparation for the *Color Directions™*, each member developed color projections based on their products or field of expertise and their analysis of socio-economic trends and influences.

During the conferences, members met in small workshops comparing and reviewing each other's color cards for a final consideration. From this, a *Color Palette* was produced. The oldest printed *Color Directions™* cards available in CMG archives date back to 1978. This program was the precursor to CMG color forecasting as it is known today. In 1975, only those who participated by sending their forecasts worksheets were allowed to participate actively in these color workshops.

Figure 2. Color Directions '78 envelope and First Color Contract 86.

In 1977, the BoD decided to grow and expand the organization domestically and internationally, develop a full-time administrative staff, create strong regions, and develop effective and continuous public relations. Four Directions committees emerged: Color, Education, Marketing, and Technical. By December of the same year, CMG hired the first full-time person and opened its first office in Washington, DC. Prior to that, administrative work was done in Mr. Everett Call's home office.

CMG conferences were attracting increased color professionals and the 1979 Fall International Conference in White Sulfur Springs, WV, was attended by an all-time record breaking of 304 participants.

In July 1980, CMG started the first evaluation of the *Color Directions™* to validate the forecast direction was on target and assess the influence it had over individual color decision making. Members were asked for their 1979 top color sellers, and by comparison against CMG 1979 Color Palette, the reports with CMG colors were used, and which were not. This provided insight into the consumer acceptance of color. The exercise led to a *Design/Graphics Tracking Committee* and a computerized *CMG Tracking Program* to keep members abreast of design influences and to augment the color forecasting process. The results of the pilot study to track past color movement were announced at the 1984 Spring International Conference in Nashville, TN. It provided members with information on 1983 color preferences in the high, medium, and low ends of a multitude of industries. This color tracking information, in combination with color forecasts, supplied the critical link to enable management, manufacturers, retailers, stylists, designers and advertising executives to make color and marketing decisions based on substantiated data.

The *Color Directions™ Program* was a good cooperative effort to forecast consumer colors two years ahead in the industries represented in CMG. However, members requested for a more valid color palette. At the 1984 Spring Conference in Nashville, TN, core groups of color decision makers conferred with design, marketing, and technical specialists to form *Consumer Color Directions™*. At the Fall International Conference of the same year, in Dallas, TX, the concentration was on Contract Colors. Mixed workshops of members spending 50% or more of their time in the contract market worked to produce CMG's first *Contract Colors* for 1986 (Figure 2), which was later reproduced on color cards and distributed to the membership for use as a directional tool. In the 1990 Fall International Conference in San Antonio, TX, there was a growing interest in referring to the *Contract Colors* as a *Palette* rather than a collection of *Color Directions™*. The interest was considered a sign that CMG Contract *Color Directions™* were becoming more usable because the rationale of the driving influences was more integrated and focused, enhancing the marketability of the colors.

Volunteer members served as Facilitators of Workshops, with the responsibility to organize workshop participants input into *Workshops Color* or *Design Boards*, and written notes with insights as to why the colors or designs were selected. Prior to the Workshops, Facilitators collected the color swatches or designs from the Worksheets of individual members and grouped them to assemble a basic color or design board for discussion in the Workshop sessions. Through discussions, led by the Facilitator and documented by the Co-Facilitator, each Workshop produced a consensus color or design board and written comments. After the color boards were constructed with input from each Workshop member, the Steering Committee (Workshop Facilitators, supervised by the Committee Co-Chairmen) met to determine the content of the final *Palette*. Each Workshop's color board and written and verbal comments were used as input to help come to a consensus. The *Color Palettes* published by CMG represented the consensus-projected colors. *Color Palettes* were interpreted by CMG members and used as input for determining the colors to be used in their product lines. Colors were not applied exactly as shown in the consensus *Palette* but were varied to fit market and technical requirements.

By the fall of 1986, only members who submitted a color worksheet in advance of the Conference were allowed in the Contract Workshop. By 1987 CMG's *Contract Color Directions™* and *Consumer Color Directions™* Programs, Color Tracking efforts and Mixed-Industry Color and Design Workshops, along with its timely presentation of pertinent topics at both regional and national meetings, have established CMG as the foremost authority for color professionals.

By the end of the 1980s decade, CMG members were classified under various categories, including *Color Designer* which referred to members involved in the creation of colors. They were allowed to participate in *Contract* and/or *Consumer Color Directions™* Forecast Workshops. *Color Marketer* refers to members in marketing, technical or design roles dealing with the application or design, rather than the creation of color. Members were assigned a workshop category based on their industry and the percentage of time their responsibilities required them to be involved in color, whether in the creation or production sides of it.

In 1990, CMG conducted an *Analysis of Needs Assessment Survey* which led to the inclusion of *Let-Downs* (Figure 3) in the *Consumer* and *Contract Color Directions™*. The *Let-Downs* were prepared by Munsell® Color and consolidated into a fan deck by MacBeth Division of Kellmorgen. The let-downs of a color were presented as five value extensions of a color in Munsell Color System. In today's terminology, let-downs are referred to as the various degrees of graying out of a color to tone it down by adding white to its composition in different degrees.

Figure 3. First Let-Downs for CMG 1993-1994 Contract Colors.

In the 1991 Spring International Conference, in Dearborn, MI, CMG introduced *Color Combinations* as part of the *Colors Current*™ Workshops. This workshop became an integral part of CMG experience at both spring and Fall International Conferences. Until 1993, the *Color Combinations* workshops were developed by participants and were applicable to their industry or product using colors from various CMG *Contract Color Directions™* Palettes. Each participant was given the opportunity to share their creative approach of combining colors. After the exchange of ideas, participants worked as a team to develop outstanding boards of combined colors created for a predetermined scenario.

By 1993, CMG offered *Consumer Color Directions™*, *Colors Current™*, *International Trends*, *Contract Color Combinations*, and *Industry Exchange* Workshops during its Spring International Conferences. During the Fall International Conferences, it offered *Contract Color Directions™*, *International Trends*, *Consumer Color Combinations*, *Marketing*, and *Design Influences* Workshops. *Consumer and Contract Color Directions™* Workshops were open only to participants who were responsible for color decision and recommendation making, and or develop color lines that were to appear in the marketplace in a period of two or more years. The other workshops were open to all members.

In the Fall International Conference of 1993 in San Diego, CA, a new Worksheet was introduced including three sections. The first, titled *Thoughts and Concepts* was meant to list random thoughts that will influence design and/or color. The second, titled *Cause and Effect, was* dedicated to select one trend from the previous section and trace its movement, where it started and where it was in the present and where it was going. This worksheet has a historic importance to CMG as it was the precursor of Worksheets used in current times.

In 1994, during the Fall International Conference in Bal Harbour. FL, CMG established *Contract Colors Current™* Committee and Workshops to analyze color trends and directions 12 to 18 months out in contract markets. The committee was distinct from the *Contract Color Directions™* whose focus was on color movement for products which will reach the marketplace in a period of two or more years.

In 1994, CMG decided to expand its international color communication goal of providing valid international color marketing information by refining the International Trends Workshops during the spring and summer conferences. To this effect, it organized an annual Heimtextil Regional Meeting in Frankfurt for members to share insights. It also sought new International ColorLinks™, which were a formal international color exchange program between CMG and other like-minded organizations similar to the one established with the UK Color Group. It also formed the European Color Focus Committee to evaluate the 1995 Consumer Color Directions™ on European color application by European CMG members. In the same year, CMG held its first mini meeting in Europe in conjunction with Heimtextil in Frankfurt, Germany.

On September 13, 1996, CMG held its first, formal Regional European Meeting at the offices of mode...information in London, UK. The meeting was attended by over 45 CMG members and non-members from Sweden, Germany, France, Belgium, Portugal, Denmark, the Netherlands, the UK, and the USA. They represented automotive, electronics, consumer products, textiles, fashion, home, and contract interiors markets. CMG international growth was marked with given names to newly formed regions. This included the expansion of ColorLink™ with the establishment of Colorways Australia, UK Color Group and DECOSIT Trend Committee of Belgium, in addition to the newly formed Canadian Region and the European Regional Committee.

Since 1980, CMG has held semi-annual Fashion Forecast Workshops at the Fashion Institute of Technology in New York City, NY. The workshops were divided into five areas of interest: Women's Better Apparel, Women's Volume Apparel, Menswear, Children/Juniors/Active Apparel, and Cosmetics/Intimate Apparel. Separate workshops were scheduled for Fall/Winter and Spring/Summer colors each year. In 1996, CMG halted the New York City workshops and incorporated them in the Spring International Conference in New Orleans, LA.

In 2000, CMG opted to include NCS Color System notations in the Color Report Backs. This was in addition to the color systems and values already in use: Munsell®, Colorcurve®, Pantone® Textile, Pantone® Coated/Uncoated, RAL, RGB and CMYK. With the acceleration of product development and the demand for special effects, in 2001 a Special Color Effects Planning team was created to look into eliminating the barriers to producing CMG Color Directions™ and Colors Current™ Palettes with special effects. Historically, there were logistical, economic barriers to producing the color palettes in other than plain matte finish. This program was later dropped owing to the previous barriers. In the Spring International Conference of 2001, in Orlando, FL, CMG introduced the first *Trend Catalyst* Workshops. The Workshops were designed to complement the *Consumer* and *Contract Color* Workshops. They allowed members to select a Workshop topic from eight different subjects to participate in focused, mixed-industry discussions about the demographic, economic and technological trends that drove change in *Color Directions™*, and product design and development. The Workshop topics included five generational demographic groups, cultural demographics and international markets, modern technologies, and product design.

By 2002, predicting color and trends continued to evolve at an ever-increasing rate. The effects of the post 9/11 economy, the dot com bubble, technology, globalization, social unrest, ecology, population shifts and changing values, were creating a highly fluid and demanding environment in which CMG created forecasts and trend projections. CMG performed with wisdom and flexibility in meeting the changing demands of the marketplace. it modified its organization structure, expanded international involvement, realigned the workshops, tightened the membership requirements, redefined the color forecasting process, delved into long-term planning, improved conferences content, and reassessed its services. As a result, CMG became stronger than ever before.

At the BoD meeting of April 15, 2003, in Hollywood, FL, the members discussed and analyzed the possibility of having one international conference per year rather than two. However, it was not until 2011 that CMG opted for one International Summit.

In April 2006, at the Denver, CO, Spring International Conference, new workshop categories were added. The new workshop categories were: 1) *Colors Current™* – colors that were applied to a current product or will be introduced in the next product cycle. *Colors Current™* included members that applied or created colors for industry specific products. Later, *Colors Current™* started to include *New Introductions* which were colors that had been specified for a product not yet introduced into the market or being introduced on a product for the first time. The *New Introductions* were determined by designers who specified or developed colors for new products. b) *Established Colors* which were colors that had been introduced and accepted in the marketplace and sold well. Members who marketed products or made color selections from existing color lines determined *Established Colors*. 2) *Color Directions™* were colors that had not been applied to a particular product but were under consideration for future product introductions. *Color Directions™* included members performing industry specific color research or proposing color to be applied to a particular product. 3) *Color Visions™* were general directions for the future based on trends and influences that were not industry or product specific. *Color Visions*™ included Contract and Consumer members performing cross-industry future color research and proposed color for multiple industries. 4) *Classic Colors were* bestselling basic colors over a sustained period of at least five years.

In 2008, at the Phoenix, AZ, Spring International Conference, *Contract Color Current™* were renamed *Contract Colors Now™,* and Contract *Color Directions™* were renamed *Contract Colors Next™.* In 2010, at the Portland, OR, Fall International Conference, *Consumer Colors Next™* was dropped, and only *Consumer Color™* and *Contract Color™* Workshops, in addition to *Visions* and *Color Expressions* Workshops were held.

In 2011, CMG introduced the concept of ChromaZone™. These result-oriented color meetings were focused on regional color preferences and directions. Members and non-members were allowed to participate at the meetings and a Worksheet was required for submission in advance. The information gathered and the colors deemed most important from each ChromaZone™ moved on to steering to become part of the North American palette during the North American International Summit. The meetings took place in various cities in North America between February and July. In the same year, CMG combined the two conferences into one and called it Summit in San Antonio, TX. By that time, CMG offered two mixed-industry Contract and Consumer Workshops and Color Expressions Workshops. The latter included the categories: Color Combinations, Product Combinations, Environmental Combinations, Exterior Home, Metal Finishes, Graphic Design, Wood Grain, and Special Effects Workshops. During that Summit, CMG announced its first-ever Key Colors. Boys N Berry for North America, Gorgona for Latin America, Limbu for Asia Pacific, and Phidias for Europe.

In 2012, for its 50th anniversary celebration at the Summit in Miami, FL, CMG revamped its programs to meet the ever-changing color field landscape. CMG introduced the Color Apps Workshops. Color Apps Workshops were created as a new way to engage in color at the Summit. These Workshops were about the application of color rather than forecasting. Various categories were introduced: Palette Stories, Color in Action, Color in Contract, Special Effects and Color Industries. Participants to the Color Apps received the Key Colors from the ChromaZone™ events, printed fan decks from the International Regional Meetings and a digital printout of the final North American Palette. The Color Apps replaced Contract and Consumer Color Directions™ Workshops. CMG also introduced CMG World Color Forecast, an aggregate of the 64 colors from the four Regional Color Forecast: North America, Latin America, Asia Pacific, and Europe.

In 2016, at the Santa Fe, NM, International Summit, CMG introduced *Regional Evolution Cards* which tracked the evolution of the Regional Color Forecast by color family throughout the five previous years. These cards continue to be produced until recent times.

In 2020, at the onset of the COVID-19 lockdowns, CMG opted not to stop the color forecast process and was the first organization ever to introduce virtual color forecasting events via Zoom. The Virtual ChromaZone™ Workshops were held internationally in 2020 and 2021. Similarly, the International Summit for the same years was held virtually on Zoom and was successful.

Conclusion

Through the analysis of CMG's own property archived material, we concluded that over the last sixty year of its existence, CMG has provided a think-tank-like setting in which color and design professionals came together to share insights on societal trends, economic, political, technology and environmental driving forces that influenced design and color to create and validate color forecasts. CMG Color Forecast has been used as an important marketing and design tool by thousands of its members around the world. The value of CMG lies in its unique format showing the interdependence of industries, sharing knowledge on new products, colors and developing technologies with qualified, creative color design and color application-oriented professionals. The success of CMG and its legacy as a reliable organization and a source of reliable color forecast information could be attributed to the fact that CMG is an association of members who give themselves unselfishly. CMG byline *Color Sells and the Right Colors Sell Better* states CMG's objective of its main product: color forecast. The impact of CMG continues to influence the world of color by supporting the professional credibility and expertise of its members, who move daily in the circles of color, marketing, color design and color planning.

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Aesthetics and Emotions of Colour Harmonies in Architectural Context

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Abstract

In an architectural context, colour is a multifaceted problem. Harmony of colours is one of the major concerns of design. Architects and designers may refer to various sources for their initial colour inspirations which embody both aesthetic and emotional features at the same time. Developing a colour palette is related with subjective sensations and objective parameters of design, and during the architectural design process various criteria are effective over colour design decisions. This paper aims to observe such a process for exploring emergence, continuity and changes of colour design decisions on colour harmonies during sequential stages of the colour design process. The results indicated that subjective/intuitive criteria were apparent in the initial stages of design. While passing into the architectural context, subjective/intuitive criteria (preferences and emotions) started to leave their place to objective/knowledge based/analytic ones (systematic, formal, and functional criteria). It is also observed that aesthetic and emotional aspects of colour harmony are significantly correlated at all stages of the colour design process. For the designer/architect, there is no clear distinction between aesthetically harmonious and emotionally pleasant colour design.

Keywords: *architectural colour, colour aesthetics, colour emotions, harmony, pleasantness*

Introduction

Colour vision and perception is a resultant of three components: 1) the spectral energy distribution of the light; 2) the spectral characteristics of the object; and 3) the activity and sensitivity of the eye and brain of the observer. Although a number of these elements or their numerous variables are isolated from the others due to theoretical and/or methodological reasons, recent research qualifies the significance of context on colour studies. Many disciplines such as philosophy, history, chemistry, physics, biology, art, etc., approach colour from different perspectives. Mahnke and Mahnke (1999) states that designing the man-made environment involves all these perspectives and disciplines to some extent. In this respect, architecture is a platform to comprise both objective and subjective aspects of colour, and a discipline to combine, compose and control all the factors related to the above-mentioned components of colour vision and perception (Ural 2016).

Harmony of colours is one of the major concerns of design. As a *measure of aesthetics*, *colour harmony* is mostly explained by orderly arrangements of colours or their interrelations (Ou and Luo 2006). On the other hand, pleasantness of colour combinations is a *measure of emotion* – a response of the subject. In general terms *pleasantness* is defined as a quality of being enjoyable, attractive, friendly, or easy to like (Ezez. 2022), and there is a strong link between colour harmony and the emotion of pleasure (Ou and Luo 2006).

Colour design is a multifaceted problem. In architectural context colour harmony is taken as a subjective sensation and an objective parameter of design. By intending to achieve a colour design both aesthetically concordant and emotionally pleasant, architects and designers have recourse to their preferences (Portillo & Dohr 1993), or they may refer to various sources as a starting point of their colour planning process. During the later stages of the process these initial ideas are then elaborated again and again regarding various criteria which are specific for each case (Portillo and Dohr 1993; McLachlan and McLachlan 2014; Ural, Akbay and Altay 2017).

Experimental Study

This paper aims to explore aesthetical and emotional aspects of colour harmonies in an architectural context. In order to observe emergence, continuity and changes of colour design decisions on colour harmonies during colour design process, a set of studies carried out as a part of the elective course 'Colour Theory and Applications' given in Bilkent University, Department of Interior Architecture and Environmental Design, was focused. These studies were conducted as part of a colour design project and defined as a series of stages (Fig.1). in 2020-2021 spring semester:

- Analysis of a contemporary artist/painter to derive an inspiration for colour harmony; In this stage 28 contemporary Turkish artists were listed and the students were asked to choose one to be studied. Then they researched the chosen artist and analyzed his/her works to derive a source of inspiration.
- Developing a colour composition for an architectural context; In the second stage students were expected to develop their colour compositions retaining the original character of the source and considering architectural/spatial design parameters.
- Elaboration of the colour composition within a given interior space; In the third stage of the project the students were required to finalize their colour design within the given architectural context which was a public interior - a cafe area next to the entrance of a community center where the artist's exhibition takes place.

25 students attended the class and a total of 14 project proposals were accomplished individually or in groups of two. Figure 2 shows examples of the project proposals. During the project regular panel discussions and table critiques were held to uncover the students' criteria for colour harmony decisions.

Figure 1. Stages of the project: "Anonymous 1990" by Özdemir Altan – Project by Güleycan Söylemez - Merve Borazancioğlu,

The project proposals were evaluated by another student group in 2021-2022, to observe the continuity of colour harmony characteristics between the source of inspiration and the project proposals. The aesthetics of colour harmonies was considered as interrelationship of colours (Ou and Luo 2006) and classified as similarities and/or contrasts of hue, value and chroma. In exploration of the emotional aspects of colour harmonies, pleasantness and the meanings attributed to pleasantness were traced.

Results and Discussion

Colour design criteria extracted from the conversations with the students listed and classified under six domains (Table 1.). As the source of inspiration was set by the instructor, the criteria for the first stage were questioned for the selection of the artist and his/her work(s). For the other stages the reasons for the intervention in the colour scheme of the students were investigated.

In the first stage, the major reasoning behind the choices was preferences. For 85% of the projects, students made a choice in line with their personal colour preferences. This category was followed by colour emotions (71,4%), where students declared that they chose works that contain colour emotions that appeal to them. The third domain covers the thematic reasons (57,1%) for the representation of the selected artist and/or artwork. In the second stage, the strongest domain is colour aesthetics with 78,6 %. Here, the students mentioned the interventions they made to establish a more appropriate colour composition for a spatial context. This category was followed by formal - compositional reasons (50%) and functional – contextual reasons (42,9%). In the third stage, for 100 % of the projects students mentioned formal - compositional reasons for their interventions. This category includes the reasons explaining the revision of the colour scheme according to the formal design principles such as unity, variety, balance, Figure-ground relations etc. Criteria related to systematic - colour aesthetics (85,7%) and functional – contextual reasons (85,7%) are other strong categories following the first.

The above findings imply very intricate mechanisms in the architectural colour design process. As stated by previous research (Portillo and Dohr 1993; Ural et.al. 2017), personal preferences play a very important role especially at the initial stages of the colour design process.

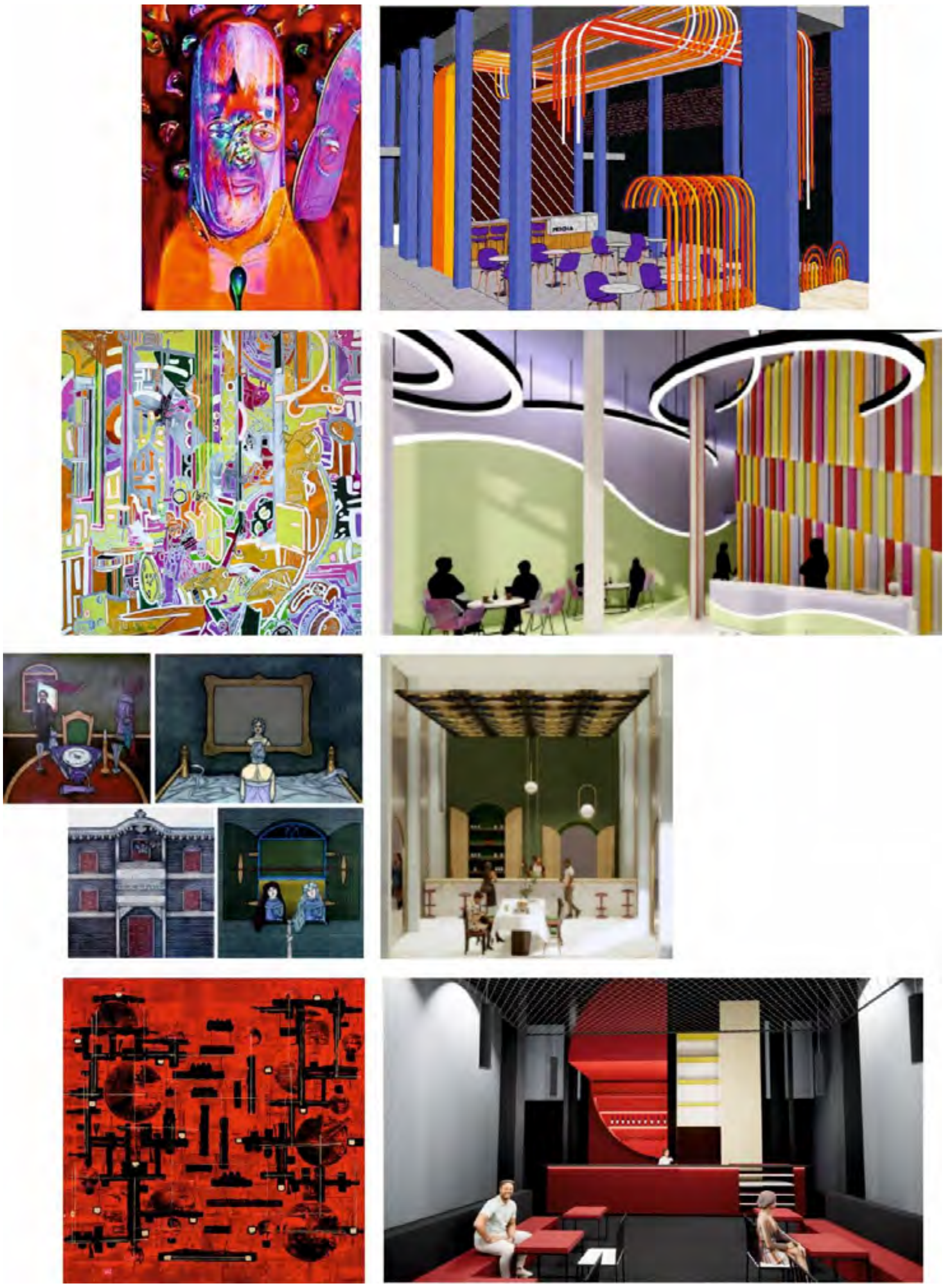

Figure 2. Examples of the project proposals:
1st row: "I in Portrait 2003" by Ergin İnan – Project by İpek Güven & Ecem Öntürk,
2nd row: "RTU 210816 2016" by Yiğit Yazıcı – Project by Sena Memigüven & Nigar Hasanzade
3rd row: "Collapse Period 1974-1978" by Balkan Naci İslimyeli – Project by Berre Denkbaş & Helin Sönmez
4th row: "Unknown 2019" by Esra Şatıroğlu – Project by Ceren Şahmaran

Colour emotions also appeared as an important determinant in the first stage. While passing into the architectural context, subjective/intuitive criteria (preferences and emotions) started to leave their place to objective ones (systematic, formal, and functional criteria). At the final stage – during elaboration of the colour design decisions within the architectural/spatial context, the objective criteria were observed at the highest level. The Reappearance of emotional criteria at the third stage may be due to the content of the problem referring to the art of painting.

	Stage 1		Stage 2		Stage 3	
Categories/Domains for the Criteria	**freq**	**%**	**freq**	**%**	**freq**	**%**
Preferences - Favorite colour(s)	12	85,7	2	14,3	-	0
Symbolic - Colour emotions	10	71,4	4	28,6	9	64,3
Thematic – Representational reasons	8	57,1	5	35,7	2	14,3
Systematic - Colour aesthetics	5	35,7	11	78,6	12	85,7
Formal - Compositional reasons	4	28,6	7	50,0	14	100
Functional – Contextual reasons	2	14,3	6	42,9	12	85,7
None	1	7,1	-	0	-	0

Table 1. Students' colour harmony/design criteria during the three stages.

For further evaluations, a survey was conducted with 43 students of Faculty of Art, Design and Architecture, in Bilkent University. There were two sets of questions in the survey; a set of bipolar five-step scaled adjective pairs to investigate constructs related to the artwork and project proposals, and a group of questions to explore the aesthetical and emotional ties between them as they transfer from an artwork to an architectural context. Within the scope of this paper, the evaluations related to *harmony* and *pleasantness* were emphasized.

The correlations between harmony and pleasantness are significant at all stages. These findings point to the strong ties between the two constructs, once again (Ou and Luo 2006; Ural and Yilmazer 2010). Mean values of harmony of colour compositions were generally higher than mean values of pleasantness of colours especially in the second and the third stages. This can be interpreted as the architectural/spatial context strengthens the aesthetical aspects of colour compositions, or may have resulted from the educational background/context of the subject group where aesthetic values stand out from emotional ones. In the study no distinctive effect of similarities and/or contrasts of colour interrelationships on colour harmony was observed. However, similar hues and similar values can have more extreme effects on colour emotions which has been observed as extreme values in pleasantness. The findings also indicate strong significant positive relationships among *harmony, pleasantness, spaciousness, and comfort* in the second and third stages. This indicates that in an architectural/spatial context, constructs related to architectural/spatial quality cannot be separated from ones related to the sense of taste.

In order to explore the aesthetic and emotional ties between the stages as colour composition transferred from an artwork to an architectural context, the subjects were asked to evaluate the continuity of the harmony and pleasantness between the stages. Tracing the characteristics of aesthetical aspects of colours appeared easier to detect for the subject group. The findings showed that subjects had more difficulty tracking emotional aspects of colour compositions while they were transferred to architectural context. Here, the indicators of tracing were extracted as colour interrelationships (80,0 %), shapes/lines (47,5 %) , emotions (45,8 %), compositional features (44,2 %), light (27,5 %), meaning (13,3 %), physical characteristics (8,3 %), respectively.

The results presented here are limited within the scope of this paper. Further studies, particularly the ones including other design parameters as much as possible, will reveal a better understanding of the relations between colour and architectural space, and contribute to literature specific to architecture and design (Caivano 2006).

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References

Caivano, J. L. . 2006. "Research On Colour In Architecture And Environmental Design: Brief History, Current Developments, And Possible Future". *Colour Research & Application* 31 (4): 350-363. doi:10.1002/col.20224.

Mahnke, F. H. , and R.H. Mahnke. 1999. *Colour And Light In Man-Made Environments*. London: Academy.

McLachlan, F. and E. McLachlan. 2014. "Colour And Contingency: Theory Into Practice". *Architectural Theory Review* 19 (2): 243-258. doi:10.1080/13264826.2014.995338.

Ou, L. and M.R. Luo. 2006. "A Colour Harmony Model For Two-Colour Combinations". *Colour Research & Application* 31 (3): 191-204. doi:10.1002/col.20208.

"Pleasantness". 2022. *Cambridge Dictionary*. Cambridge University Press.

https://dictionary.cambridge.org/us/dictionary/english/pleasantness.
Portillo, M., and J. H. Dohr. 1993. "A Study Of Colour Planning Criteria Used By Noted Designers". *Journal Of Interior Design* 18 (1-2): 17-24. doi:10.1111/j.1939-1668.1993.tb00068.x.
Ural, S. E., and S. Syilmazer. 2010. "The Architectural Colour Design Process: An Evaluation Of Sequential Media Via Semantic Ratings". *Colour Research & Application* 35 (5): 343-351. doi:10.1002/col.20583.
Ural, S. E. 2016. "Multiple Choice Of Colours In Architecture". In Fill In The Blanks, 195-201. İstanbul: Beykent University Press.
Ural, S.E., S. Akbay.and B. Altay. 2017. "Progression Of Colour Decision Making In Introductory Design Education". *Colour Research & Application* 42 (6): 849-860. doi:10.1002/col.22129.
Ural, S.E. and P. Ural. 2018. “Colour and Spatial Comfort in Architectural Context.” *AIC 2018*: *Colour and Human Comfort*, *Lisbon, Sept. 25-29, 2018*. https://www.aic-colour.org/resources/Documents/AIC2018%20Proceedings.pdf

Color influence on the usability of kitchen utensils: An empirical study in Ergonomic design

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Abstract

Color can influence human perception and behavior during interaction with a product. However, it is still unclear how color could interfere in instrumental activities of daily living, such as human-kitchenware interaction. Therefore, the main aim of this study was to investigate the color effect on the usability of two sorts of kitchen utensils. As a secondary aim, age was also considered in the statistical analysis as it is a recognized variable on usability tests. A total of 120 female participants (18-29 and 30-55 years old) evaluated a garlic peeler (Experiment I) and a potato masher (Experiment II) in green, red, and gray colors. The usability was measured by a SUS questionnaire (satisfaction), task precision (efficacy), and activity time (efficiency). In both experiments, the results indicated a color effect on satisfaction ($p \leq .05$), and age majorly influenced efficiency ($p \leq .05$). The industrial application of these findings may contribute to the product's development and tests to create user and color-driven designs. Besides, this study may contribute to other research.

Keywords: *Color, Age, Usability, Ergonomics, Design*

Introduction

Color belongs to a complex phenomenon that embraces physics, physiological and psychological processes, a piece of scientific knowledge from absorption and reflection of wavelengths to meaning associations (Ng & Chan, 2018; Witzel & Gegenfurtner, 2018; Won & Westland, 2018). Furthermore, it is an essential visual cue perceived by the chromatic optical system, responsible for extracting information from what is seen to assist human development (Witzel & Gegenfurtner, 2018).

As a visual interaction variable for Design and Ergonomics, color can influence the perception of a product's attributes (shape, size, texture) (Abegaz et al., 2015; Ding et al., 2021a), the performance and human behavior during human-product interaction (Giorgio et al., 2018; Ding et al., 2021b) and subjective judgments as well (Prado-Léon, 2015; Won & Westland, 2018; Liu et al., 2021; Buchmüller et al., 2022). In task ergonomic evaluations, age is considered another relevant variable because it influences biomechanics (Teixeira, 2006; Barbieri et al., 2014), neurological processing (West et al., 2012), aesthetic preferences, and emotional arouse (Sonderegger et al., 2016; Alves et al., 2022). Although this is referential literature, there is a lack of research adopting color as an independent variable in usability studies in which subjective and efficiency aspects work together. Therefore, this study aimed to investigate the effect of color and age on the usability of two different kitchen utensils through an ergonomic design approach.

Experimental design

Participants and ethics

A total of 120 female volunteers participated in the usability test and were divided into two age groups: 18-29 years (younger adult) and 30-55 years (middle-aged adult). The age stratification considered the findings of biomechanics (Teixeira, 2006; Barbieri et al., 2014) and neurological studies (West et al., 2012). We distributed the sample into four groups (n = 30) to perform the usability tests: Experiment I for the garlic peeler evaluation with 30 younger adults (M = 21.3, SD ±2.32 years) and 30 middle-aged adults (M = 40.9, SD ±7.76 years), and Experiment II for the potato masher evaluation with another 30 younger adults (M = 21.5, SD ±2.36 years) and another 30 middle-aged adults (M = 44.1, SD ±7.87 years). According to Serdar and colleagues (2021), some statistical models calculate 30 individuals as a critical sample size.

All participants reported no musculoskeletal symptoms in the upper limbs in the 12 months preceding the usability tests and the absence of color perception disorders (e.g., color-blindness). Concerning the education level, each experiment had 43% of undergraduate students (n = 52) and 57% of higher-educated people (n = 68). This study agrees with the Declaration of Helsinki and was approved by a local research ethics committee (code approval CAAE 90897318.5.0000.5663).

Interaction stimuli - Products evaluated

In Experiment I, the usability test used a garlic peeler made by Joseph & Joseph® Model '20045' (Figure 1) in three colors: red (HSB color space - 357, 63%, 36%), green (HSB color space - 61, 67%, 41%), and gray (HSB color space - 40, 8%, 22%). In Experiment II, the participants tested a potato masher made by Weck Home Utilities® Model 'Colors' (Figure 1) in three colors: red (HSB color space - 1, 66%, 38%) and green (HSB color space - 167, 70%, 40%) and silver (unpainted). The color selection criteria are in line with the findings regarding the color wavelength size effect on the human pleasantness (Abegaz *et al.,* 2015), the color wheel/color opponent-process theory (Feisner, 2000), and the color preferences - neutral color (Prado-Léon, 2015). In addition, the kitchen utensils should have only one color to enable us to evaluate the color effect on user evaluation.

Figure 1. Models of garlic peeler and potato masher tested in this study.

Measures, environmental setup, and statistical analysis

Usability can be understood and divided into three variables of human-technology interaction: efficacy, efficiency, and satisfaction (ISO, 2018). In this study, the usability was evaluated by a mixed methodology, gathering qualitative data through a System Usability Scale (satisfaction) (Brooke, 1996) and task precision (efficacy) and quantitative data with activity time (efficiency).
The SUS questionnaire used had twelve (12) statements covering the aspects to assess the color and material quality; color and functionality; color and pleasure; color and perceived performance; product and its practical design features. Each statement presented a Likert scale with 5-point and "Strongly agree"/"Strongly disagree". The SUS questionnaire's statements are reported below:

1. The product is as simple and straightforward as it can be.
2. The colored material of the product is inadequate because it does not transmit its quality.
3. The product fulfills its proposed functions.
4. It is not possible to use the product without prior instructions.
5. It was uncomfortable to use this product during the activity.
6. I would use this product often.
7. The color of the product is not suitable for its function.
8. The product is suitable for the size of my hand.
9. The product did not satisfy me.
10. The color made the product's user experience pleasant.
11. The product hindered the performance of the activity.
12. The fact that it is colored improved the performance of the product.

The usability tests happened at a university's laboratory with controlled environment variables to minimize disparities during data gathering. Following the recommendations of Sonderegger (2010) and Giorgio et al. (2018), we set up the temperature (24° C), light temperature (6000 K), luminance (290 cd/m2), noise (50dB), and visual cues (white color of the walls and ceiling). More details about the environmental setup and the usability tests' procedures can be seen in a related previous publication (Alves et al., 2022).

Data management and analysis were performed using IBM SPSS Statistics® (version 27) by non-parametric statistics as the data showed a non-normal distribution ($p < .05$). For all statistical tests, we used an alpha level of .05. In the dependent samples (color effect), we applied the Cochran Q test to efficacy and Friedman's ANOVA test (Bonferroni correction of .0167) to efficiency and satisfaction. In the independent samples (age effect), we used the Chi-square test for efficacy and the Mann-Whitney test for efficiency and satisfaction. In addition, we used Fisher's exact test when the Chi-square assumption for the expected count was violated (value < 5).

Results

Overall, the results indicated a color and age effect on the usability of the kitchenware tested. On the one hand, color was the main variable in satisfaction ($p \leq .05$). In both experiments, the gray product had the best SUS score. On the other hand, the age effect majorly influenced efficiency with a significant difference ($p \leq .05$) in both experiments. The younger and middle-aged adult groups performed differently during the usability tests.

Experiment I - Garlic peeler

According to the data analysis, there was no color and age effect on efficacy results ($p > .05$). Regarding efficiency, there was no color effect ($p > .05$). However, the results showed a significant difference in the three interaction stimuli conditions between the age groups, being two conditions with a medium effect size ($.5 < r \geq .3$) (Table 1). Interestingly, there was a stronger difference ($p \leq .01$) between the age groups when interacting with the red garlic peeler, being the middle-aged adult group with the lowest time of activity (Md = 44.5).

Lastly, the satisfaction results indicated a color effect only in the middle-aged adult group [x^2 (2) = 8.788; p =.012]. The post hoc test revealed a significant difference (p =.024) between the green (Md = 37.50) and gray (Md = 42.71) colors. The red product got a SUS score of 41.67. When verifying the age effect on the satisfaction, we did not find a significant difference ($p > .05$).

Garlic peeler	**Younger adult group**	**Middle-aged adult group**	**Mann-Whitney results**
gray	65.5s	47s	[(Md = 51.5), U = 304; p = .031, $r \approx -.28$]
green	81s	51s	[(Md = 57), U = 287; p = .016, $r \approx -.31$]
red	66s	44.5s	[(Md = 52.5), U = 268; p = .007, $r \approx -.35$]

Table 1. Time of activity in seconds (median) for both age groups.

Experiment II - Potato masher

Based on the statistical analysis, no evidence was found for color and age effect on efficacy results ($p > .05$). Likewise, in Experiment I, the efficiency results of Experiment II showed only a significant difference for the age effect ($p < .05$), and the middle-aged adult group presented the lowest activity time for all interaction stimuli conditions. As seen in Table 2, there was a stronger difference ($p \leq .01$) between the age groups with the gray and red potato mashers, with large and medium effect sizes, respectively.

Potato masher	Younger adult group	Middle-aged adult group	Mann-Whitney results
gray	45.5s	34s	[(Md = 40.5), U = 174.5; p = .000, $r \approx -.53$]
green	44s	39s	[(Md = 42), U = 331.5; p = .08]
red	44.5s	38s	[(Md = 40), U = 220.5; p = .001, $r \approx -.44$]

Table 2. Time of activity in seconds (median) for both age groups.

Regarding satisfaction, the statistical tests revealed a significant difference for both variables. When verifying the color effect, only the younger adult group presented a significant difference [x^2 (2) = 18.672; p = 0.000]. The post hoc test showed statistical differences between gray (Md = 78) and green (Md = 63) (p = .000), and gray and red (Md = 63) (p = .006) as well. In turn, when analyzing the age effect, we found just a significant difference with medium effect size [(Md = 73.5), U = 299.5; p =.025, $r \approx -.29$] for the gray potato masher, being the younger adult group attributing the higher SUS score (Md = 54.17).

Discussion

The color scheme applied to products is several times a project decision based on market trends; despite the body of knowledge concerning user perception (Abegaz et al., 2015; Prado-Léon, 2015; Ng & Chan, 2018; Won & Westland, 2018; Ding et al., 2021a; Liu et al., 2021; Alves et al., 2022; Buchmüller et al., 2022) and the behavior outlined (Giorgio et al., 2018; Ding et al., 2021b; Alves et al., 2022) by scientific research worldwide. The current study adopted an ergonomic design approach to discover how color and age could influence the usability (efficacy, efficiency, and satisfaction) of two kitchen utensils; a garlic peeler and a potato masher.

In contrast to the findings of Giorgio and colleagues (2018), efficacy and efficiency results suggested no color effect ($p > .05$) in Experiments I and II. Considering the literature review, a possible reason is the short exposure time to the product (time of activity) or even the simplicity of the product interface. However, these hypotheses need to be investigated deeply with different product interface complexities and kinds of activity to confirm. Regarding the satisfaction results, a color effect ($p \leq .05$) was identified in both experiments. In Experiment I, the gray garlic peeler had the highest SUS score (Md = 42.71) compared to the green garlic peeler from the middle-aged adult group's evaluation. In Experiment II, the gray potato masher had a higher score (Md = 78) in relation to the green and red potato mashers from the evaluation of the younger adult group. These results can be interpreted by combining three subjective association processes: color meaning, color-concept, and product-concept association. The participants may have associated gray with simplicity and reliability, with meanings of pragmatic order often attributed to this color.

In addition to this, the current study works with color applied to products, so there was possibly a context of use bias associated with the products tested. Neutral colors have been used in kitchens and appliances for decades in Brazil. Thus, the participants may have mitigated the color preference bias proposed by Prado-Léon (2015) to fulfill the SUS questionnaire statements. According to Alves et al. (2022), this age group considered the gray product as least preferred. This explanation was also suggested in a related previous publication (Alves et al., 2022) and supported by the findings of Ng and Chan (2018), Won and Westland (2018), and Buchmüller et al. (2022).

When analyzing the age effect, there was no evidence that it influenced the efficacy in both experiments and the satisfaction in Experiment I. However, the efficiency results showed a statistical difference ($p \leq .05$) between the younger and middle-aged adult groups. In Experiments I and II, the middle-aged adult group had better activity times, in other words, shorter times. This finding opposes the study of Sonderegger et al. (2016), which considered age only as a negative variable on usability tests. Although age impacts biomechanics (Teixeira, 2006; Barbieri et al., 2014) and neurological processing (West et al., 2012), the middle-aged adult group may have performed the tasks with less difficulty as a result of their cooking experience, in general. It is essential to say that the age groups had similar novelty rates for the two kitchen utensils (Alves et al., 2022), so there was not a group with more experience using the tested products.

Lastly, Experiment II had an age effect ($p \leq .05$) on satisfaction. The younger adult group attributed a higher SUS score for the gray potato masher (Md = 54.17). It is possible to notice that this age group had a better satisfaction evaluation for the gray potato masher in the product color comparison (color effect) and between age groups (age effect). In this study, the SUS questionnaire was elaborated with more questions concerning the 'product and its practical design features' compared to the one discussed by Alves et al. (2022). On the basis of the foregoing, the younger adult group may have been more influenced by the associative processes mentioned above than the adult group.

Conclusion

Based on the current findings, this study confirmed that color and age are important variables in the usability of kitchen utensils, shedding light on a rich research field for designers, ergonomists, and human factors practitioners. It is crucial to highlight that this study does not intend to discuss results for a generalizing color interpretation because it has an exploratory path. The study gap indicated in the literature review about a systematic approach for investigating the color effect on the usability of a product started to be filled, although their limitations. The industrial application of the findings may contribute to the product's development and tests to create user and color-driven designs and also better human-product interactions. Besides, the methodology used can be applied in usability tests with categories of products and may contribute to other studies.

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References

Abegaz, T., E. Dillon, and J. E. Gilbert. 2015. Exploring affective reaction during user interaction with colors and shapes. *Procedia Manufacturing* 3:5253-5260.

Alves, A. L., M. R. de Giuli, E. Zitkus, and L. C. Paschaoarelli. 2022. Color influence on the use satisfaction of kitchen utensils: An ergonomic and perceptual study. *International Journal of Industrial Ergonomics* 90: 103314.

Brooke, J. 1996. SUS: A 'Quick and Dirty' Usability Scale. In: Jordan, P. W., et al. (Eds.). *Usability Evaluation In Industry*. London: Taylor & Francis, chapter 21, pp. 189-194.

Buchmüller, K., A. Bearth, and M. Siegrist. 2022. The influence of packaging on consumers' risk perception of chemical household products. *Applied Ergonomics*, 100: 103676. De Giorgio, A., et al. 2018. Enhancing motor learning of young soccer players through preventing an internal focus of attention: The effect of shoe colour. PLoS One, 13(8): e0200689.

Ding, M., Y. Cheng, J. Zhang, and G. Du. 2021a. Product color emotional design based on a convolutional neural network and search neural network. *Color Research & Application*, 46: 1332–1346.

Ding, M., M. Song, H. Pei, and Y. Cheng. 2021b. The emotional design of product color: An eye movement and event-related potential study. *Color Research & Application*, 46: 871–889.ISO 9241-11:2018. 2018. Ergonomics of human-system interaction —Part 11: Usability: Definitions and concepts. The international organization for standardization.

Liu, W., Y. Cao, and R. W. Proctor, 2021. How do app icon color and border shape influence visual search efficiency and user experience? Evidence from an eye-tracking study. *International Journal of Industrial Ergonomics* 84:103160.

Ng, A. W. and A. H. Chan. 2018. Color associations among designers and non-designers for common warning and operation concepts. *Applied Ergonomics*, 70: 18-25.

Prado-León, L. R. 2015. Color preferences in household appliances: data for emotional design. Procedia Manufacturing, 3: 5707-5714. Sonderegger, A. 2010. Influencing factors in usability tests: the testing situation, the product prototype, and the test user. Doctoral dissertation, Université de Fribourg.

Sonderegger, A., S. Schmutz, and J. Sauer. 2016. The influence of age in usability testing. *Applied Ergonomics*, 52: 291-300.

Witzel, C. ,and K. R. Gegenfurtner. 2018. Color perception: Objects, constancy, and categories. Annual Review of Vision Science, 4: 475-499. Won, S. and S. Westland. 2018. Colour meaning and consumer expectations. *Color Research & Application*, 43(1): 100-109.

Wood colours in contemporary architecture: a comparison in three European countries

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Abstract

Wood is an incredibly universal and eco-friendly material. Currently, many initiatives in Europe aim at directing attention to the universality of wooden and wood-based products, to foster a more sustainable future and promote the development of healthy living spaces and new objects built of wood. European countries have set different targets to increase the use of wood in architecture. However, in this context there is little discussion about colour. The "natural colour of wood" may indicate different colours in different countries, which can have different local wood specifies, different traditions to use wood, and different ways to protect it with paint or other ways. This research refers to the colour scheme and characteristics of wood in three countries: Italy, Poland, and Finland. The authors studied how the selected types of wood commonly used in these three countries are applied in architecture. Is there a colour "specifics" of wood – different for three countries in Europe? Can we speak of a typical colour palette of products made of wood in the context of these countries? What is the main challenge with the colour and the wood in the national and international perspective?

Keywords: *Colour, Wood, Architecture, Design*

Introduction

The subject of research is finding the characteristic colours schemes and finishings of wood in Italy, Poland, and Finland. It is also an attempt to answer the questions: How do contemporary architects and designers use wood? The main study area refers to marking out the leading types of wood in each of three countries and presenting its colour parameters. The selected most popular wooden materials are described as regards their properties and usage. The observed regularities refer to several aspects such as local wooden material in three countries, atmospheric and climatic factors connected with wood and ageing and its effect on the natural material and the possibilities of "designing" the related visual change.

Method

The scope of the described and analysed objects includes buildings and constructions raised or manufactured after the year 2000. It is not, therefore, a historical analysis, but rather a study of the contemporary architectonic solutions using the colour schemes of wooden elements. The buildings selected for this research are the most characteristic examples of Italian, Polish and Finnish architecture respectively. These include public buildings, residential spaces, exhibition pavilions and other objects that could be considered characteristic or iconic by their outstanding form and the use of wood as a leading material, which determines the visual reception of the object. The key aspect was assumed to be the geographic one, ie. the location / execution of the selected objects in the three described countries. Such a restriction regarding the wood material used in architecture is not possible due to globalisation – wood sourced in Asia and Eastern Europe is applied in buildings worldwide. Although there were no limitations assumed in reference to the nationality of architects, the final group turned out to go beyond the representation of a given country.

10 most characteristic buildings were selected for each country. The authors analysed professional literature, wood and architecture journals and branch portals in pursuit of innovative solutions awarded and appreciated in the circles for their inspiring selection of wood materials accentuating the beauty of designed spaces. The emphasis was put on visual, creative, utility, and pragmatic aspects as well as on the notions of technology and ecology in the selection of materials. There were complementary interviews conducted with the designers of described objects regarding their motivation to use a given material, manners of its utilisation, conclusions drawn during their work and after implementation from the perspective of life cycle of the design.

Observation and results

Observations were carried out for the three selected countries simultaneously. The authors were fascinated to discover that these differences (manifested in design decisions of their designers) resulted from the following factors:

1. Cultural/historical
2. Scale (urban planning context of development, spatial: form of buildings)
3. Technical
    a) Air temperature, wind, humidity in connection with the general accessibility of technologies.
    b) Availability: in the Northern European countries wood is the element of construction as well as finishing of the interior and elevation, while in the Southern countries this role is taken over by stone and brick materials.
    c) Fire and earthquake protection: legal requirements for public and residential buildings.
4. Economical (connected with accessibility of raw material, cost of its transport and processing as well as availability of construction technology in a given country)
5. Ecological (legal norms regarding recycling and percent value of recyclable materials in the newly-built investments)

Characteristics of the Polish architecture (Central Europe area)

In the selected buildings executed in Poland, *larch* dominates. The material is so popular due to its universality and diversified effect achievable by its use. This wood is appreciated for its excellent properties: resilience to fungi, decay and atmospheric conditions, high hardness, and outstanding aesthetic. In the selected buildings, larch is present in the raw elevation boarding [1] and in the form of more processed boarding [2]. Larch as an accent complementing the contemporary character of a building can be observed in the soffit and finishing elements of the exterior [3]. The visual consistency achieved by means of coherent colour scheme of larch boards material can be noticed in large open public spaces such as the kayak marina in Tychy Paprocany [4] and the internationally awarded "Mies Van der Rohe" centre of local activity in Rybnik [5]. Designers favour the use of unimpregnated, naturally patinating larch wood. As a relatively not light material, larch is the first choice in the conditions of moderate lighting and temperature of Eastern Europe and gradually changes its colour to very dark, blackened. Another type of wood characteristic of this region of Europe is *aspen* shingle. Its use is strongly conditional on the historic context as aspen has always been the most available, economical, and easily processable – and therefore popular – material. The regional and ecological aspects go hand in hand with practicality: this roof and elevation cover is characterised by high durability (up to 40 years) and tightness. The small mass of this natural material makes it applicable to light and atypical constructions [6].

What is atypical about this material is its colour scheme – such "white" wood provides an interesting visual accent. The final natural material typical of the wooden architecture of the Central European area is *acacia*, which replaces the exotic wood commonly used in other parts of the world. It presents aesthetic values similar to the types of wood naturally absent from our climate (e.g. cedar). Although both acacia and exotic woods are resistant to humidity, very durable and hard, thereby resilient to mechanical damage, acacia also features a very low swelling and contraction coefficient which makes it much less prone to cracking, bending and deformation e.g., resulting from extreme temperatures. *Cedar* is scarcely used in this latitude for the reasons mentioned above, as well as its price and availability of the local material. An example of a large holistic construction where the natural unimpregnated acacia wood was used for elevation, roof cover and interior of the building is Muzeum Wsi Opolskiej – Museum of the Opole

1 Detached house in Rybnik Wielopole: Jojko + Nawrocki Architekci studio, Marlena Wolnik Architekci, http://www.jna.com.pl/dom-na-mokrad%c5%82ach/
2 Arcade house in Małopolska region: BXN studio, https://bxbstudio.com/project/chata-podcieniowa/
3 Willa Reden: Franta Group, https://www.frantagroup.com/projekty-3/apartamentowiec-reden/
4 Kayak marina in Tychy Paprocany: RS + Robert Skitek, http://rsplus.pl/pl/zrealizowane/przystan-kajakarska-mosm/
5 Centre of local activity in Rybnik: Marlena Wolnik Architekci. https://mwarchitekci.pl/category/publiczne/
6 Votum Aleksa Church in Tarnów: Pracownia Beton, Marta and Lech Rowińscy, http://www.betonon.pl/pl/projekty-dzialania/kaplica-w-tarnowie

Countryside[7]. The use of the equivalent of acacia – exotic wood is exemplified by the application of raw Canadian cedar in the design of Pixel office building [8].

Characteristics of the Italian architecture (Southern Europe area)

In recent years, wood has gained a new image: from a rustic and traditional material to a modern high-tech product. In Italy, wood, which until a few years ago was mainly used for roof construction, is once again becoming one of the structural materials par excellence and, thanks to new technologies developed by wood research institutes, is being used in floors and walls, forming the entire structural framework of the building. For every 12 buildings constructed in Italy in 2010, one was made of wood. In 2020, despite the effects of the pandemic, a total turnover of EUR 1.39 billion was achieved, confirming Italy as the fourth largest country in Europe in terms of construction of wooden buildings after Germany, UK, and Sweden.

According to Federlegno Arredo's report[9] on wooden houses and buildings, the Italian region with the most wooden houses is Lombardy, where 22% of the green building residential constructions in Italy are concentrated, followed by Veneto with 19%, Trentino-Alto Adige with 12% and Emilia-Romagna with 11%. This result shows a clear distribution of wooden houses above all in northern Italy, which proves to be an area particularly ready to take up the advantages of wooden buildings and to invest in green building. Wooden buildings are very safe from an earthquake point of view because they are lighter and more flexible. The diffusion of wooden houses in central and southern Italy, although with decidedly lower values, is growing steadily; the regions of central and southern Italy are in fact characterised by a typically Mediterranean climate, with short, mild winters and very hot summers. Wood is not a competitive material for these climates. The most relevant materials in use in southern Italy in building and architecture are stone, which varies from region to region, and brick.[10] Milan, Turin, Florence, and the major cities of Northern and Central Italy now present numerous examples of how wooden engineering can be developed in height. In urban and suburban areas, building spaces are scarce and it is therefore useful to build vertically: wood, being ductile and light, can be used for this type of intervention.

The designers have used wood to create a dialogue with the natural context, exploiting both its emotional characteristics of welcoming, warmth, domesticity, naturalness and its technical characteristics of lightness, elasticity, and ease of processing. In Italy, structures made of fair-faced wood in recent years are

7 Museum of the Opole Countryside: DB2 Architekci Iwona Wilczek and Mariusz Tenczyński, http://www.db2.pl/projects/24
8 Pixel office building in Poznań: JEMS Architekci studio, https://jems.pl/projekty/wybrane-prace/pixel.html
9 ASSOLEGNO 6° Wood Construction Report - 03 dicembre 2021, https://www.federlegnoarredo.it/it/associazioni/assolegno/attivita-e-servizi-per-i-soci/analisi-di-mercato/6-rapporto-edilizia-in-legno
10 Local materials in the building tradition of Southern Italy, Università degli studi di Napoli "Federico II", Crescenzo De Simone

characterised by a strong innovative character; it has been used for spaces with uses that were not traditional for example, for temporary spaces, music theatres, institutional spaces...

The new technology of solid wood panels with crossed layers, XLAM, has reached 33% of the market in just a few years. This type of construction is closer to Italian habits, because it allows the construction of real "wooden walls", to be covered both inside and outside with the preferred and most suitable material for the area. As far as the type of wood used (for structural elements) is concerned, it is mostly made of fir, immediately followed by larch and pine. Thanks to the XLam Cross Laminated Timber technique, the Via Cenni social housing[11] was constructed in just 18 months. This building brought Italy to the forefront of architecture: wood was used for everything, including floors, walls, and the lift shaft. Another building constructed in record time is the Unicredit Pavilion by Michele De Lucchi: one year, one month and ten days. It was created to combine the use of cutting-edge technology with a deep sensitivity towards nature and meets the most stringent international standards for environmental sustainability, hence the achievement of the LEED GOLD® certificate of excellence[12]. The external load-bearing structure is made of glued laminated larch wood that has been 'sanded' for reasons of aesthetics and durability; for the roof system, multilayer wood panels were used, covered with zinc-titanium laminate panels[13].Wood is used as a 'symbol' of respect for the environment and harmony with nature in the Green Pea commercial building[14] in Turin. The outer shell consists of a double layer of surfaces and a skin of spruce louvres. Spruce is not normally used for construction, but was recovered from trees that fell in the Vaia storm that hit the Triveneto region in 2018. The wood used is a special kind of wood, the 'harmonious wood' from Val di Fiemme, which has been made suitable for construction through a special heat treatment. The New Convention Centre[15] signed by Kengo Kuma is under construction in Padova (7).-To clad the façade, 28 pillars of laminated larch wood were used with a wave pattern that will change colour with the wear and tear of time. Wood was also chosen for its acoustic and earthquake-proof properties in Renzo Piano's Auditorium Parco della Musica in L'Aquila. The structure is built with wooden beams to which panels made of layers of glued laminated timber (XLAM) are dryly connected. In the external treatment of the surfaces, the protagonist material is fir wood, worked with a weave of horizontal staves of different colours and thermally treated. Another type of timber construction that is developing in the Italian market to meet the need of creating a strong link with nature and the surrounding landscape are prefabricated houses[16] , which can be placed in any context, and

11 Via Cenni Social housing: Rossi Prodi, http://www.rossiprodi.it/?project=social-housing-via-cenni
12 https://greenbusinessbureau.com/industries/building-and-construction/leed-certification-checklist-for-building-design-and-construction-bdc/
13 The Unicredit pavilion: Michele de Lucchi, https://www.archilovers.com/projects/135743/unicredit-pavilion.html
14 GreenPea building: Negozio Blu Architetti Associati, https://www.greenpea.com/en/
15 New Convention Centre of Padova: Kengo Kuma, https://www.fieradipadova.it/quartiere/nuovo-centro-congressi/
16 FRAME integrated architecture: LEAPFactory, https://www.leapfactory.it/residential-live-freely-live-healthy-build-freely/

small mountain huts. Larch wood is also the protagonist in many renovations of houses and mountain huts. This dark-grained wood is used for both cladding and furniture and is revisited in a modern key with brushed finishes, antiqued, blackened with iron oxides, finished with wax, etc.[17] [18]

Characteristics of Finnish architecture (the Northern Europe)

The Helsinki Central Library 'Oodi'[19] demonstrates the versatility with which wood species can be used in one building. The façades claddings are made of domestic *spruce*, the pillar ceiling on the second floor of *birch*, the third-floor parquet of *solid oak,* and the terrace boards of the balcony of acetylated radiata *pine*. The exterior of the 'Kamppi Chapel of silence'[20] is made of bent *spruce* strips. The interior walls are clad with planks of *alder*. The furniture is made of solid *ash*. The 'Hopealaakso daycare'[21] centre, winner of the 2021 Finnish Wood Award, is constructed mostly using different types of CLT elements (e.g., load-bearing exterior and stairwell walls, ceiling beams). The exterior consists of larch and zinc coated panels. New solutions, such as CLT constructions and elements, broaden the concept of wooden based colour to include wooden based materials. The 'Meteorite house'[22], winner of the 2020 Finnish Wood Award and displayed virtually at the Venice Architecture Biennale 2021, experiments the use of CLT on exterior material; to date, glued wood products have been used outside only in covered spaces. The exterior of 'Café Birgitta'[23] is black with charred surfaces of 50x50 laminated wood. By contrast, the interior is bright with log walls. The 'Shingle Church'[24] at Kärsämäki exemplifies a traditional use of wood. Its exterior is made of 50000 *aspen* shingles, tarred black.

The urban sauna and restaurant 'Löyly'[25] is not only a building; it is also a part of the landscape. The free-formed sculptured "cloak" (exterior) is made of Nextimber panels, an innovation produced from residues of the plywood industry (*birch* core wood). Since there is no surfacing on the exterior, it will turn to grey like old hay barns. The walls and benches of the saunas are made of *termo pine*. The 'Four-cornered villa'[26] by the same architecture office is a modest villa in the middle of the forest. Its exterior is *spruce*, treated to black, but the interior is very light. The

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17 Mountain pasture in Petosan: Brambilla Orsoni Architetti Associati, https://www.archilovers.com/teams/608256/brambilla-orsoni-architetti-associati.html#projects
18 Villa TS semi-detached house: Bergmeisterwolf, https://www.bergmeisterwolf.it/it/
19 Helsinki Central Library Oodi: ALA Architects, https://puuinfo.fi/arkkitehtuuri/julkiset-rakennukset/helsingin-keskustakirjasto-oodi/, https://ala.fi/work/helsinki-central-library/
20 Kamppi Chapel of Sience: K2S Architects LTD, https://puuinfo.fi/arkkitehtuuri/public-buildings/kamppi-chapel-of-silence/?lang=en
21 Hopealaakso Day care: AFKS Architects, https://puuinfo.fi/arkkitehtuuri/daycare-centres-and-schools/hopealaakso-daycare-centre/?lang=en, https://afks.fi
22 Meteorite House: Ateljé Sotamaa, https://puuinfo.fi/2021/11/24/meteorite-house-a-study-in-the-insulation-and-surface-treatment-of-clt-structures/?lang=en
23 Café Birgitta: Talli Oy, https://puuinfo.fi/2021/11/17/wood-rises-to-the-surface/?lang=en
24 The Shingle Church at Kärsämäki: Antti Lassila, https://puuinfo.fi/arkkitehtuuri/public-buildings/the-shingle-church-at-karsamaki/?lang=en
25 Löyly: Avanto Architects, https://avan.to/works/loyly/, https://proofer.faktor.fi/epaper/Puu316/#12
26 Four Cornered Villa: Avanto Architects, https://avan.to/works/four-cornered-villa/

walls are made of *spruce* and the floor of *pine*. Both have been surfaced with whitish oil vax.

The interviews with architects shed light on the realities constraining their colour choices. Thus, the need for weather and fire protection strongly defines the aesthetics of colour choice. Although the aim may be to generate a ‘wooden façade’ and thus, to keep the typical colour of the selected wood species, the façade still needs protection against the weather and the sun. Likewise, although the aimed effect may be one of natural aging, bigger buildings however need fire protection, which lessens natural greying. With respect to species, *pine* and the *spruce* are the most common, while *birch* and *oak* are used in interiors. As the availability of larch is decreasing, spruce is increasingly used. Simultaneously, new glued wooden materials are constantly being developed while the use of massive timber continues to increase. The world’s largest (8770m2) massive timber log school ‘Monio’[27] will be built in Tuusula in 2023.

Trends

The authors noticed the following trends in the use of wood colour scheme in their geographic areas. First, there is the “black and white” trend, where wood is used as a near-monochrome material. It was observed that both the exterior and interior was created with elements of considerably different lightness with no other colour accents used in the space. Regarding the specificity of climate (light temperature and cool/warm air), three sets can be determined:

1) Black on the outside / white or “wooden” on the inside (typical of Northern, present in Central Europe)[28]
2) Grey on the outside / grey on the inside (wood of moderate lightness, present in Central Europe)[29]
3) White on the outside / black on the inside (typical of Southern Europe with high degree of insulation). The “black” dark-grey or brown colour is obtained with impregnation by means of scorching various types of wood or allowing the natural patina of time. The “white” light elements of space and furnishings of the interior are usually made of natural light plywood or CLT (cross laminated timber) board. In between, there is wood of medium lightness or such that does not turn brown in the natural ageing process.
4) The use of natural wood colour scheme combined with purposefully designed colour accents, e.g., larch elevations with colour accents of boarding coated with acrylic paint with the colour scheme based on the flower meadow around the building[30]. In Finland, the natural colour of wood is an aesthetic value in its own right, and it is viewed as the ‘honest’ hue of wooden material.

27 Monio: AOR Arkkitehdit Oy; https://aor.fi/Tuusula-High-School-and-Community-Centre
28 Origami House: Medusa Group, https://www.medusagroup.pl/projekty/mieszkaniowe/origami-house-2/
29 Kindergarten in Paniówki, Gierałtowice: Jojko studio + Nawrocki Architekci, http://www.jna.com.pl/przedszkole-w-paniowkach/
30 Dom Ekologiczny – Ecology House near Pszczyna: Piotr Kuczia, https://kuczia.com/pl/dom-ekologiczny-nad-jeziorem-lackim/

5) Polychromacy with paint is inextricably connected with the use of wood in general in the climate conditions of Northern Europe, where it is necessary to protect wood. In Finland, especially in one family houses, there are several colour scales based on the detailed plan and on design guidelines: Falun red/ masonry red/ red ochre, blackish / greyish, pastel colours and high chromatic with many hues. In the social housing blocks, the variation of colours is used to create a vivid environment without additional cost.[31]

Summary

This paper is background research for an international research project to add knowledge for increasing colour use in wooden architecture. The main target is to study the role of the colour in contemporary wooden architecture and find challenges and new questions of our time. The species of wood varies in Italian, Polish and Finnish architecture. However, the wooden architecture of the 2000's displays similar colour trends. Next steps could serve as a set of design guidelines or a catalogue, or the presentation of the actual state in this area, a specific colour trend book of wooden materials in the current design view. On the other hand, the colour design of the wooden architecture faces several challenges in the future. While the target is to increasingly use wood as a building material, the availability of for example the larch is declining. Moreover, colours are not based only on the typical colours of different species but are also influenced by CLT and other increasingly common building materials. Moreover, technical factors such as weather and fire protection have priority over the aesthetics of colour design.

References:

Thompson, R. 2017. *The Materials Sourcebook for Design Professionals.* London: Thames & Hudson.
Van der Lugt, P. and A. Harsta. 2021. *De Houtbouw Revolutie*, Naarden: MaterialDistrict.
Ennos, R. 2020. *The Age of Wood,* New York: Scribner.

31 HEKA Virtarannankatu 3-5: Kirsti Sivén & Asko Takala Arkkitehdit Oy; https://puuinfo.fi/arkkitehtuuri/pientalot/heka-virtarannankatu-3-5/

Session 3
Colour & Language

Two kinds of explanation for basic color terms?

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Abstract

Different types of explanation have been proposed for basic colour terms (BCTs). This paper makes a distinction between local and global explanations and argues that these different explanation types need not be in conflict. They have different explanations. Local explanations explain the origin of BCTs in local cultures. Global explanations target the role of BCTs in abstract colour classification.

Keywords: Basic Colour Terms, Colour Naming, Berlin and Kay Theory, Explanations.

Introduction

In an article about cross-cultural colour categorization and naming the psychologist Jules Davidoff writes that

> The distinction, in Berinmo, between leaves that are edible (green) and those that are inedible (yellow) makes up two of their terms. Their red term is the name of a berry which, like most berries, is a dark, saturated red when at its best to eat. The red term in other cultures is the word for blood (Rivers, 1905), which is a similar hue to the color of ripe berries. So a physiological explanation for the origin of color terms is not needed for any language, nor is it needed for the similarity of its terms to those in other languages for which there would be similar natural constraints. (Davidoff 2015, 272-273)

This passage contains an argument. The premises: (P1) Colour words in Berinmo are a consequence of natural constraints. (P2) Explanations in terms of natural constraints can be given for all languages. The conclusions are (C1) Colour terms in any language do not require a physiological explanation, and (C2) Cross cultural explanations for colour term similarity are not required, for languages with similar colour terms.

One thing that this argument does not do, *prima facie*, is invoke the analytical categories “universal” and “culturally relative.” In that sense it is in keeping with some recent literature that holds discussions of colour naming, cross culturally, are not well served by such reductive characterization (e.g. Witzel 2019, Abbot et al 2016) I want to follow in this line of thought here. Davidoff’s remarks are significant, in they lead us to focus on what I will call *local explanations* in relation to *global explanations*. What happens when these two different kinds of explanations are both in play? Must one or the other be correct?; Are multiple explanations compatible or is the phenomenon "overdetermined" when it has multiple explanations?; Is it possible that they, in fact, explain different things? One of the clear targets of Davidoff's argument is "physiological explanations." Physiological explanations (facts about the eye-brain-mind explain facts about colour naming) have fallen out of favor (NB Witzel 2019 sec 4.2 for a review of the issues) and there is no currently plausible physiological explanation to cite in relation to Davidoff's contrasting class of explanation, his "naturalistic constraints." There is also a problem with that wording: what constraints would not be "naturalistic"? I prefer for these reasons, to distinguish types of explanation that are *local* from types that are *global*. Local explanations are grounded in facts about a particular language, while global explanations apply to all (or possibly some larger set of) languages. This characterization does Davidoff no disservice. His example of Berinmo is an example of a local explanation for the Berinmo colour words for green, yellow, and red (in their closest English gloss) while the physiological explanations he mentions are implied to have global applicability. With this change of terminology in place, one addition is required to connect with the larger literature on colour naming. Davidoff is concerned with terms deemed "basic colour terms" (BCTs) according to a definition of basicness derived from Berlin and Kay (1969) and related, more contemporary work (see Biggam 2012, ch.3; Witzel 2019 sec. 3, for reviews). I thus reconstruct Davidoff's argument as follows:

[P1] Local explanations for basic colour terms can be given.
[C1] Basic colour terms in any language do not require a global explanation.
[C2] Explanations for the similarity in BCTs across different languages are not required.

Local explanations [P1]

We can start with a consideration of [P1]. In terms of the passage it is derived from, the evidence in its favour is slim: the Berinmo have local explanations for their BCTs. Sample size of one (or a few if we include the reference to Rivers) is too small for anything but "hasty generalization." We can muster support on our own for this claim: the ethnographic literature is full of local explanations, similar to the Berinmo (e.g. Groh 2016, Haynie and Bowren 2016, Blust 2001, Stanlaw 2007, Levinson 2000, Conklin 1973, Berlin and Kay 1969). But there is a larger idea at work here, and it is the idea that colour words have an etymology which will lead back from the current status of a term as basic—as an abstract classification—to some object or property that was named. (We can give two easy examples in English, *orange* and *purple*—which is not to say that the etymology is easy). In the beginning was the word, and the word was the name of a thing or a property of a thing. We can see this plainly in the common linguistic phenomenon of duplication which can be used to generate colour terms: "These [reduplicative languages,] are languages which, as part of their normal structure, duplicate words to create a new but usually related meaning. In Samoan, for example, *mū* means 'red hot; to burn' and *mūmū* means 'red'." (Biggam 2012 p. 23) Similar Samoan terms for black, white, and yellow have similar kinds of derivation. (See Urbanczyk (2017) for discussion of reduplicative languages, as linguists call them.) Colour terms created by duplication are mentioned in the ethnographic section of Berlin and Kay (1969) named "The Data." They are very common in Oceanic languages (Blust 2001) and unlikely to appear in languages where duplication is less common. The upshot of this discussion of colour words and things (or properties) is that Davidoff's view, expressed now in my [1] is plausible for a variety of reasons, and possibly even trivially true. If one is a stickler for empirical data, one can accept [1] in a restricted sense, applying to the many BCTs that are related to objects and properties. I take it that [P1] is thus *prima facie* plausible and has significant evidence in its favour for many actual languages and BCTs.

Global explanations [C1] & [C2]

If we accept [P1] as plausible, does it provide sufficient support for [C1] and [C2]? Roughly, the question is whether local explanations block out global explanations? Isn't one explanation enough? If you are an ethnographer, and you uncover the experiential root for a basic colour term in some local natural property, what more is there to say? The development of the basic colour term theory suggests the answer is: possibly quite a lot. For those unfamiliar: Berlin and Kay (1969) argue that once you have decided on the BCTs in a language, according to their stipulated criteria for basicness (see Biggam 2012 and Witzel 2019 for issues with this), you can compare those terms to other languages and find a variety of interesting positive correlations: there is a relatively small number of BCTs over all and there is an order in which core BCTs, words for black, white, red, yellow, green, and blue appear in any given language (suggesting a constrained global pattern of development). When people are asked to identify the best examples of their BCTs, there is significant agreement.

All of this indicates to those that accept the basic colour term theory, that there is something global at work. A BCT may have a local explanation, but the global patterning of BCTs, cross-culturally, requires a more global explanation. It is worth pointing out that, unlike ubiquitous (if piecemeal) local explanations, there is no agreed upon global explanation. Davidoff mentions "physiological explanations." The idea is that some colours (the basic colour *categories* or some aspect of the category such as its *best example* or *focal colour*—the things named rather than the name) are salient for reasons that relate to visual physiology (see Hardin 1988 for the clearest statement of this view; also Kay and Maffi 1999). But there are difficulties with this view, or class of views (e.g. Witzel 2019, Kuehni 2014, Witzel and Franklin 2014, Malkoc et al 2005), and even those once supportive of perceptual global explanations recognize that is so (e.g. Kay 2015, Hardin 2014) I point out here that a recent review of the literature (Lindsay and Brown 2019) marks a difference between social and innate (e.g. physiological) forms of explanation for the patterning, and points out that the social explanations are in ascendence. At this point, the nature of the correct explanation can be set aside. I am interested in the larger question of explanation-types and their implications for one another. To come back to the question this section began with, and to reformulate it slightly: Isn't one kind of explanation enough?

Some views to rule out, provisionally

We should rule out this view: [A] local explanations block the "need" for global explanations. Given one accepts the patterning obtained, cross culturally, one would have to view [A] as treating the BCT data and models as artifacts of actual local practices whereby the statistically unlikely actual patterning is just a by-product of locally grounded naming practices. But local explanations don't have the resources to explain the improbability of the global distribution. Why, for example, should there be similar sets of basic colour terms and categories in languages that have had no contact? The World Color Survey (WCS n.d.) describes many of these.

We should also rule out [B] global explanations eliminate local explanations. This is equally implausible. It involves a type of error theory, according to which local explanations are in fact not explanatory (though we think they are—that is the "error"). So even though, to take Davidoff's example, "their red term is the name of a berry" that is not an explanation for why they have a term for red. Really, it is because there is a global disposition (of some sort) to name red things. The fact that one cannot point to what that disposition is—that is of course an issue—but one cannot assume that just because there is (might be) such a disposition, local explanations are not causally significant. We should, I propose, *not* hold that [C] local and global explanations must exclude one another.

Local and global explanations and their explananda

I don't take the considerations advanced against [A], [B] and [C] to be decisive. It could be the case that we are always in error about local explanations, in the way that, for example, Chomskian linguists have taken individuals to be in error as to the source of their grammatical rules. On the other hand, it is possible that the BCT patterning is an outcome of local practices and not caused by some global disposition: cultural transmission from local sources plus the ability to judge chromatic similarity does all the work. (Roberson 2005) Both these possibilities are unlikely and it would be better if we could articulate some version of [D]: local and global explanations are compatible. The most obvious way that [D] can be true is if, in fact, they explain different things, if their *explanations* are distinct.

Here, put simply, is the version of [D] I advocate. Local explanations, e.g. *red is the name of a berry*, ground colour naming practices in local experience but what they ground then forms a new base for an abstract system of classification (BCTs). Local explanations have one foot in the local and the other in the abstract (which is

why one can easily take the local and the global to be in competition). Nowhere is this clearer than in reduplicative languages, where, for example, *mū* means 'red hot; to burn' and *mūmū* means 'red'. The duplication of the root says: *talking about colour now*, and of course the historical linguistic relationship to the non-colour base word is crystal clear. Not all languages exploit duplication for colour (or any) words, but the case is no different for non-duplicative languages, just less clear to us. Abstract colour words do not come to us in abstract form—that is something that needs to be accomplished conceptually and socially, and with that social accomplishment comes a distinct set of desiderata: once one can understand one's colour related words as abstract, one can begin to think about them in a variety of ways. Questions like *is it more red than yellow*? start to make sense—and this sort of question, evaluating relative similarity (is X more like Y than it is like Z?) can function as a conceptual base for an abstract classificatory system.
I cannot defend this view in detail here, but there is some relevant empirical evidence we can point to:

- Reduplicative languages form colour words by duplication, indicating explicitly the dual nature of colour words. It is true that duplicated colour terms were not counted in the original basic colour term theory (Berlin and Kay 1969). They fail to satisfy certain of the conditions for being a BCT (notably, the conditions that states BCTs are (i) not the name of objects; and (ii) mono lexical. But these criteria need to be treated with some flexibility, not so that anything can count as a BCT but so that words which function as abstract colour classifiers are treated as such. That a word is *used* as an abstract colour classifier is, as a number of writers (e.g. Blust 2015; Biggam 2012) have pointed out, more important than its retained objectual referent. In any case, for the argument here, reduplicated colour terms show plainly something that may be harder to see in other cases: BCTs have a grounding in objectual reference, but the thing that is grounded is independent of that referent in the sense that BCTs come to name a colour, not a coloured thing.

- There is often dispute as to whether a word is a BCT or not, and that debate often turns on whether the word is *too* object specific as opposed to abstract. Discussion as to whether a word is abstract *enough* is common throughout Berlin and Kay's analysis of the ethnographic literature (1969, 45-104), and central to the idea of the BCT.

- BCTs in a language have etymological ties to objects, even though those ties may not be obvious or even known to speakers. Etymology and historical colour semantics uncovers relations of colour words to things that are discoveries of unknown objectual grounding. Biggam walks the reader through some examples and discusses the difficulties involved in actually making such origin-cases. (Biggam 2012, 152-168)

Children take a significant amount of time to master abstract colour terminology (BCTs). Children may learn basic colour term names in one-shot learning, and then take years to get the adult reference class correct enough to be competent colour language users (Wagner et al 2013). The difficulty of learning colour words has a name in German: *farbendummheit* ("colour stupidity"). Dedrick discusses this (2002); Wagner et al contextualize it in terms of developmental psychology (2018).

Basic colour terms live in two worlds: the abstract world of colours and their relationships to one another as socially instantiated (regimented, this is the world of colour ordering systems), and the natural world where they are used to describe the colour of things. Here it is argued that there are two related explanation types that are not in competition but, indeed, complementary and have different explanations. Local explanations tie colour names to objects, they explain their linguistic experiential origins. They also play a role in BCT bootstrapping. Global explanations, though there is not unanimity as to what these are, trade in larger conceptual questions about abstract colours and colour naming systems as their primary object of reference

References

Abbott, J. T., T.L. Griffiths, and T. Regier. 2016. "Focal Colours across Languages Are Representative Members of Color Categories." *Proceedings of the National Academy of Sciences* 113: 11178–83. https://doi.org/10.1073/pnas.1513298113

Berlin, B. and P. Kay. 1969. *Basic Color Terms: Their Universality and Evolution*. Berkeley, Ca: University of California Press.

Biggam, C. P. 2012. *The Semantics of Colour*. Cambridge, UK: Cambridge University Press.

Conklin, Harold. 1955. "Hanunóo Color Categories." *Southwestern Journal of Anthropology* 11 no. 4: 339-344. https://doi.org/10.1086/soutjanth.11.4.3628909

Davidoff, J. 2015. "Color Categorization across Cultures" in *Handbook of Color Psychology*, eds. Andrew J. Elliot, Mark D. Fairchild, and Anna Franklin. Cambridge UK: Cambridge University Press, 259–78.

Dedrick, D. 2002. The roots/routes of color term reference. *Theories, Technology, Instrumentalities of Color*. Anthropological and Historiographic Perspectives, 53-68.

Groh, A. 2016. Culture, Language and Thought: Field Studies on Colour Concepts. *Journal of Cognition & Culture*, 16(1/2), 83–106. https://doi.org/10.1163/15685373-12342169

Haynie, H. J., and C. Bowern. 2016. Phylogenetic approach to the evolution of color term systems. *Proceedings of the National Academy of Sciences*, 113(48), 13666–13671. https://doi.org/10.1073/pnas.1613666113

Hardin, C.L. 1988. Color for Philosophers: Unweaving the Rainbow. Indianapolis: Hackett.-

--- 2014. "Berlin and Kay Theory." In *Encyclopedia of Color Science and Technology*, edited by Ronnier Luo. New York: Springer (Living Edition). https://doi.org/10.1007/978-3-642-27851-8_62-2

Kay, P. and L. Maffi. 1999. "Color Appearance and the Emergence and Evolution of Basic Color Lexicons." *American Anthropologist* 101: 743-60.

Kay, Paul. 2015. "Universality of Color Categorization." In *Handbook of Color Psychology*, eds. Andrew J. Elliot, Mark D. Fairchild, and Anna Franklin. Cambridge, UK: Cambridge University Press, 245–58.

Kirby, S., M. Dowman, and T.L. Griffiths. 2007. Innateness and culture in the evolution of language. *Proceedings of the National Academy of Sciences*, 104(12), 5241–5245. https://doi.org/10.1073/pnas.0608222104

Kuehni, R. G. 2014. Unique hues and their stimuli—State of the art. *Color Research & Application*, 39(3), 279–287. https://doi.org/10.1002/col.21793

Levinson, S. C. 2000. Yeli Dnye and the Theory of Basic Color Terms. *Journal of Linguistic Anthropology*, 10(1), 3–55. https://doi.org/10.1525/jlin.2000.10.1.3

Lindsey, D. T., A.M. Brown, E. Reijnen, A. N. Rich, Y. I. Kuzmova, and J. M. Wolfe. 2010. Color Channels, Not Color Appearance or Color Categories, Guide Visual Search for Desaturated Color Targets. *Psychological Science*, 21(9), 1208–1214. https://doi.org/10.1177/0956797610379861

Malkoc, G., P. Kay, and M.A. Webster. 2005. Variations in normal color vision. IV. Binary hues and hue scaling. *JOSA A*, 22(10), 2154–2168. https://doi.org/10.1364/JOSAA.22.002154

Roberson, D. 2005. Color Categories Are Culturally Diverse in Cognition as Well as in Language. *Cross-Cultural Research*, 39(1), 56–71. https://doi.org/10.1177/1069397104267890

Blust, R. 2001. Reduplicated colour terms in Oceanic languages, In Pawley, A., Ross, M. and Tryon, D. editors, The boy from Bundaberg: Studies in Melanesian linguistics in honour of Tom Dutton. PL-514:23-50. *Pacific Linguistics*, The Australian National University, 2001. https://doi.org/10.15144/PL-514.23

Stanlaw, J. 1997. “Two Observations on Culture Contact and the Japanese Color Nomenclature System.” In *Color Categories in Thought and Language*, ed. C.L. Hardin and Luisa Maffi. Cambridge, England: Cambridge University Press, 240-60.

Urbanczyk, S. 2017. Phonological and Morphological Aspects of Reduplication. Oxford Research *Encyclopedia of Linguistics*. https://doi.org/10.1093/acrefore/9780199384655.013.80

Wagner, K., J. Jergens, and D. Barner. 2018. Partial Color Word Comprehension Precedes Production. *Language Learning and Development*, 14(4), 241–261. https://doi.org/10.1080/15475441.2018.1445531

Wagner, K., K. Dobkins, & D. Barner. 2013. Slow mapping: Color word learning as a gradual inductive process. *Cognition*, 127(3), 307–317. https://doi.org/10.1016/j.cognition.2013.01.010WCS (World Color Survey). n.d. Data Archive. Accessed April. 13 2022. http://www.icsi.berkeley.edu/wcs/data.html.

Witzel, C. 2019. Misconceptions About Colour Categories. *Review of Philosophy and Psychology*, 10(3), 499–540. https://doi.org/10.1007/s13164-018-0404-5

Witzel, C., & A. Franklin. 2014. Do focal colors look particularly “colorful”? *Journal of the Optical Society of America. A, Optics, Image Science, and Vision*, 31(4), A365-374. https://doi.org/10.1364/JOSAA.31.00A365

The Difference in Colour Categorization between South Korean and Chinese Language

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Abstract

There has been a long debate between universalists and relativists on how language affects people's perception of colours. This study aims to investigate whether different languages affect how people categorize colours that illustrate linguistic differences. A total of 30 Native South Korean and Chinese speakers were asked to classify fifteen colour chips selected from blue-green spectral regions and free-sort those that appeared similar together, allowing them to be grouped that shared the same colour terms in their native language. After classifying them into different numbers of groups, they were asked to name them with standard colour terms in their language and the number of groups and the names they assigned each group were then analyzed. The findings indicated that in general, they showed similar grouping behaviour categorizing the colour chips, but showed different colour naming for the groups, especially for one particular colour, "blue-green", which is a familiar colour term for Korean speakers, *Cheongrok*, but unfamiliar for Chinese speakers. Also, compared to Chinese participants who divided the green into light and deep, Korean participants did not have such division for the green colour chips. Overall, this experiment showed that the people from different languages demonstrate different colour categorization. It seems that people's way to divide the colour spectrum is a perceptual phenomenon, but it also seems that depending on how people learn the colour names in their own language, the way they categorize colours is affected. Thus, this study seems to support both views that colour categorical perception is language-relative as well as universal in that two forces seem to be at work together in colour categorization.

Keywords: *Colour categorization, universality, language-relative, South Koreans, Chinese*

1. Introduction

1.1 Background

Do Chinese speakers perceive the colours the same way as Korean speakers do? This culturally and linguistically related question arises as there is an active exchange between two countries that are geographically close yet culturally distant. Needless to say, the largest group of foreign students studying in South Korea come from China and as a graduate student majoring in Colour Design, exploring whether these speakers perceive the colours similarly or differently is of a great interest and investigating these two groups of people would contribute in understanding the more general question: does language affect how people perceive colours?

Until now, there's been a long debate on the relationship between language and perception - especially whether language can have an effect on one of the human perceptual experiences, such as colour perception. There has been a belief that cultures divide the colour spectrum into arbitrary categories and in turn, a relativist would agree to the question above that language does have an effect on colour perception, but a universalist would say otherwise.

The color dimension is a perceptual continuum within which humans can detect millions of just-noticeable-differences of hue, brightness, and saturation, (Brown & Lenneberg, 1954) and colour appearance has a categorical nature and the colour is a great domain to be used to investigate categorization (Belpaeme, 2001). This is immediately suggested by the fact that every language has different color words to indicate different color sensations and that there are diverse ways that different cultures divide the continuum of visible colors linguistically in their own language. Roberson (2005) defines colour categorical perception to be the physical continuum of the chromatic spectrum perceived as qualitatively discontinuous, discrete segments such as red, orange, and yellow etc. Distances between colours from different categories, relative to just-noticeable differences, an objective measure mentioned above, are perceived as greater, whereas distances between colours from the same categories are perceived as smaller. Therefore, it would be easier to distinguish, for example, blue from green than to make distinction between different shades of blue. Here, colour categorization performance in two language groups is measured with a simple perceptual task.

1.2 Relativistic perspective

Relativistic side of this debate is supported by the hypothesis posited by Benjamin Lee Whorf who claims that our perception of the world is shaped by the semantic categories of our native language, and that these categories vary across languages with little constraint and therefore our colour categorical perception is also influenced by our native language (Regier and Kay, 2009). Ozgen (2004) adds that people speaking different languages have different color-name repertoire showing differences in the way they perceive colours. This seems self-evident because languages differ in the parts of the colour spectrum which they have names. The studies supporting the Sapire-Whorf hypothesis shown that there is 'categorical perception' (CP: faster or more accurate discrimination of stimuli that straddle a category boundary) for colour, and that differences in colour category boundaries between languages predict where CP will occur (Regier and Kay, 2009).

Color perception, especially color categorization, seems to be the most plausible way to investigate the linguistic relativity hypothesis for many researchers have observed that languages differ in the ways they encode color space. Furthermore, the studies also showed that colour CP disappears when verbal interference task was performed concurrently, confirming that colour CP is language based.

1.3 Universal perspective

The other side is the universalist view, which argues that colour categorical perception is a universal perceptual effect determined by biological mechanisms and is not language-specific. This view is supported by Berlin and Kay (1969) who provided empirical evidence that although languages vary in the way they encode colour space with basic colour terms, there are also strong similarities that suggest universal tendencies in colour categorization. For example, they proposed that humans have eleven basic perceptual color categories; basic meaning that the corresponding color term is a monolexemic, unique color term, salient and unambiguous to all language speakers. Human languages have at least two to, at most eleven basic color terms referring to these perceptual color categories (English has all eleven of them: black, white, red, green, yellow, blue, brown, purple, pink, orange, and gray). Roberson et al (2009) give a perceptual explanation of CP that our perception is warped so that an otherwise smooth continuum of change becomes ‘stretched’ at category boundaries and ‘compressed’ in category centers and such perceptual inequality might rise from the innate structure of human colour vision.

1.4 Colour categorical perception in the brain

Regarding the functional organization of color categorical perception in the brain, many results support the Whorf hypothesis and relativistic perspective. Many researchers have claimed that the right visual field is involved in colour categorical perception significantly as nearly all language tasks are operated in the left cerebral hemisphere, including those requiring lexical access (Gilbert et al. 2006). Regier and Kay (2009) suggested an interesting possibility, approaching the question: that language might affect half of perception, physiologically that the right visual field (RVF) is where language is expected to shape perception more than in the left visual field (LVF) because the left hemisphere of the brain is dominant for language and the visual field projects contralaterally to the brain. Therefore, they argue that half of the human perceptual world might be viewed through the lens of their native language, and half viewed without such a linguistic filter. Gilbert et al. (2006) found that colour categorical perception appears in only the right visual field and not in the left visual field in lateralized visual search tasks, implying that color categorical perception is a linguistic phenomenon. Drivonikou et al. (2007) found that significant color categorical perception appears in both visual fields, these results illustrate that both language and perception might affect color categorical perception, however, because more significant effects are observed in the right visual field, the role of language is stronger. Roberson et al. (2008) showed that color categorical perception occurred only in the right visual field in certain faster-responding subjects, resulting that color categorical perception takes place in only the left hemisphere in faster subjects implying that color categorical perception is indeed a language priority. Overall, these studies have confirmed that color categorical perception in adults is dominated by the left brain, so they drew a conclusion that color categorical perception in adults is a language effect or, at least, exhibits language priority.

1.5 Related studies

There is much research done on the issue of different languages affecting the categorization of colours; swinging back and forth between linguistic relativity and universality. He et al. (2019) examined Chinese and Mongolian speakers' colour perception. There are two terms in Mongolian dividing the blue regions into a darker shade ("huhe") and a lighter shade ("qinker"), while both lighter green and darker green are both described with one word, "nogvgan". Mongolian speakers exhibited the categorical advantage in the rapid colour discrimination task using blue stimuli, and this categorical advantage was disrupted by verbal interference and not by spatial interference, this result suggest that the effect of language is online. Winawer et al (2006) did similar research comparing English and Russian blue where Russians make an obligatory distinction between lighter blue ("goluboy") and darker blue ("siniy") just like Mongolians do. They did a speeded colour discrimination task with English and Russians using the blue stimuli spanning the light and dark blue border. While Russian speakers showed categorical advantage which was eliminated by the verbal tasks, English speakers showed no categorical advantage demonstrating that language indeed affected the performances on perceptual colour tasks.

There have been many studies done with languages such as English, Russian, and Greek; and Chinese and Korean were chosen because of the geographic values and to add to linguistic diversity. Chinese use a single word "lan" to describe both light and dark blue and "lv" to describe both light and dark green and this is similar to English that divides the spectrum into two categories as well (green and blue). Korean language on the other hand, divide the spectrum into three basic categories: "chorok" to describe green, "cheongrok" to describe blue-green and "parang" to describe blue (Kim, Pak, & Lee, 2001). To compare the colour categorical perception of Korean and Chinese speakers, both groups performed free-sorting task (Roberson et al., 2008), a simple perceptual task, using blue and green stimuli spanning lv/lan border in Chinese and chorok/cheongnok/parang border in Korean. If colour categories are affected by these languages, Chinese speakers should put green in one category and blue in the other; whereas, Korean speakers should divide them into three categories.

2. Material and Method

2.1 Experiment: Free-Sorting Task

2.1.1 Participants

Fifteen native Korean speaking graduate students and fifteen native Chinese speaking graduate students from Ewha Womans University participated in the experiment upon experimenter's approach and request. All participants were residents at the dormitory designated for graduate and international graduate students and they all had corrected-to-normal vision based on self-report.

2.1.2 Stimuli

Fifteen colour chips from the green-blue spectral region (1 to 15) were selected for the use as shown in Appendix Table A1 and Figure 1. The colour chips were adapted from the experiment of He et al (2019) and 3 more blue-green chips were added onto their green and blue chips. The colour chips were measured 20x20mm cut out from "KS195 Colors" and cardboard paper was added at the back to make the chips durable.

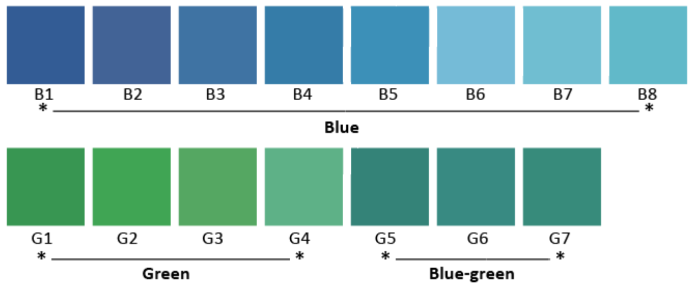

Figure 1. 15 selected colour chips selected from the blue-green spectral region.

2.2 Procedure

While fifteen colour chips were being spread randomly on the light grayish table, the participants were first asked to think of the colour names in their own language, Korean or Chinese. Then, they were asked to classify the chips and sort those that appeared similar together, allowing the members of the same color family to be grouped accordingly. When they asked if there was a number of groups that they needed to categorize the chips in, they were told that they could freely sort them in any number they wanted and there were no right or wrong answers to complete the task. After the participants organized the colour chips in different categories, they were asked what each group was belonging to which colour. The number of groupings, the colour names for each group given by the participants and the chips belonging to each group were recorded by the experimenter and the data was graphed and analyzed.

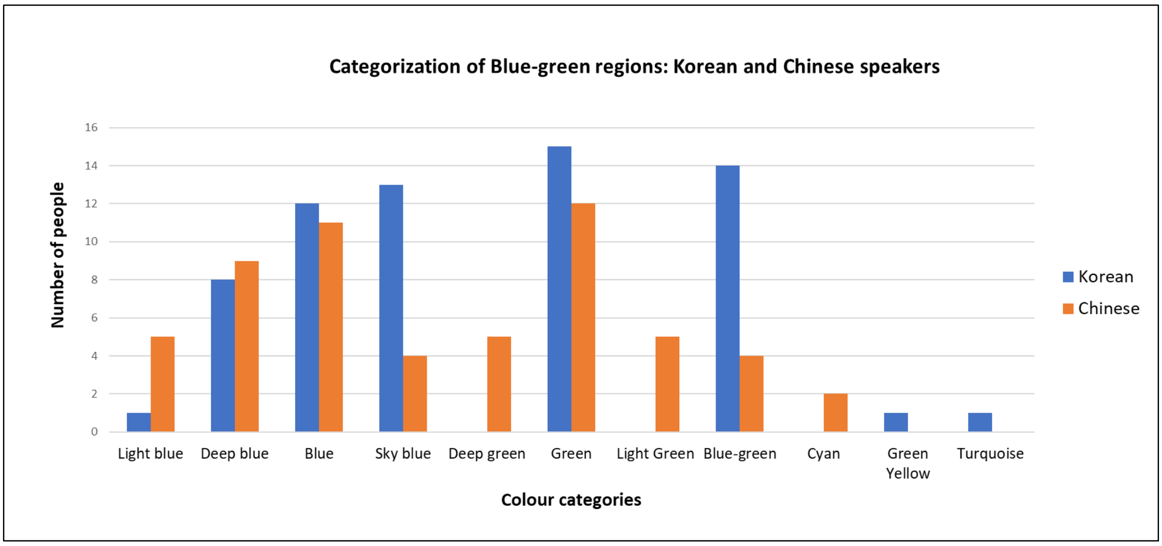

Figure 2. List of colour names that both Korean and Chinese participants assigned the free-sorted colour chips with.

3. Results

The main question for this experiment was whether the languagesaffect the way people categorize colours. Did the Korean and Chinese participants show different behavior categorizing blue-green colour chips?
Figure 2 shows the distinct differences in the way the participants from two different nationals categorized the colours in different ways, especially in three colours that both groups decided to categorize the chips in: light blue, sky blue and blue-green. These colour terms were named by both participating groups but the number of people using these terms with their categorization differed with three colours mentioned.

Table 1 shows the colour names that both Korean and Chinese participants assigned the groups that they free-sorted with. From the 15 colour chips, the total of 8 colour names were used for the green-blue region by the Korean participants and 9 colour names were used by the Chinese participants for the same region. The colour names show that they have 6 overlapping names in both participant groups: blue, light blue, deep blue, sky blue, green, and blue-green. Both Korean and Chinese separated blue into deep and light however, Korean participants did not separate green into deep and light whereas Chinese participants had such a separation for green. Korean participants had additional colour groups that Chinese participants did not have such as yellow-green and turquoise and Chinese participants had the colour group.

Korean word	Korean-English	Chinese word	Chinese-English	Colour name
1. 파란색	Paran-saek	1. 蓝色	Lán-sè	Blue
2. 진한파란색	Jinhan-Paran-saek	2. 深蓝色	Shēnlán- sè	Deep blue
3. 밝은파란색	Baleun-Paran-saek	3. 浅蓝色	Qiǎnlán- sè	Light blue
4. 하늘색	Haneul-saek	4. 天蓝色	Tiānlán-sè	Sky blue
5. 초록색	Chorok-saek	5. 绿色	Lǜ-sè	Green
6. 청록색	Cheongrok-saek	6. 青绿色	Qīnglǜ-sè	Blue-green
7. 연두색	Yeondu-saek			Yellow-green
8. 옥색	Ok-saek			Turquoise
		7. 青色	Qīng-sè	Cyan
		8. 深绿色	Shēnlǜ-sè	Deep green
		9. 浅绿色	Qiǎnlǜ-sè	Light green

Table 1. List of colour names that both Korean and Chinese participants assigned the free-sorted groups with.

Figure 2 also shows the list of colours for both languagesin graphs. The colours that were mainly mentioned (more than 8 times) in these categories for Korean speakers were blue, sky blue, green and blue-green. As for the Chinese speakers, they were green, blue, and deep blue. It's interesting to note that out of 15 participants, 14 Korean participants had "cheongrok: blue-green" group in their categorization, whereas only 4 Chinese participants used that colour term to make categorization. 2 of the 4 Chinese participants that made such a category showed uncertainty on which colour name that they wanted to assign the group with. They knew to make separate categorization for blue-green coloured-chips but did not come up with a specific Chinese colour term quickly or at all. Figure 3 shows that both participant groups categorized 15 colour chips into 2 to 6 groups. Both categorized the colours mainly into 4 groups. Koreans mainly categorized the colour chips into 4 groups, followed by 5 then, the least for 2, 3, and 6 respectively. Chinese speakers also mainly categorized the chips into 4 groups followed by 2 groups, then 6 and the least for 3 and 5 respectively. Figure 3 shows that out of 15 Korean participants, 5 of them had the same categorization with 4 consistent colours: blue, sky blue, green and blue-green, and 14 out of 15 had blue-green in their categories which was distinctively different from the Chinese participants where only 3 out of 15 included the colour in their categorization. 2 of the participants had “blue-green” group but were unsure of the colour name for that group.

Figure 4a shows that out of 15 Korean participants, 5 of them had the same categorization with 4 consistent colours: blue, sky blue, green and blue-green. 3 Korean participants made the same colour categories with 5 colours: deep blue, blue, sky blue, green and blue-green. 2 of them made the same category with 4 same colours: deep blue, sky blue, green and blue-green.

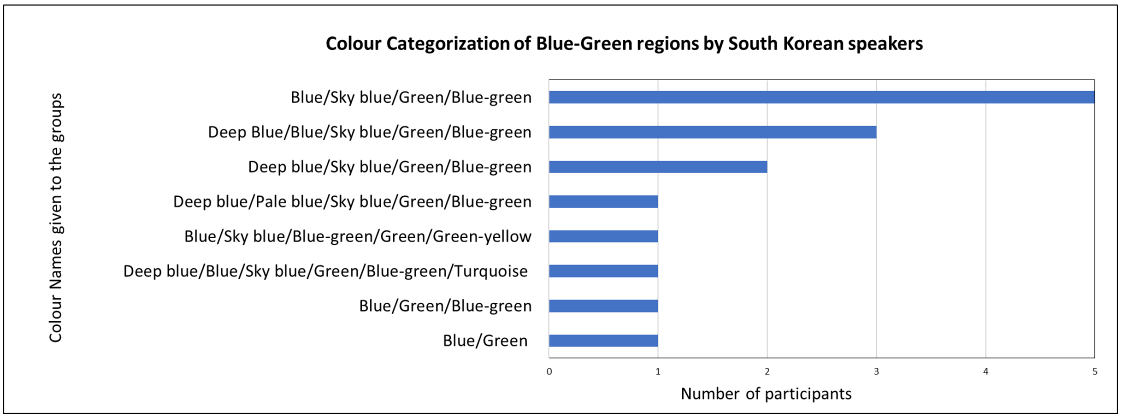

Figure 4a. The number of groups made by the Korean participants and the colour names given to each group.

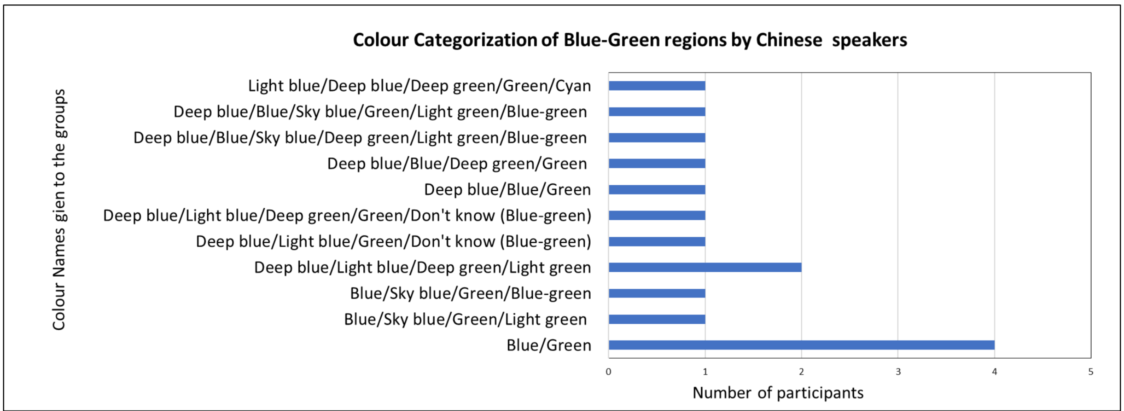

Figure 4b. The number of groups made by the Chinese participants and the colour names given to each group.

The rest of 5 participants made a category of their own that did not overlap with anyone else. Of the 15 Korean participants, all of them had “green” in all their groups, 14 participants had “blue-green” groups in their categories. They categorized more “sky blue” than “blue” where “blue” is divided into “deep blue” and “blue”. One participant divided blue into “deep blue” and “light blue”, then had the three dominant colour groups: sky blue, green and blue-green were included. One participant had a “turquoise” group included in her deep blue, blue, sky blue, green, and blue-green groups. One participant grouped the chips into three groups: blue, green, and blue-green where the other participant grouped the chips in only two groups: blue and green. Figure 4b shows that the majority of the Chinese participants divided the colour chips into two groups: blue and green. Compared to the Korean participants, Chinese participants show inconsistency (with others) in their grouping of the colour chips. Chinese participants had the tendency to divide green into "deep" and "light" green whereas Korean participants did not. Two of the participants had "blue-green" chips grouped but did not come up with a Chinese colour term right away or at all and left the answer "don't know."

4. Discussion

This study investigated whether languages have an effect on colour perception, especially with the way people with different languages categorize colours. There are numerous cross-linguistic studies investigating colour categorization and they provide abundant evidence regarding the relationship between language and perception. In this study, the free-sorting task of Korean and Chinese participants with the colour chips from the blue and green spectral region were compared.

The research by He et al. (2019), which the stimuli and procedure of this experiment were adopted from, reported that Chinese speakers had one colour term for blue and one colour term for green patches; Mongolian speakers had two colour terms for blue (dark and light) and one colour term for green patches. However, with the 15 colour chips having "blue-green" colour chips added onto the colour chips from their experiment, Chinese participants in this study showed different colour discriminating behavior. They separated blue into light and deep as well as adding sky blue and cyan aside from having blue as one of the groups. It was expected that the majority of Chinese speakers would separate the colour chips into two groups: blue and green, but they showed similar grouping behavior as the Korean participants where they separated the chips into four groups instead of two. For blue categorization, they were more similar to the Mongolian and Russian speakers who make an obligatory distinction between light and dark blue with colour terminologies (He et al, 2019 & Winawer et al, 2006). As for green, instead of grouping them altogether in one group, of which 4 of the 15 participants did, they separated green into 5 different groups: deep green, light green, green, blue-green, and cyan.

As for the Korean participants, they showed more similar results to those of Mongolian speakers' where they had different terms for blue but had one term for green aside from the "blue-green" category. Korean participants also categorized blue into light, deep, blue and sky blue but there is a distinct difference in the way that Korean and Chinese participants categorized light shades of blue. Koreans have the colour term "haneul-ssaek," meaning sky blue, which is a familiar colour term for Koreans, therefore, 13 out of 15 participants made that categorization instead of categorizing it as light blue like some Chinese participants did. Also unlike the Chinese participants who divided green into different shades, Korean participants did not make such a distinction but only divided blue-green from green, which was an interesting result. Korean participants who have distinctive colour word for "blue-green" did not hesitate much to separate those colour chips and name the group accordingly but only few Chinese participants separated "blue-green" colour chips and even if they made the separation of the colour chips, half of them had trouble coming up with the colour name for that group. This seems to support the Whorf hypothesis that human cognition is influenced by language and culture but the fact that some Chinese participants, however, separated the "blue-green" apart from other blue and green suggest that the relativistic perspective is constrained by universal forces. This result also comes in line with what Regier and Kay (2009) argued with in which colour naming across languages is shaped by both universal and language-specific forces.

This study showed that colour categorization and colour naming are shaped by both linguistic relativity and universal forces. Participants from two different countries showed similar colour categorizing behaviors that are governed by physical perception yet had different naming systems for the groups that they categorized the colour chips in. This observation led to a thought that it would be crucial to use the colours that are not only based on their functionality but also related to people's familiarity with the colour terminologies in their native language in culturally-sensitive contexts. Aslam (2006) emphasizes on the cross-cultural perspective on colour research that it is a vital element for adapting to the global environment that calls for global marketing strategies that require cultural sensitivity. Thus, not only the cultural meanings of colours, but also the familiarity of the colour terminology of the people in different cultures should also receive attention for colour-related cultural exchange and this could be an area of further research in the future.

5. Conclusion

In conclusion, this study demonstrates how Korean and Chinese speakers categorize, discriminate, and name the colour chips in selected colour spectral region showing the relationship between human perceptual phenomenon and higher cognition related to language which can be a complex process that does not involve just one but an interplay of both universal and relativistic forces.

References

Aslam, M. M. 2006. Are you selling the right colour? A cross-cultural review of colour as a marketing cue. *Journal of marketing communications*, 12(1), 15-30.

Belpaeme, T. 2001. Simulating the formation of color categories. IJCAI.

Berlin, B., and P. Kay. 1696. Basic Colour Terms: Their Universality and Evolution.

Davies, I., G. Corbett, D. Roberson, and M. Vandervyver. 2005. Free-sorting of colors across cultures: Are there universal grounds for grouping?. *Journal of Cognition and Culture*, 5(3-4), 349-386.

He, H., J. Li, Q. Xiao, S. Jiang, Y. Yang, and S. Zhi. 2019. Language and perception: Evidence from Mongolian and Chinese speakers. *Frontiers in psychology*, 10, 551.

Kim, Y.S., H. Park, and Y.H. Lee. 2001. A study on Munsell color space for Korean color names. *Journal of Korean Society of Colour Studies*, 15, 29-36.

Özgen, E. 2004. Language, learning, and color perception. *Current Directions in Psychological Science*, 13(3), 95-98.
Regier, T., and P. Kay. 2009. Language, thought, and color: whorf was half right.
Roberson, D., J. R. Hanley, and H. Pak. 2009. Thresholds for color discrimination in English and Korean Speakers. *Cognition 112*, 482-487
Roberson, D. 2005 . Color categories are culturally diverse in cognition as well as in language. *Cross-Cultural Research*, 39(1), 56-71.
Winawer, J., N. Witthoft, M. C. Frank, L. Wu, A. R. Wade, and L. Boroditsky. 2007. Russian blues reveal effects of language on color discrimination. *Proceedings of the National Academy of Sciences*, 104(19), 7780-7785.

A Comparative Analysis of Estonian, Swedish and Turkish Colour Idioms

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Abstract

Previous research has shown that there are both universally recognised colour idioms as well as culture-specific opaque ones. We collected colour idioms from three languages that belong to three different language families: Swedish (Indo-European, Germanic), Estonian (Finno-Ugric, Finnic) and Turkish (Altai, Turkic). We analysed the colour idioms of these languages using the conceptual metaphor theory. The results reveal that at the conceptual level, the meaning of the idioms in the three languages is often similar, even though it can seem to be different at first glance. Black mostly bears a negative connotation in all three languages, whereas white can have both a positive and a negative meaning.

Keywords: *Colour Idioms, Cognitive Metaphor Theory, Estonian, Swedish, Turkish*

Introduction

George Lakoff and Mark Johnson stated in the 1980s that figurative language reflects our inner world and our cognitive frames of reference which are shared between speakers of one language and understandable within one culture or shared by different languages and cultures. Idioms can be defined as expressions that contain two or more components and the meaning of these expressions cannot be predicted from the meaning of their parts (see for example Kövecses and Szabó 1996). Figurative language (such as metonymy, metaphors, and idioms) has been viewed as a decorative element and as a device for categorising our daily experiences (see Lakoff & Johnson 1980). Generally, idioms have a figurative meaning. Colour idioms consist of at least one colour term which carries the figurative meaning of the idiom or functions as the source domain of a conceptual metaphor. For example, “white” in the English colour idiom “white lie” (comparable to *vit* in the Swedish idiom *vit lögn* and *beyaz* in its Turkish counterpart *beyaz yalan*) is based on the conceptual metaphor INNOCENCE IS WHITE. Thus, the colour term in an idiom names the most distinctive feature of an entity and is metonymic by nature (Verspoor & Bie-Kerékjártó 2006: 87).

Research on colours shows that colours can carry meanings that can be both culture-specific and universal (see for example Gheltofan and Pungă 2018: 29). However, there is a need for further research for drawing broader conclusions about the universality and variability of colour idioms across cultures and languages. This paper contributes by comparing three languages that belong to three different language families: Swedish, Estonian, and Turkish. Comparing the idioms of languages that have not had many contacts (Swedish and Turkish; Estonian and Turkish) provides a good opportunity for examining the universality and variability of the meanings that colour words carry. In addition, it helps us determine how speakers of different languages and cultures interpret the world.

Method

Data Collection

We gathered 156 Turkish, 146 Estonian, and 114 Swedish colour idioms with the goal to identify as many colour idioms as possible in each language. For this, we used Hans Luthman's (2017) Swedish dictionary of idioms *Svenska idiom: 5000 vardagsuttryck* [Swedish idioms: 5000 everyday expressions]; the Swedish-Estonian dictionary *Rootsi-eesti sõnaraamat: ~100 000 märksõna = Svensk-estnisk ordbok: ~100 000 uppslagsord* [Swedish-Estonian Dictionary: ~ 100,000 keywords] (Aidla et al. 2004); the Dictionary of Proverbs and Idioms of Turkish Language Association (TDK); and the dictionaries of Estonian phraseology Fraseoloogiasõnaraamat [Dictionary of Phraseology] (FRS) and *Eesti fraseologismide elektrooniline alussõnastik* [Basic Electronic Dictionary of Estonian Phraseologisms] (FES). We included idioms with all the basic colour terms as well as idioms with the colour terms "dark", "light" and "bright". The idioms with the word "dark" were grouped together with the idioms with the word "black" and the idioms with the words "light" and "bright" were grouped together with the idioms with the word "white". The rationale for doing so is the similar connotations of these words. Moreover, in Turkish, there are two terms for referring to the colour black: *siyah* and *kara*. The former means 'black', while the latter means 'black' or 'dark'.

Data Analysis

We carried out a cross-cultural comparison of the collected idioms. At first, we inspected the material on the idiom level and categorised the idioms as shared and unshared between the languages under scrutiny. Then we selected all idioms containing the colour terms "black", "white" and "red". We identified the motivations (conceptual metaphors and metonymies) behind each idiom and identified the overlappings and differences on a more conceptual level. We focused mostly on the similarities, a longer discussion dealing with the rest of the colour idioms and the conceptual level differences will be published in a future paper.

Results and Discussion

Idiom Level

We gathered 156 Turkish, 146 Estonian, and 114 Swedish colour idioms. We compared the colour idioms of these three languages and categorised them as shared and unshared (as in Bazzanella et al. 2016). Some interesting patterns emerged: all three languages, seem to have the highest number of colour idioms with the colour term “black” (Turkish 61, Estonian 44, Swedish 34, followed by the colour terms “white” (Turkish 47, Estonian 37, Swedish 27) and “red” (Turkish 21, Estonian 17, Swedish 17). The same pattern has been observed by other researchers comparing English, Lithuanian and Russian (Stunžaitė 2015) and Turkish and English (Hastürkoğlu 2017). The pattern appears to have a connection with Brent Berlin and Paul Kay’s (1969) findings that established the emergence of colour terms in languages in a certain sequence: the first colour terms to appear in any language are always “black” and “white”, which are followed by “red”. In other words, the diachronic colour emergence model seems to coincide with the three first colour terms that most frequently form colour idioms. Moreover, our findings seem to suggest that there is a larger number of colour idioms in Turkish compared to Swedish and Estonian and this seems to be mainly due to a larger number of idioms with the colour terms “black” and “white” in Turkish (see the comment about Turkish black “Data collection”). Swedish seems to have the least colour idioms out of the three compared languages,according to our findings.

Of all the idioms gathered, there were 43 (3x43) that were shared between all the three languages on the idiom level – both the meaning and the linguistic form matched (for example *kara ölüm*, *must surm*, *svarta döden* ‘black death’). More colour idioms were shared between Estonian and Swedish (43+22) than between Swedish and Turkish (43+4)or Estonian and Turkish (43+7) which was expected because Estonian and Swedish have had and still have more linguistic and cultural contacts and belong to the Circum-Baltic linguistic area (Koptjevskaja-Tamm & Wälchli 2001).

We found a few colour terms (for example “purple”) with which there were idioms but none of them were shared between the three languages However, most colour categories had some shared idioms between all three languages.The shared meanings were often related to universal conventions (for example *punane kaart* in Estonian, *kırmızı kart* in Turkish and *rött kort* in Swedish (‘red card’), which refer to football rules), embodiment (in all three languages one can turn red when embarrassed) or other universally recognised phenomena (for example “yellow journalism” (*kollane ajakirjandus*/ *sarı gazetecilik*/ *gula pressen*). Some opaque idioms were related to culture-specific phenomena (for example *sarı lacivertliler* ‘yellow blues’ or *kara kartallar* ‘black eagles’ when referring to popular Turkish football clubs Fenerbahçe FC and Beşiktaş FC, respectively).

All three languages contrast the colour terms “black” and “white”. “Black” mainly carries a negative connotation in all three languages and “white” a positive connotation when contrasted with “black”. However, in other idioms “white” also refers to negative things (for example, when “white” refers to paleness of the skin or to something otherwise unhealthy – examples of which could be found in all three languages). In addition, we found two examples in which Turkish “black” referred to a mainly positive characteristic: bravery (*gözü kara* ‘brave, fearless, foolhardy´, lit. ‘eye is black’ and *gözünü karartmak* ‘to summon up the courage’ lit. ‘to make one's eye black’).

An interesting difference that we observed was that Turkish people associate aging and the change of hair colour with the colour term “white,” while Swedish and Estonian speakers use “grey” instead. Turkish also strongly associates “yellow” with turning pale from fear, nervousness, excitement, or sickness. Swedish and Estonian speakers use “white” instead.

Conceptual Level

After identifying the similarities and differences on the idiom level, we also mapped motivations (conceptual metaphors and metonymies) behind the colour idioms with the colour terms “black, “white” and “red”. It should be mentioned that identifying the motivations is somewhat subjective and dependent on the view of the researcher(s).

If we compare idioms with “black, “white” and “red” (the idioms with the rest of the colour terms will be compared in a future publication) on the idiom level, 31 (3x31 out of the total of 305) idioms were shared between the three languages, but if we examine the conceptual metaphors and metonymies behind them, we find a larger proportion of shared idioms. 49 additional idioms (36 with “black” – including the idioms with “black” and “white” (18 Turkish, 10 Estonian, 8 Swedish) 11 with “white” (6 Turkish, 3 Estonian, 2 Swedish) and 2 with “red” (0 Turkish, 2 Estonian, 0 Swedish)) are motivated by a shared conceptual metaphor or metonymy and should, thus, be at least somewhat transparent between the speakers of all three languages. Therefore, about half of the idioms containing the colour terms “black”, “white” and “red” are similar at least on a conceptual level between all three languages. For example, the Turkish idiom *karanlığı deşmek* ‘to strive to escape from great distress and sorrow’ (lit. ‘to dig out of the darkness’), the Swedish idiom *det ser mörkt ut* ‘the outlook is bad’ (lit. ‘it looks dark’) and the Estonian idiom *mustad päevad* ‘days of (financial) trouble’ (lit. ‘black days’) are comparable on the conceptual level, even if they seem to be quite different. Consequently, we can claim that they are all motivated by the same conceptual metaphor DIFFICULT SITUATIONS ARE BLACK/DARK. If we were to step a level back and look at the idioms as being motivated by the conceptual metaphor BLACK IS NEGATIVE, an even larger number of idioms would prove to be somewhat transparent since most idioms containing the colour term “black” in all three languages refer to something negative. The exception being only the Estonian idioms *mustaverd* and *musta* *krunti* 'dark-featured' (lit. 'black blooded' and 'dark primed'), *tume maa* 'unknown subject' (lit. 'dark ground'), *nii et mustab* 'excessively' (lit. 'so that it is black of something'), the Swedish *svart av folk* 'crowded' (lit. 'black of people'), the Turkish *gözü kara* 'brave, fearless' (lit. 'the eye is black') and *gözünü karartmak* 'to summon up the courage' (lit. 'to make one's eye black´) *hava kararmak* 'to get dark' (lit. 'the air to turn dark'), *sular kararmak* 'to get dark' (lit. 'waters to turn black') and *kara kartallar* 'Beşiktaş FC' (lit. 'black eagles') that don't have a definite negative meaning (10 idioms out of 139). Thus, all shared conceptual metaphors containing "black" could be grouped under the umbrella metaphor BLACK IS NEGATIVE. All shared conceptualisations of the words "black", "white" and "red" in the idioms are shown in Table 1.

Black	**White**	**Red**
BLACK IS BAD	WHITE IS GOOD	RED FACE STANDS FOR ANGER/ EMBARRASSMENT (metonymy)
EVIL IS BLACK	PERFECTION IS WHITE	RED CARD STANDS FOR PUNISHMENT (metonymy)
NEGATIVITY IS BLACK	SNOW REPRESENTS THE WHITEST OF WHITES	COMMUNISM IS RED (metonymy)
MORBIDITY IS BLACK	WHITE FACE STANDS FOR FEAR (metonymy)	
SICKNESS IS BLACK	PEACE IS WHITE	
MYSTERY IS BLACK	WHITE COLOURED DWARF REPRESENTS A TYPE OF STAR (metonymy)	
ILLEGALITY IS BLACK	INNOCENCE IS WHITE	
EXCLUSION IS BLACK		
DEPRESSION IS BLACK		
GUILT IS BLACK		
UNCONSCIOUSNESS IS BLACK		
DIFFICULT SITUATIONS ARE BLACK		

Table 1. Shared conceptual metaphors and metonymies found in all three languages.

There are some idioms in all three languages that contain both a colour term for "black" and "white". These are mostly used for contrasting the good with the bad, one extreme with the other, like in the idioms *mustvalge mõtlemine*, *siyah-beyaz düşünme* and *svart-vitt tänkande* 'black and white thinking'. The Turkish *kara kış* lit. 'black winter', the Swedish *svartvinter* lit. 'blackwinter' and the Estonian *must talv* lit. 'black winter' also seem to be similar on the idiom level but differ semantically – the first referring to the most difficult period (in the winter) or a very difficult situation and the second to a snowless winter.

While black mostly carries a negative meaning and it is often contrasted with white, the idioms containing the colour term "white" did not have as many positive motivators as "black" had negative ones. In fact, there were quite a few negative ones among the positives. For example, the Turkish *beyaz çekmek* 'to use heroin' (lit. 'to pull the white') and the Estonian *valge joove* 'drug intoxication' (lit. 'white intoxication'). Among the idioms containing the colour term "white" we also find three idioms that on the idiom level seem to be shared between the three languages *valge surm*, *beyaz ölüm* and *vita döden* that all share the literal meaning 'white death' but have different meanings and motivations behind them. The Estonian *valge surm* and Turkish *beyaz ölüm* are both motivated by conceptual metonymies where the most salient feature (here: colour) stands for the whole entity, the Estonian idiom referring to sugar and the Turkish to heroin. The Swedish *vita döden* 'tuberculosis' has most likely got its meaning from the comparison with another deadly disease – the black death or *svarta döden* 'the bubonic plague'.

Some idioms seem to be shared on the idiom level but are actually different among the idioms containing the colour term "red". For example, the similarity of the idioms *punane joon/ niit*, *kırmızı çizgi* and *röd tråd* seems to suggest that they all share a meaning, but only the Estonian and Swedish *punane joon/ niit* lit. 'red line/ thread' and *röd tråd* lit. 'red thread' does and refers to 'a connecting theme'. The Turkish *kırmızı çizgi* lit. 'red line' refers to a limit or boundary instead which in turn seems to be a quite universally intelligible meaning (although there were no Estonian or Swedish idioms in our sample that derived from the same conceptual metaphor).

Conclusion

According to our study, a large number of colour idioms are similar between Turkish, Estonian and Swedish, especially when investigated on a conceptual level, even though the languages belong to different language families. This seems to suggest that the three cultures categorise the world in a similar way. However, further research is needed.

Our research also suggests that there is a connection between the diachronic colour emergence model and the three colour terms that most frequently form colour idioms (black, white, and red).

Comparing languages of different origins that have not had many contacts (Swedish and Turkish; Estonian and Turkish) provides a good opportunity for examining the universality and variability of the meanings that colour terms carry across cultures and languages. Furthermore, it helps us determine how speakers of different languages and cultures interpret the world.

References

Bazzanella, C., I. Ronga, and E. Strudsholm. 2016. Colour Words in Danish and Italian Idioms. In: *Color Language and Color Categorization*. ed. by G. Paulsen, M. Uusküla, and J. Brindle. Newcastle upon Tyne: Cambridge Scholars Publishing, 356–387.

Berlin, B., and P. Kay. 1991. *Basic Color Terms: Their universality and Evolution*. Berkeley: University of California Press.

Gheltofan, D., and L. Pungă. 2018. Colour-based Phrases in Romanian, Russian and English. *Scientific Bulletin of the Politehnica University of Timişoara. Transactions on Modern Languages,* 17 (1), 19–31.

Hastürkoğlu, G. 2017. "A Cognitive Study on the Comparison of Basic Colour Terms in Turkish and English Idioms." PhD diss., Haceteppe University. Ankara.

Koptjevskaja-Tamm, M., and B. Wälchli. 2001, The Circum-Baltic languages: An Areal-typological Approach. In: *The Circum-Baltic Languages, vol. 2. Grammar and Typology*. Ed. By Dahl, Ö., M. Koptjevskaja-Tamm. Amsterdam/Philadelphia: Benjamins, 615–750.

Kövecses, Z., and P. Szabó. 1996. "Idioms: A View from Cognitive Semantics." In *Applied Linguistics*, 17(3), 326–355.

Lakoff, G., and M. Johnson. 1980. *Metaphors We Live By*. University of Chicago press.

Luthman, H. 2017. *Svenska idiom: 5,900 vardagsuttryck*. Lund: Folkuniversitetets förlag.

Õim, A. 2000. Fraseoloogiasõnaraamat (FRS). http://www.eki.ee/dict/frs/index.cgi (03.04.2022)

Õim, A., and K. Õim. 2008.–2010. Eesti fraseologismide elektrooniline alussõnastik (FES). http://www.folklore.ee/justkui/sonastik/ (03.04.2022)

Stunžaitė, A. 2015. "Manifestation of Color Idioms in the English, Lithuanian and Russian Languages." Master's thesis. Lithuanian University of Educational Sciences. Vilnius.

Türk Dil Kurumu. Atasözleri ve Deyimler Sözlüğü (TDK). http://tdk.gov.tr (03.04.2022)

Verspoor, M. H. and A. de Bie-Kerékjártó. 2006. Colorful bits of experience: From bluestocking to blue movie. *English Studies*. 87, no. 1: 78.

“The painters had done it all in green” [IN *COLOR] – A Cognitive Linguistic Construction Analysis

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Abstract

How do we structure the conceptual nature of language and our experience of color? I discuss one of the ways in which we conceptualize and sense color through the construction [IN *COLOR]. IN is one of the three most frequent prepositions to be used with basic color terms, together with OF and WITH (as emerged in the Corpus of Contemporary American English). A STATE IS A LOCATION is one of the basic conceptual metaphors that allows us to structure our color sense. Duly the primary perceptual embodied experience of COLOR and SEEING directly involves the establishment of a process of mapping between the source domain of COLOR/SEEING, both as a substance/object and a light/object, and the target domains of the occasion. It follows that COLOR may be conceptualized according to the SPACE, PATH, and CONTAINER image schemas, developing through the 45 different senses of IN. The senses stem from metaphors such as COLORS ARE LOCATIONS, as in *The painters had done it all in green*, where IN is used to indicate “qualification of a condition” or state. I present corpus data on the polysemy of this COLOR construction; and propose a cognitive analysis of meaning evolution to describe the data.

Keywords: *Cognitive Linguistics, Color Semantics, COLORS ARE LOCATIONS, Construction Grammar, Image Schemas*

Introduction

In this study, I would like to discuss one of the ways in which we conceptualize, structure, and sense color through the linguistic construction [IN *COLOR]. IN is one of the three most frequent prepositions to be used with basic color terms, together with OF and WITH; as emerged from the Corpus of Contemporary American English (henceforth COCA). In conceptual metaphor theory we see language as grounded in basic concepts. A STATE IS A LOCATION is one of the primary conceptual metaphors that allows us to structure abstract conditions, and also our color sense. I delve here into the specific locational image schema. The concept of LOCATION fits with the image schemas that serve as an underlying spatial structure of language, which include: SPACE; PATH; and CONTAINER (Johnson 1987, Talmy 2000, Croft and Cruse 2004:45). As Geeraerts (2006) outlines the four fundamental cognitive operations we constantly apply to understand and express our experience are: conceptual metaphor, conceptual metonymy, image schemas, and conceptual integration.

Duly the primary perceptual embodied experience of COLOR and SEEING directly involves the development of conceptual metaphors and, therefore, the establishment of a process of mapping between the source domain of COLOR/SEEING, both as a substance/object and a light/object, and the target domains of the occasion and association (Sandford 2012, 2018, 2021). It thus follows that COLOR as a STATE may be conceptualized according to the SPACE, PATH, and CONTAINER image schemas, developing through the 45 different senses of *in* (see the Oxford English Dictionary)[1]. These senses stem from metaphors such as COLORS ARE LOCATIONS, for example, *The painters had done it all in green* [FIC 1991][2], where *in* is used to indicate "qualification of a condition", or with *The boy's gifts are wrapped in blue* [BLOG 2012] *in* is used to indicate "a means" like *in ink*. In both of these cases there is a conceptual metonymy underlying our understanding where the COLOR PART FOR WHOLE is activated. Furthermore, we can see CHANGE IS MOTION, CHANGING COLOR IS MOVING TO A LOCATION that is specified with examples like *Sunlight at the bottom of the atmosphere ends up peaking in red* [BLOG 2012] (see Sandford 2021: 191-193). This paper presents corpus data on the polysemy of this COLOR construction [IN *COLOR]. The analysis proposes a cognitive analysis of the construction processing to describe the data. The second paragraph illustrates the theoretical basis of this approach to color semantics; defines my usage of conceptual metaphor and metonymy, images schemas, and constructions. The third paragraph describes the construction [IN *COLOR]; giving corpus analysis examples of the polysemic usage of "in". The fourth paragraph discusses the results of the corpus analysis and proposes a conceptualization of this construction drawing some conclusions.

Theoretical Approach

According to Cognitive Linguistics, color semantics must deal with how we conceptualize our experience according to conceptual metaphor and metonymy, image schemas, conceptual integration, and constructions. Conceptual metaphor and metonymy are structured according to the separate conceptual domains A IS B, or SOURCE DOMAIN A IS TARGET DOMAIN B for metaphor, and A FOR B, or A IS MENTAL ACCESS FOR B for metonymy, where each type of relation involves the parts and the wholes of the object/event conceptual domain, e.g., an attribute is seen as an intrinsic part of an object or event whole. These conventional syntaxes are useful to express the patterns of the cognitive operations at the foundation of

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[1] "in, prep.". OED Online. March 2022. Oxford University Press. https://www.oed.com/view/Entry/92970?rskey=EeGFQo&result=7 (accessed April 27, 2022).

[2] The square brackets indicate the type of text and the year of the example from COCA. The corpus consists of more than one billion words of text (25+ million words each year 1990-2019) from eight genres: spoken, fiction, popular magazines, newspapers, academic texts, and updated in March 2020 with TV and Movies subtitles, blogs, and web pages. https://www.english-corpora.org/coca/ (accessed April 27, 2022).

our everyday embodied experiences –and which are not simply a matter of rhetoric or figurative language (see a.o. Lakoff and Johnson 2003, Kövecses 2010, Sandford 2021).

Image schemas are also seen as part of our cognitive operations used to understand schematic relations, which operate as organizing structures or patterns of the sensory input we receive from the world around us as we interact with it. The inventory (developed by Clausner and Croft 1999, from Johnson 1987, and Lakoff and Turner 1989) include: SPACE, SCALE (PATH), CONTAINER, FORCE, UNITY/MULTIPLICITY, IDENTITY, EXISTENCE.

A linguistic construction, as defined in Construction Grammar, is a unit of language that constitutes a conventional unit pairing form and meaning[3]. Hence, when considering the usage of color terms, by investigating the constructions that emerge in corpus analysis we can reveal the predominant underlying conceptualization processes. In this case the construction [IN *COLOR] is analyzed. The asterisk before *color* is used to indicate the slot for any color word that is set after *in*. In this brief study I have considered the 6 primary basic color terms: WHITE, BLACK, RED, GREEN, YELLOW, BLUE, and the category word COLOR.

Usage of Color Construction [IN *COLOR] Corpus Analysis

The results for a generic query in COCA asking for the prepositions that collocate with the color terms resulted in three top prepositions OF, IN, and WITH. The specific numbers in Table 1 are the results of that day I queried the corpus, see footnote 2. Although the numbers change in time the general tendencies average similarly. It would be interesting to verify if there are relevant changes in 10 years from now. For example, the hits for [IN YELLOW] occur most in Fiction texts, and across the years from 1990-2019 range from 0.67 to 0.98 per million. The hits for [IN BLUE] also occur most in Fiction texts, and across the years from 1990-2019 range from 2.59 to 3.39 per million. So there is fluctuation, but the average variation is not apparently significant.

Table 1. describes the corpus query results. Column 1 lists the total occurrences of the color term. Column 2 shows how for all the color terms the IN collocations is second in ranking compared to all preposition hits, except YELLOW where IN is third ([OF *COLOR] is the most frequent for all color terms, and alternately in the group of the top 3 is [WITH *COLOR]). Column 3 shows the query, and 4 the number of relative collocation hits. 5 shows the total hits of that color with any preposition. 6 shows the ranking of the MI[4] within the specific color query for all prepositions,

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[3] Form typically concerns a particular string of segments conventional in a particular language; meaning connects to a mental representation, or a lexical concept, which is conventionally associated with a form. Construction Grammars, developed by Fillmore, Kay, and Goldberg, among others, basically sees that grammar may be described as a series of constructions rather than "words and rules" (see Evans 2007: 44-46).

[4] MI stands for mutual information, which is the ratio of the collocation frequency of any two words to the products of the two words' respective probabilities of occurring independently. The statistical value measures the

and 7 shows the MI score. All of the MI scores are considered statistically significant being over 3 (this is especially true when considering the high frequency of the prepositions queried).

1. ALL OCCUR. OF [*COLOR]	2. RANK FREQ ALL PREPS	3. [IN *COLOR]	4. COLLOCATION HITS	5. Out of ALL PREP [*COLOR]	6. Rank of MI Out of ALL PREP	7. MI
369,146	2	IN WHITE	5043	42,316	16	3.88
309,890	2	IN BLACK	8442	54,033	15	4.09
169,751	2	IN RED	4088	21,265	5	4.38
128,402	2	IN GREEN	2391	14,511	10	4.14
111,917	2	IN BLUE	2733	13,022	7	4.66
43,763	3	IN YELLOW	754	5,023	6	4.02
124,814	2	IN COLOR	2526	22,841	8	3.78

Table 1. Summary of results of COCA query for [IN *COLOR]

We may observe how the ranking in color term frequency does not even out with the ranking of the collocation hits. [IN BLACK] is higher than [IN WHITE] in this collocation and in all the preposition color collocations [*COLOR], even though WHITE is most frequent in general. Looking at the examples, this change in frequency and MI is most likely due to the fixed expression in this construction "in black and white" where *black* collocates with *in* and *white* is the second element. [IN BLUE] is higher than [IN GREEN] in this collocation, even though [PREP GREEN] is more frequent in all the collocations with prepositions and in general. YELLOW is always last in ranking. Moreover, [IN COLOR] ranks after BLUE but before GREEN in this collocation, and higher, after BLACK and WHITE, for all prepositions [PREP COLOR]. The MI ranking out of all the possible prepositions shows how [IN RED] has the highest rank (5) in comparison to the other color term preposition MI for [IN *COLOR], varying from 5 to 16. IN BLUE has the highest MI 4.66 of the precise collocation (ranging from 3.78 to 4.66); this could be due to the expression "in blue" used to identify the police in uniform.

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extent to which the joint occurrence of the two words is exclusive. This thus expresses the relevance of the couple of words vs. frequency. The formula used in COCA is MI = log ((AB * sizeCorpus) / (A * B * span)) / log (2)

Construction Conceptualization and Conclusions

Thus, we may consider that the high saliency of the construction [IN *COLOR] reflects the basic image schemas. I concentrate on those directly implicated with the use of the preposition IN, as indicated in Figure 1.

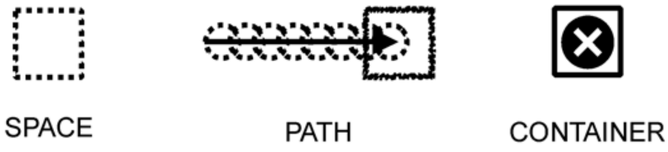

Figure 1. IN Conceived as a SPACE, PATH, CONTAINER (see Langacker 2008:101)

SPACE refers to an area or a location that can be physical or imaginary (i.e., a category). PATH implies change<>motion along a trajectory with a source, a direction, and a landmark or purpose<>goal. And CONTAINER is the orientational schema that is primary in the association of the position, infers there is an inside and outside, and that there is a boundary. So if we think of these basic schemas in relation to the 45 meanings of IN, we find there are 17 definitions that apply to color.[5] Each of these usages are understood in the association of the elements within the utterance. They fall under the basic headings: SPACE - of position or location; PATH - of situation, condition, state, material, and other attributes; and CONTAINER - constructional uses in which the noun phrase following IN defines or limits the application of the expression preceding it. A simplification of these definitions is used in COCA which lists three definitions of IN: 1. Used to indicate inclusion within space, a place, or limits, 2. Used to indicate inclusion within something abstract or immaterial. 3. Used to indicate inclusion within or occurrence during a period or limit of time.[6] COLOR does not appear to fall into the polysemy of time however.

Some specific examples for each image schema and color follow:

[5] The definitions that apply to the use of color terms are: I. Of position or location. 1.a. Expressing the situation of something that is or appears to be enclosed by something else: within the limits or bounds of, within (any place or thing). 4. Expressing relation to something that covers, clothes, or envelopes, or to its material, its colour, etc.: clothed in, wearing, enveloped in, wrapped in, bound in. 6. Expressing membership or belonging. 8. a. Indicating the particular part of something which is affected. 11. a. Belonging to, as an internal quality, attribute, faculty, or capacity; inherent in; hence, within the ability, capacity, thought. II. Of situation, condition, state, occupation, action, manner, form, material, and other circumstances and attributes. 18. a. Expressing situations determined by the nature of the location or physical surroundings. Frequently figurative. c. Expressing situations as regards light, darkness, and atmospheric environment. d. (a) Expressing situations within the range of sensory perception of another. 20. a. Expressing the form, shape, configuration, arrangement, or order of something. c. Expressing the manner, style, or fashion in which something is done. 22. Expressing means or instrumentality. b. Combining a sense of in (or on) with a sense of with or by. 26. Expressing material or constituents. V. Constructional uses in which the noun phrase following in defines or limits the application of the expression preceding it. 45. With a noun or noun phrase, forming an adverbial phrase.

[6] As defined in https://www.english-corpora.org/coca/ last accessed 29 April 2022.

SPACE
The man **in white** was short, five-seven at the most [FIC 2003]
riding in the passenger seat is a man dressed **in black** [FIC 1995]
The words stood out in red, like blood [FIC 1997]
Strange trees grew here; very tall, with multi-colored leaves **in green** and orange [FIC 2016]
This one is **in blue** li -- **in blue** -- cobalt blue. [SPOK 1999]
The same words are highlighted in yellow [BLOG 2012]

PATH
I'm doing everything **in white** and blue [TV 1992]
And wrote Kelly **in black** over bare flesh [FIC 2004]
Sunlight at the bottom of the atmosphere ends up peaking **in red** [BLOG 2012]
a tower of the City Hall is seen veiled **in blue** [FIC 1998]
thick honeysuckle vines, all leafed out **in green**, with small white flowers [FIC 1999]
The entryway light splashes them **in yellow** [FIC 1993]

CONTAINER
when the dads **in white** situations can be played by ladies' men [NEWS 1991]
He's got all the Figures **in black** and white [MOV 1994]
wealth in blue, energy consumption rates **in red**, and the value of the constant **in green** [BLOG 2012]
an old standard like Gershwin's "Rhapsody **in Blue**" is used [NEWS 1997]
this tree is … with trachypachids marked **in green** and dytiscoids **in blue** [WEB 2012]
a crater of exposed muscle, ringed **in yellow** [FIC 2015]

I argue that the three separate aspects of SPACE, PATH, and CONTAINER illustrate this cognitive processing, stressing that they are not necessarily conceptualized separately but may be integrated in the understanding of the COLOR STATE. The SPACE schema accesses A STATE IS A LOCATION where a STATE is a COLOR and the LOCATION is a SPACE/CONTAINER relative to a *condition*, or better COLOR IS A SPACE/CONTAINER. The PATH schema is relevant in our understanding of color as a process of change and hence movement to a place, or a goal, which yields COLOR CHANGE IS COLOR MOTION ALONG A PATH or a *means* to a goal. The CONTAINER schema seems to emerge as a clear concept of definition or *limit*, emerging from COLOR ATTRIBUTE FOR OBJECT/CONCEPT.

To conclude, through the Cognitive Linguistic approach combined with Construction Grammar and a usage-based account supported by real language corpus analysis, I am able to propose an explanation of the complex embodied patterns English speakers use to conceptualize usage of color words, in this case of [IN *COLOR].

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References

Croft, W. and D. A. Cruse. 2004. Cognitive Linguistics. Cambridge: Cambridge University Press.
Davies, M. 2008-. The Corpus of Contemporary American English (COCA): 560 million words, 1990-present. Accessed April 9, 2022. https://www.english-corpora.org/coca/.
Evans, V. 2008. A Glossary of Cognitive Linguistics. Edinburgh: Edinburgh University Press.
Fillmore, C.J., P. Kay, and L. A. Michaelis. 2006. Construction Grammar. US: Center for the Study of Language and Information.
Geeraerts, D. 2006. Introduction - A rough guide to Cognitive Linguistics. In Cognitive Linguistics: Basic Readings, D. Geeraerts (ed.). Berlin: Mouton de Gruyter. 1-28. (2006:19).
Goldberg, A. 2006. Constructions at Work: The Nature of Generalization in Language. Oxford: Oxford University Press.
Johnson, M. 1987. The Body in the Mind. The Bodily Basis of Meaning, Imagination, and Reason. Chicago: The University of Chicago Press.
Lakoff, G. and M. Johnson. 2003 [1980]. Metaphors We Live By and Afterward. Chicago: The University of Chicago Press.
Lakoff, G. and M. Turner. 1989. More than Cool Reason. Chicago: The University of Chicago Press.
Langacker, R.W. 2008. Cognitive Grammar. Oxford: Oxford University Press.
Sandford, J.L. 2012. Red Clover: Linguaggio e percezione dei colori: uno studio cognitivo applicato alla lingua inglese. Rome: Aracne Editrice.
——. 2018. Methodological Approaches and Semantic Construal of the Seeing Domain in English. In Sensory Perceptions in Language, Embodiment, and Epistemology, Studies in Applied Philosophy, Epistemology and Rational Ethics. A. Baicchi, R. Digonnet, and J. L. Sandford (eds.). Vol. 42: 111–132. Switzerland: Springer.
——. 2021. The Sense of Color: A cognitive linguistic analysis of color words. Perugia: Aguaplano
Talmy, L. 2000. Toward a Cognitive Semantics. Cambridge, MA: MIT Press.

Session 4
Colour in Architecture - I

Polychromic Space. Architectural Agencies of Colour

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Abstract

This paper discusses the art and colour installation Polychromic Space (Copenhagen, DK, 2021-22) and the ideas and approaches, historical as well as contemporary, that led to its creation. It is a colour statement and an argument against chromophobia which has overshadowed architectural and interior design practice since the advent of modernism. First, we introduce the idea of polychromic spaces as spatial experiments that evolved in art and architecture at the beginning of the 20th century in Europe. Some artists and architects questioned, each within their own creative principles, the conventional space perception by intervening with space through the application of colour and colour planes. They operated in an interdisciplinary field in which architectural space and art blended into new, immeasurable spatial dimensions. Second, we explore how we can recapture and appropriate the historical, almost forgotten, spatial concepts from the early 20th century by means of the installation Polychromic Space. Stating that space can be shaped using colour, this project illustrates how spatial dimensions can be influenced, – how properties such as heights, lows, distance, and proximity can be elicited, how the spatial framework can be manipulated and figuratively dissolve – and how colour can turn static surfaces into plastic, dynamic elements.

Keywords: *Colour Installation, Spatial Polychromy, Colour History, Neo-plasticism, Architectural Colour*

Introduction

This paper reflects on colour in space and colour as a space making element. It specifically elaborates on approaches in which colour is tied to both form and space. It aims to gather historical as well as contemporary, intellectual as well as designerly findings that illuminate various architectural agencies of colour in relation to the concept of spatial polychromy.

The concept of spatial polychromy developed in European art and architecture at the beginning of the 20th century. Artists and architects questioned, each within their own creative principles, conventional space perception by intervening with space through the application of colour and colour planes. They operated in an interdisciplinary field in which architectural space and art blended into new, immeasurable spatial dimensions and sensations. Their achievements disappeared however into the background from the 1930s onwards. This had to do with the apparent complicated relation that architects and interior designers had and still have with colour, – a condition which can be defined as chromophobia.

Chromophobia

Chromophobia, or said differently, the fear of colour, has according to artist and writer David Batchelor since Antiquity been a cultural phenomenon. Batchelor notes that colour has been an object of extreme prejudice in Western culture and systematically marginalized, reviled, diminished, and degraded by generations of philosophers, artists, art historians and cultural theorists. Bathelor (2007:22); Barnstone (2022). It is associated with the primitive, the infantile, the vulgar, the queer or the pathological – or it is downgraded to the realm of the superficial, the supplementary, the inessential, or the cosmetic. Bathelor (2007:23).

In architectural practice the exclusion of colour has been dominating since the advent of modernism, where – one could argue – colour preference became limited to hues of white and grey. This evolution of avoiding colour in architecture can partially be ascribed to the photographical distribution of architecture projects in journals, which at the beginning of the 20th century still was black and white. Wigley (2002: 318). We tend to think about architectural modernism as colourless, but in reality architectural practice was everything but chromophobe. A specific development of *spatial colour application* took place in an interdisciplinary field between architecture and visual arts. Works and writing of architects and artists like Le Corbusier, Theo Van Doesburg, Piet Mondrian, Jozef Peeters – and many others[1] – in the late 1920s and the early 1930's point to elaborated thoughts and agencies about colour and architectural space.

Le Corbusier

In 1931 the Swiss-French architect Le Corbusier (1887-1944) wrote the essay "Polychromie architecturale". In architecture, he argued, it is necessary to subject the countless combinations of colours to the laws of architecture. A wall that is illuminated from the front, or with skimming light, or with backlighting, requires corresponding decisions. Therefore, he claimed, it is necessary to apply certain rules, such as to exclude colours that are non-architectural and choose colours that are architectural. Le Corbusier favoured earthy colours; they were 'eternal' as they had accompanied architecture since ancient times, a property which makes them architectural, according to Le Corbusier.

The interplay of light and surface is a determining element when choosing an appropriate colour, Le Corbusier continued. Everything that is a play of volumes, modelled or sculpted gets alive through the effect of shadow, semi-darkness, and light. If the light is at play, it would be wrong to apply multiple colours. Le Corbusier concludes that polychromy works on smooth surfaces, while it kills everything sculptural. What is sculptural should be monochrome, and what is smooth could become polychrome.

Monochromy, according to Le Corbusier, enables an exact appreciation of the volumes of an object. Polychromy abolishes the pure form of an object and changes its volume. Either way, we can conclude, colour application is a powerful instrument. It can be employed to manifest a certain architectural context, or to adjust a shape or a space optically.

Le Corbusier discusses this spatial property of colours referring to a square room. If the walls are painted in the same tone, the shape of the room will remain intact, emphasized if the tones hold the walls in place – reds, for instance, weakened if the tones on the walls dissolve – blues, for instance. The shape of the room will be preserved and made visible if the ceiling is painted white. If the ceiling has the same tone as the wall, the impression changes; it becomes something clearly rounded to something very tempered, soothed, seductive. The spatial effect is that of a dome. Such implementation encloses the space.

In "Polychromie architecturale" Le Corbusier offers moreover some concrete recommendations concerning the choice of colour, particularly about the qualities of blue and red: Blue creates space, while red establishes the presence of the wall. The blue, and the greens that derive from it, make the wall seem more distant and difficult to grasp. The red and its derivatives, browns, oranges, etc. hold the wall in place, confirm its size and its presence. De Heer (2008).
White belongs in the work of Le Corbusier to another category but was equally important as colours: he didn't regard white as an active colour, but as a backdrop for the effect of other colours. Le Corbusier (1933).

Theo van Doesburg

While Le Corbusier developed his ideas about colour in space from the perspective of an architect, the Dutch painter and founder of the art movement De Stijl Theo van Doesburg (1883-1931) explored the possibilities of joining architecture and artistic painting as important means in the evolution towards a better understanding of the role of colour in spatial contexts. He elaborated his approach in the essay "Farben in Raum". Van Doesburg (1928). Like le Corbusier, he points to light and colour as indispensable for the perception of space. They are both fundamental – and complementary architectural elements. The organic connection between space and material is only possible by means of light but is only completed by the addition of colour. Architectural design is inconceivable without colour, he argued. He saw colour as a means to give expression and meaning to architecture. It meets psychological needs and rises above the dominant expressionless, rational functional architecture which characterized the 1920s.

Van Doesburg lamented the approach of contemporary architects who focused on organizing architecture according to function, for whom form had become secondary, without room for colour at all. In an atmosphere of fanatical glorification of the utilitarian and functional, he claimed, these architects limited themselves to the practical and factual and ignored the needs of the eye, the touch, and the mind, - neglecting that modern man has as great a need for colour as for light. The functionalists were only prepared to recognize colour if it fulfilled a useful function, Van Doesburg continued. Accordingly, functionalist architects made a virtue of necessity. Nevertheless, colour and space began to develop around a common axis, - with as a result that an inner coherence between these elements started to evolve.

In collaboration with the architect Cornelius Van Eesteren (1897-1988), Van Doesburg explored the properties of colour as a distinguishing element in the architectural design. They abandoned any artistic, compositional tendency. The surfaces, which created the space, were each painted in a certain colour, depending on their position in the space. Height, length, and width were indicated with red, blue, and yellow and volumes were indicated with grey, black and white. In this way, they expressed the dimensions of the space vividly but left the architecture itself undisturbed, according to Van Eesteren and Van Doesburg.

Such application of colour in space, Van Doesburg clarifies in "Farben in Raum", removes every form of illusion. When the painting is no longer a closed individual expression of personal experience it comes into contact with space. And, more importantly, painting comes into contact with man. A relationship develops between colour and space and between man and colour. Through this relationship of the moving human in space, a new experience in architecture arises, namely: the experience of time.

This new approach makes it possible to experience the total content of space as an optic-aesthetic sensation in which a synoptic effect of painting and architecture, - seeing and experiencing everything together, is attained. To achieve such experience, a relationship between the painted surfaces, both architecturally and artistically, is conditioned. The space has to be created as a coherent body. It is now a matter of placing the human being in the painting rather than in front of it, Van Doesburg maintained. Van Doesburg (1928); De Heer (1986); Van Faessen (2019).

Piet Mondrian

Another prominent figure of De Stijl, the Dutch painter Piet Mondrian (1872-1944) shared a similar approach to colour and space as Van Doesburg, known as neo-plasticism. During the 1920s Mondrian explored the synoptic effect of painting and architecture in several of his Parisian studio's by literally using walls as canvas. Manacorda (2014). Painting and architecture merge into a three-dimensional expression, defined by the relationship of one colour plane to another. Mondrian

(1917). In this ideal world of Mondrian, both the conventional painting and space dissolve as it were, and get replaced by a plastic, spatial experience.

In 1926 he designed a workroom for art collector Ida Bienert. It was never realized but is one of the most profound and outspoken studies into the possibilities of neo-plasticism in the practice of Mondrian. The orthogonal space is replaced with colour planes, distributed in compositions of rectangles that take into account the spatial proportions but ignores the differences between walls and ceiling, and even floors. It is a clear attempt to deconstruct form and counterpoint architectural mass. Komossa (2009). Mondrian was, like most of the other De Stijl members, only applying the primary colours red, blue and yellow, in combination with the so-called non-colours black grey and white.

Jozef Peeters

The Belgian painter Jozef Peeters (1895-1960) was a pacesetter of the international avant-garde art scene in Antwerp. Inspired by the writings of Van Doesburg and the principles of neo-plasticism developed by Mondrian, he started to apply colour in his own apartment in the 1930s. Peeters appropriated the concept of neo-plasticism and made his own unstrained interpretation of this new spatial approach in which he for instance used multiple colours (except black and white).

According to Peeters, it requires a profound analysis of a given room ahead of any intervention. A consideration of its spatial dimension, openings (doors, windows), fixed furniture and other features is key to the creation of a balanced outcome. Peeters composed in each room of his apartment a different pattern of colour planes, each characterized by its own colours scheme. In each room Peeters strives for a plastic, spatial totality – searching for a harmonious relation between verticality and horizontality, enhancing visual enclosure and always avoiding symmetry. The apartment remains today in its original state. Due to a careful restoration even the colours appear in their initial hues. Buyle (1998).

Despite the elaborated ideas about space and colour, demonstrated in the works of Le Corbusier, Theo Van Doesburg, Piet Mondrian and Jozef Peeters, the concept of spatial polychromy did not last. It was arguably suppressed by the influence of architectural modernism and taken over by a state of chromophobia. Colour as a space making instrument simply went into oblivion.
Although this so-called fear for colour still prevails in architectural production, a slow change toward an increased colour implementation in architecture is discernible. Komossa (2009); McLachlan (2013). In contemporary artistic practices on the contrary, a rich manifestation of colour interacting with space is at stake. Schultz (2018).

Polychromic Space

Inspired by these new – or recurring – tendencies, we conceived Polychromic Space. It is a colour installation created for an open competition which was initiated by the architecture practice Leth & Gori (DK). The brief called for an explorative exhibition, having only one condition: to take point of departure in a specific exhibition space.

We were triggered by this call. As architects and teachers in interior design we have been long-term fascinated and puzzled about colour in relation to form and space – but as many others we also struggle with symptoms of chromophobia. We sensed though immediately that this call could offer an undogmatic space for us to explore some of our imagined spatial colour experiments, using colour as an architectural instrument and as a medium to evoke a saturated spatial experience.

Retrospectively, we probably have been influenced by some of the architects and artists from the 1920s and 1930s, but basically our creative process was first and foremost propelled by the urge to center stage colour, both as a visual as well as spatial, embodied sensation.

We defined surfaces looking at existing elements in the space. We determined the composition of the colour planes by analyzing the position of existing elements such as door, floor, walls, openings, ceiling, windows, windowsills, skirting boards, radiator etc. They became decisive components for the final spatial design in combination with qualities such as daylight, spatial flow, horizontal and vertical lines, and details. Every component of the space which would be harmed by the coating of paint got protected by wooden structures. These structures eventually united the space, appearing more or less as a mono-material.

We had no colour theories in mind but started to search intuitively for the right colour composition. We chose colours based on personal preferences and contextual properties – yet, our colour choice was not arbitrary. We explored multiple colour compositions before we found the right one. We can also not explain or theorize our colour choice, but the fact is that we ended up with a mutual preference. Black and white were for one or another reason not included. Additionally, to underline or foster new perspectives in the space, we inserted both static and mobile planes. We build a wall following a diagonally path from the front door to a room situated in the back. Furthermore, we added two large window shutters in order to regulate light intensity.

Once realized, Polychromic Space was a four-dimensional place of colour. Movement in this space is inevitable and makes the visual perception change continuously. Depending on position, daylight, electric lighting, shadow etc., colours change their hues, intensity, and interaction with other colours continuously. Nothing is predictable, and no colour composition is fixed.

Figure 1. The added wall has a huge impact on both the colour perception and the spatial experience. It offers moreover the possibility to visualize the play between low and high skirting boards. Photo: Laura Stamer

Figure 2. Completely unintended, the colour planes interact in mutual ways: the skirting boards, the high and the low, correspond with each other. Photo: Laura Stamer

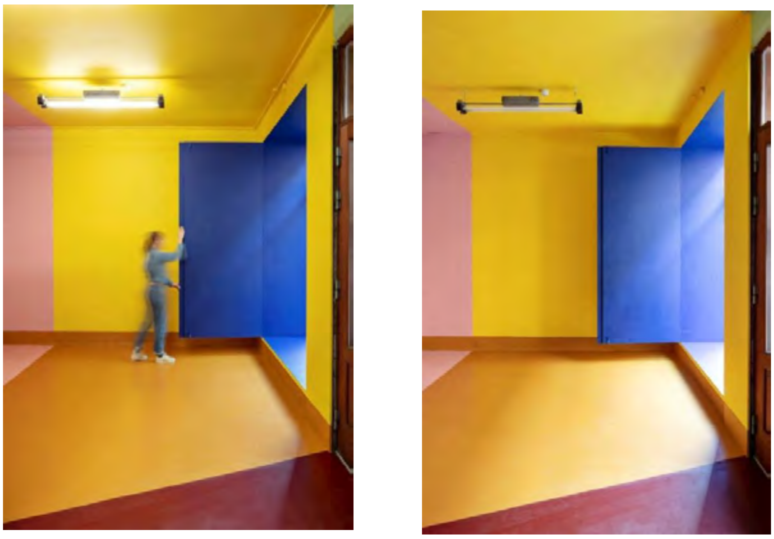

Figure 3. Electric lighting versus daylight affects colour perception significantly. Photo: Laura Stamer

Figure 4. Due to a particular colour composition the installation appears as two different spaces. Photo: Laura Stamer

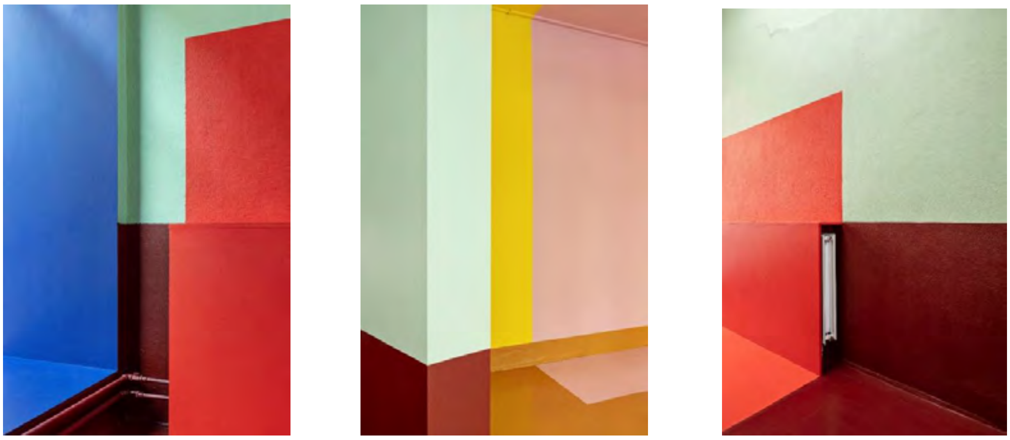

Figure 5. Zooming in on parts of the installation reveals photogenic colour compositions. Photo: Laura Stamer

In conclusion, we argue that space can be shaped through the use of colour. This project illustrates how spatial dimensions can be influenced – how properties such as heights, lows, distance, and proximity can be elicited; how the spatial framework can be manipulated and figuratively dissolved – and how colour can turn static surfaces into plastic, dynamic elements.

Acknowledgements

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References

Batchelor, D. 2007. *Chromophobia*. London: Reaktion.

Barnstone, D. A. 2022. The Color of Modernism: Paints, Pigments, and the Transformation of Modern Architecture in 1920s Germany. London: Bloomsbury Publishing USA.

Buyle, M. and M. Manderyck. 1998. Wonen in een schilderij. De conservering en restauratie van Jozef Peeters' atelierflat (1926) in *Antwerpen. Monumenten & Landschappen*. 17/4: 4-22.

De Heer, J. 2008. *De architectonische kleur*. Rotterdam: Uitgeverij 010.

De Heer, J., M. H. Cornips and H. Van Dijk. 1986. *Kleur en architectuur*. Rotterdam: Uitgeverij 010.

Komossa, S., K. Rouw, J. Hillen, et a al. 2009. Colour in Contemporary Architecture: Projects, Calendar, Manifestoes. Amsterdam: SUN.

Le Corbusier. 1933. *Polychromie architecturale*. Fondation Le Corbusier B1-18-20-001.

Manacorda, F. and M. White. 2014. *Mondrian and his Studios. Colour in Space*. London: Tate Publishing.

McLachlan, F. 2013. *Architectural Colour in the Professional Palette*. New York: Taylor & Francis.

Mondrian, P. 1917. De nieuwe beelding in de schilderkunst. De Stijl 1: 42

Schultz, K., H. Wiedemann-Tokarz, and E. M. Herrmann. 2018. *Thinking Color in Space.* Basel: Birkhäuser.

Van Doesburg, T. 1928. Farben im Raum und Zeit, *De Stijl* 87-89: 26.

Van Faassen, S., and H. Bergeijk. 2019. *De kleur lost de architectonische ruimte op*. Haarlem: Uitgeverij Eigenbouwer.

Wigley, M. 2002. White wall, designer dresses: the fashioning of modern architecture. Cambridge: MIT Press.

On different colour approaches to architecture

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Abstract

This paper explores different approaches to colour applied to architecture in France referring to three colour protagonists in France: Bernard Lassus, Jean-Philippe Lenclos, and Atelier Cler. Each of them reveals a specific way of dealing with colour in architecture and urban design. In this context it is not relevant to ask what colours were dominant and what meaning they were given. Rather, it is important to discuss what kind of approach was being used to bring colour to housing estates, new towns, and urban environments. The first of the three approaches concerns Lassus, who painted genuine images of urban and natural landscapes on building façades, covering the whole surfaces like a trompe-l'oeil. The second approach is related to Lenclos, who used large-scale graphics, typography, and geometric imagery to cover large building surfaces, which at that time became known as supergraphics. The third and last approach discussed in this paper is that of the Atelier Cler, who always used urban space as a point of departure, including not only the building façades, but also maps. It is interesting to note that these three different approaches continue to be applied today.

Keywords: *Colour, Architecture, Murals, Supergraphics, Urban Space*

Introduction

The period of the 1960s and 1970s in France was important for conceiving colour concepts for urban environments. In 1965, a Master Plan for the Urban Development of the Paris Region (SDAURP) was adopted to control urban sprawl. This policy was also launched for planning new towns in previously undeveloped areas close to rapidly growing cities such as Paris, Rouen, Lille, Lyon, and Marseille.

This paper explores different approaches to colour applied to architecture. In particular, it discusses three major colour designers in France: Bernard Lassus, Jean-Philippe Lenclos, and Atelier Cler. All three studios reveal very distinctive ways of dealing with colour in architecture and urban design.

Landscape Murals

Landscape architect Bernard Lassus painted all kinds of houses, trees, skies, and clouds on the façades of residential blocks, covering the whole surfaces like a trompe-l'oeil (Figure 1). The purpose of his colour interventions was neither to disguise the buildings nor make them beautiful. In an interview, Lassus said that his objective was to reinstall a relationship between the modern multi-storey architectural buildings and its inhabitants, since people considered new housing blocks to be too massive and ugly (Schindler and Griber 2021: 312). Since working-class people used to live in small, single-family houses surrounded by small gardens, built between the 1890s and 1930s and located in the outskirts of big cities (Conan 1989:207), Lassus chose to colour the blank walls of the multifamily architectural blocks. He does not consider paint to be a rich material, but its possibilities are limitless. As a landscape architect, he designed the park surrounding the buildings and planted trees. As an artist, he created a parallel visual world on the huge building façades. As a result, the natural scenery interacts with the imaginary landscape of painted gardens and buildings to create a multi-layered landscape–in Lassus' words: "un paysage mille-feuilles" (Lassus 1989: 161, *Le jardin* 2017: 88-89). The real is visually destroyed and deconstructed paving the way to a lively colour complexity. While nature undergoes colour changes across the seasons, the colours of the murals remain stable and permanent. Through this colour practice, Lassus could blend the buildings into the environment with the goal of transforming housing developments into a liveable and spirited landscape.

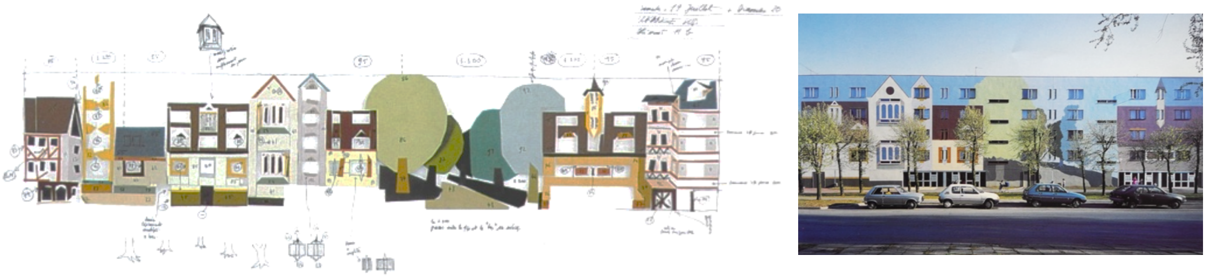

Figure 1. Bernard Lassus: Colour between sky and earth, shaping an imaginary urban landscape on large building façades. The natural landscape blends with the painted one to become a coloured, multi-layered built environment. Uckange, France. Left: Collage © Bernard Lassus. Right: Photo © Monika Nikolic. (Lassus 1989: 172-173)

From 1978 to 1987, Lassus conceived colour designs for such cities as Hagondange, Fameck, Villerupt, Amnéville, Thionville, Uckange, and many more.

Supergraphics

Supergraphics is about the power of colour to transform space and a building's facades and other surfaces using graphics, typography, and bright colours. In the 1960s, Jean-Philippe Lenclos created strong visual identities using graphic designs spanning walls, ceilings, floors, and furniture of interiors. Inspired by Barbara Stauffacher Solomon's work, a pioneering artist of the movement of supergraphics (graphics on a monumental scale), Lenclos used supergraphics on the exterior of different types of buildings.

In his AIC CADE Award Lecture, Lenclos reveals how he discovered this very specific way of applying colour: “The packaging of the Textone brand of facade paints was the perfect place to start expressing myself. I designed a graphic motif in the form of a blue and yellow geometric module, colours I selected because of the intensity of their contrast and developed on the principle of connecting one packaging to another. By rotating the packaging, we obtained infinitely variable combinations. In a way this was the beginning of supergraphics.” (Lenclos 2021a: 107).
The exterior paint for application on façades was endowed with symbolic meaning when the cans were stacked and rotated so that differing combinations generated all kinds of graphic designs (Figure 2, left).

Lenclos then explored the optical properties of colour when applying high-gloss paint to very smooth walls (Lenclos 2017). The mirror-like surfaces attracted his attention and interest because of the continuously changing aspect of the colours. Combined with supergraphics, Lenclos designed a futuristic interior structure for an auditorium that he presented at the Salon des Artistes Décorateurs in Paris (Lenclos 1989, 2021b). He also created supergraphics for school buildings. For example, the wall at the entrance of the primary school building Les Madaras in Cergy-Pontoise, France, represents a monumental, playful, and colourful typographic design of the school’s name (Figure 2, centre). While the letters are still recognisable, they morph into supergraphics covering the entire wall’s surface, and a new design emerges defined by geometric shapes and strong colours. As well, the studies for the school buildings’ façades show how Lenclos applied the graphic approach in a versatile and talented manner; however, the studies remained unrealized because of the avant-garde, unusual style (*Éloge*: 92–95).

Figure 2. Jean-Philippe Lenclos’ Supergraphics. Left: Textone paint cans stacked and rotated so that a graphic design variation is created. Centre: Les Madaras primary school building entrance, Cergy-Pontoise, France. Right: Detail, supergraphics on façades, Shipyard Gondolys, Port Barcarès, France. Photo: © Jean-Philippe Lenclos.

Lenclos also created a strong identity by visualizing the company’s name on the facades of the industrial building of the Shipyard Gondolys in Port Barcarès, France (Figure 2, right). Based on typology and vivid colours, the supergraphics create an impressive impact on the built environment and natural landscape (*Éloge*: 82–83).

Working as a colour designer for industrial products, he used a graphic approach to architecture that eventually is known as supergraphics (Brook and Shaughnessy 2010). As an artist, Lenclos explores the properties of colours in his drawings, watercolours, and oil paintings to create vibrant optical and geometric patterns that capture rhythm and movement.

Urban chromatic studies

The aim of the urban chromatic studies carried out by the Atelier Cler was to identify and specify the colour characteristics of a given urban space, enhance general chromatic developments, design chromatic harmony, and suggest chromatic ambiences (Cler 2010, CAUE 2011). These studies always combined colour charts, palettes, and colour cards with colour maps, either chromatic orientation schemes, chromatic reference plans, or outlines of chromatic ambiences (*Éloge*: 34-35). The Atelier Cler called the studies *études chromo-paysagères* (landscape chromatic studies) in order to underscore a sense of scale encompassing a broad span of landscapes ranging from local residential micro sites to large-scale urbanization, settlements, and industrial parks (Schindler 2012). Urban chromatic studies also deal with stimulating, reinforcing, and supporting a colour culture (Cler *et al* 2005). The Atelier Cler's approach is definitively an urban one and in the words of Michel Cler, "As a chromatic landscape, the atmosphere of any urban space is a process of the ongoing construction, deconstruction and reconstruction" (Cler 2011: 183).

Concluding remarks

Nowadays murals compete with super projections, supergraphics with graffiti, and urban colours with colour pixelation and colour fragmentation.

References

Brook, T., and A. Shaughnessy. 2010. Supergraphics. *Transforming space: graphic design for walls, buildings, and spaces.* Unit 2. London: Unit Editions.

CAUE de l'Ain, Conseil d'Architecture, Urbanisme & Environnement. 2011. *Couleurs, lumières, matières: ambiances et cadres de vie.* Bourg-en-Bresse: CAUE de l'Ain.

Cler, M., F. Cler, and V. M. Schindler. 2005. Chromatictownscape. Colour Policy in the French Ain Region: Colour Studies for Towns, Villages and Valleys. *Proceedings of the 10th Congress of the International Colour Association, 8–13 May 2005*, Granada, Spain. J. L. Nieves, and J. Hernández-Andrés (Eds.) Granada: Sociedad Española de Óptica and Comité Español de Color, Vol. 2, 1581–1584.

Cler, M. 2010. Paroles de consultants couleurs. *Matières à conception* 5: 24–26.

Cler, M. 2011. Colour appearance in urban chromatic studies. *New Directions in Colour Studies.* Biggam, C. P., C. A. Hough, C. J. Kay, and D. R. Simmons (Eds.) Amsterdam, Philadelphia: John Benjamins Publishing Company, 181–189.

Conan, M. 1989. Bras dessus, bras dessous: le peintre, la ville et l'architecte. *Villes-paysages: couleurs en Lorraine.* Paris: Éditions Pierre Mardaga/Batigère, 207–217.

Éloge de la couleur. 2017. Catalogue. An exhibition on the occasion of the 40th anniversary of the Centre Pompidou. Roubaix: La Piscine – Musée d'art et d'industrie André Diligent.

Schindler, V. M. 2012. 'Polychrome Environments' at the Centre Pompidou in Paris: The Work of France and Michel Cler, Architect–Colour Consultants. *Óbuda University e-Bulletin* 3(1): 325–337.

Schindler, V. M., and Y. A. Griber. 2021. The philosophy of colour in the French period of environmental

colour design. *The International Scientific Conference of the Color Society of Russia: Selected Papers*. With an Appendix Books on Colour. Y. A. Griber, and V. M. Schindler (Eds.) Smolensk: Smolensk State University Press. http://color-lab.org/files/283/bop_rucolor2020_with0.pdf
Lassus, B. 1989. *Villes-Paysages, couleurs en Lorraine*. Paris: Éditions Pierre Mardaga/Batigère.
Le jardin monde de Bernard Lassus. 2017. Paris: Éditions du Centre Pompidou.
Lenclos, J.-P. 1989. *The Geography of Color*. Tokyo: San'ei Shobo Publishing Co.
Lenclos, J.-P. 2017. *Jean-Philippe Lenclos: Painter and Designer*. Jinan: Shandong Fine Arts Publishing House.
Lenclos, J.-P. 2021a. Living in Colour. Proceedings of the International Colour Association (AIC) Conference 2021. Milan: AIC, 105–116.
Lenclos, J.-P. 2021b. *A Life in Colour*. https://www.jeanphilippelenclos.uk/en/supergraphics

Carrazedo: colours and stories of a transient landscape

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Abstract

The starting point for this research was a concern with how the image of the rural landscape is shaped and risks being impoverished by current architectural reconstruction. Colours, memories, new architectural values, and forgetfulness were all found to be aspects of the image of a place during the search for the architectural use of colour in the schist village of Carrazedo (Northeast, Portugal). This revealed above all, the complexity and transience of the landscape and of its image, contributed to the enrichment of local memory and enhanced the possibilities for the image of the place.

Keywords: *landscape; colour; narrative of a place; cultural heritage; Portugal*

Introduction: Image of a Place – Idealization and Preservation, Memory, and Recognition

The search for identity images and local singularities originates from the emergence of tourism and the consolidation of the concept of landscape associated with it (Conte, 2019; Gianni & d'Angelo, 1999). In some rural areas, especially in Europe (Renaud, 2016), such demand has, in the constructions and recoveries of the built heritage, been reinforcing architectural features that are based on an idealization of the place which are often unaccompanied by credible discourses on the reproduction of vernacular techniques. Thus, such constructions shape an image for the place which gradually comes to be recognized by the community in general.

A concern for the preservation of the place image's complexity and its link with the different layers of its history led us to the following question: how to bring to light landscape features which are disappearing due to the lack of thought about the conceptual origin of the image that is being promoted. This in turn obliterates both the recent history of the place, as well as other constructive and imaginary possibilities that are devalued and forgotten, as current techniques erase their traces. Carrazedo, a village in the northeast of Portugal, epitomises this question, and served as a case study for reflection about the use of colour in architecture and its relation with the landscape.

Case Study: The Colours of Carrazedo

Carrazedo is a village located in Serra da Nogueira, Bragança (Trás-os-Montes, Portugal) and currently has thirty inhabitants. Nestling in a valley, the houses stand out among the green of the rural landscape which consists of vegetable gardens, natural pasturelands, oaks, holm oaks, chestnut trees and (some abandoned) vineyards, olive groves and wheat or rye fields which are also components of an ancient agricultural mosaic of subsistence. There are still villagers who remember thatched roofs being replaced by clay tiles in the last century. Whitewashed plaster was the colour of the façades, while, most of the time, shale was left uncovered on the other walls for economic reasons. The palette of other architectural colours, still today almost exclusively found in the wooden balconies, doors, and windows, was largely restricted to chestnut until the middle of the 20th century, at which point the market began to provide a wider range of colours.

After a period of severe decline in the village, which began in the 1970s, with the rural exodus and consequent deterioration of buildings, the last decade brought an unexpected wave of rehabilitation, mainly by descendants who are restoring their heritage for second homes and tourism. Although Carrazedo has never been included in safeguarding or protection plans the owners, tainted by certain prejudices and city culture, share an ideal and somewhat distorted primordial image which aesthetically guides their reconstruction work and attempt to reconcile old houses with contemporary comfort. Thus, here, as in neighbouring villages, the "truth to materials" is being promoted (clearly influenced by Ruskin's thought, 1849) and the propaganda implemented during the Estado Novo (1933-1973) is unconsciously perpetuated. This created a fake imaginary asymmetry of the North of the country as using only natural stone and the South only white lime, in an exaltation of simplicity and architectural humility (Gil, 2009). As a result, the traditional white lime plasters that protected the facades here and gave a unique quality of thermal regulation to the houses, have (ironically) been progressively removed and the joints of the stones covered with cement-based mortars. Today, very few façades have this plastering; one window dating from 1737 stands out from the others for its antiquity (in a building in poor condition), as does the church (not even the priest's house resisted the anti-whitewash fashion for plastering). Colourful doors and windows have also been replaced by others that are more watertight, some in varnished wood (gaining gloss and chromatic stabilization), but the predominant material is PVC in static white, brown or red. This scenario covers houses, main and side streets in similar tones, year after year. Faced with the impracticality of reversing the built environment or influencing protection measures that would be anachronistic with advances in technology, working with other aspects of the image of the places, given its poly dimensionality (Ávila, 2008), is now becoming even more significant.

It is, therefore, important to mention the chromatic records and interviews carried out in 2008 as part of an artistic work around memory, colours, landscape, and village people's life history entitled "Reliquaries and other promises". Doors and windows, as the prominent chromatic element in houses (already in the process of disappearing in 2008) were the articulating object of the material and immaterial research. In terms of material research, colours painted on wood left abandoned in the 1970s have been exhaustively recorded with macro photography (a chromatic coded identification system made no sense, as colours were too altered). As regards immaterial research, taking the symbolic role of doors and windows as places of transition and contemplation of the landscape, these frames were the starting point for interviews (in situ) with ex-inhabitants and inhabitants with similar ages to the former when they left the village full of aspirations during the rural exodus. Respondents were asked to remember the colour of their doors and windows, and the view through them in the past, but also to describe the view of their home in the present and a projection of it in the future.

Green – The Collective Memory

The views from the windows of the interviewees who left inevitably opened to other landscapes. Their testimonies conveyed a detachment and understanding of a changed "land" in 2008, which is no longer the land of their memories or dreams. Their imagined window views for the future also revealed aspirations for other places. Accordingly, old colours recorded in 2008, which evinced the temporality and the dépaysement of those who were gone, no longer exist in 2020. A wooden door painted in green and another in blue, the last known as "the only painted door in the village", establish the relationship between the current reality and the records from 2008. Interviews (from 2008 and 2020) confirm that wooden painted colours of regular elements are not considered important by owners (inhabitants or ex-inhabitants) and are deprecated for their low durability, high cost and maintenance compared with PVC ones. Less importance is also given to the lime plaster because it hides the stone's nobility and is high maintenance. The landscape, although modified by a reduction in certain agricultural uses, remains green, the colour shared by the collective memory.

Extracts from interviews: "In the distance I see a forest, a hill, I see few houses. One or two, in front. A chapel. The landscape. Oaks, meadows, green as kitchen gardens, as trees. Below, I see houses. Inhabited and not inhabited" (inhabitant); "I don't have time to look from the window. So when I am at home I am working or sleeping, and the time I spend at home is outside in the kitchen garden. I have an apartment where I spend the weekends (...) In that apartment I have a view over Aveiro (...) In front of me I can see the sky" (ex-inhabitant); "My window I imagine it... I have no idea, I don't even think about it, but I would like to have a balcony in front of the sea. But I doubt it..." (ex- inhabitant).

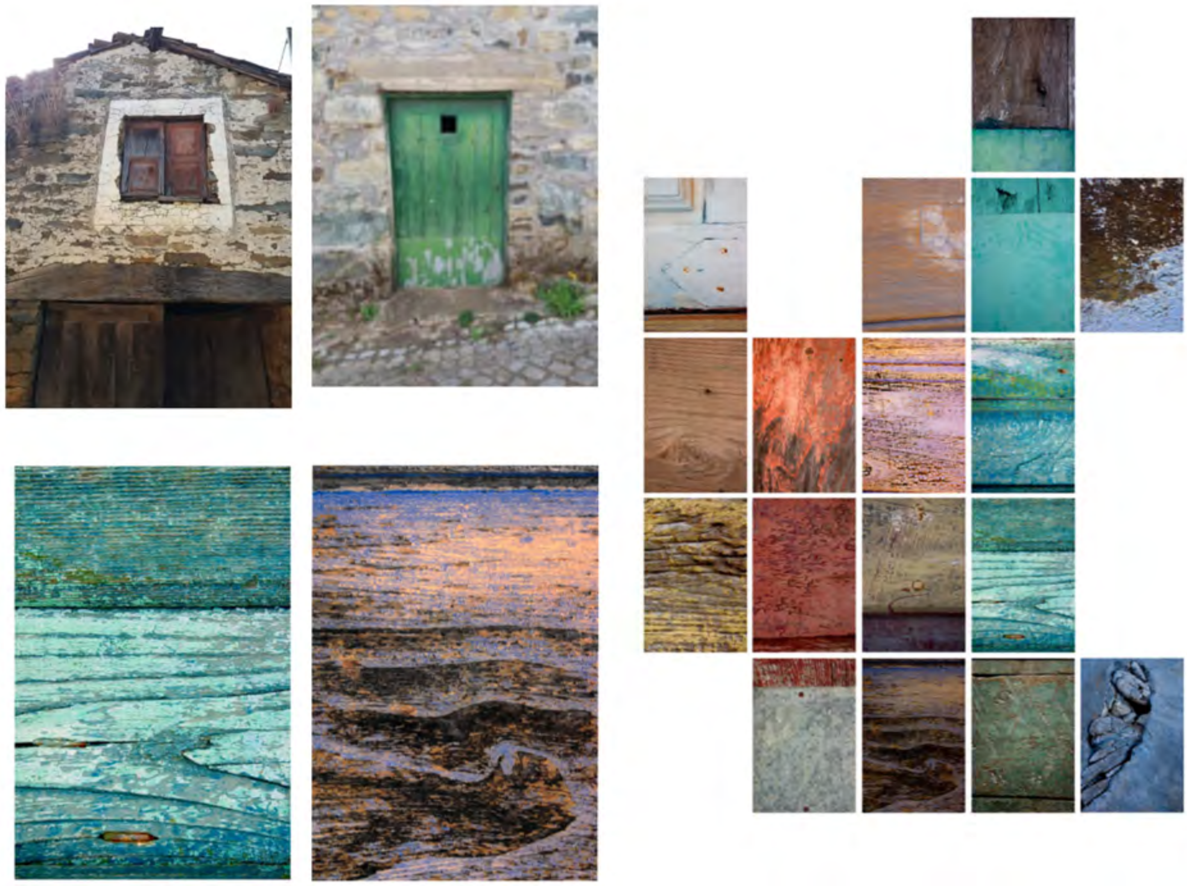

Figure 1. The window in the façade with the inscription "1737"; The green door; Other Images: Colours of Carrazedo by "Reliquaries and other promises" (2008).

Reflection: Colour as an indicator of our relationship with the landscape

The record carried out in 2008 became the only testimony and memory of colours which enabled identity distinctions between façades. It constitutes a working basis for a colour rescue for certain architectural elements (although unlikely, since it was not stated as valuable). Although this use of colour goes back only to the second half of the last century, and paintings were not even organic, I need to praise it, similarly to what Tanizaki (2008) did to shade, recognizing in it characteristics with which he defined his identity. I remember the colours of "Reliquaries and other promises" with the same vivacity with which I listened to the alternating irrigation water crossing the streets, the murmur of people working on the balconies, or the same melancholy with which I waited for the tolling of the Trinity bell, the cattle filling the streets as they return home, or those weary farmers who, not knowing how to think about landscape, understood and built it in a balanced way (Berque, 2009). I see in the use of colours painted on wood, as in lime, not only part of yesterday's poetic imagery, but also essential qualities for appreciating the landscape. Due to their materiality, they form a subtle transition between the interior space of the house and the exterior street or landscape. By their ability to age, muddy, get dirty, worn, react to humidity, heat, and rain, by their organic behavior they are more in tune with the changing seasons and rural life. The colours of lime and painted wood, like the cultivated field, require maintenance, cyclical care, presence, and a commitment to the place that is very different from that of a visitor.

This organic quality of paint, like the melancholy of colours derived from the abandonment existing in the palette of "Reliquaries and other promises" or the stativity of the current crystallized PVC colours (which materialize so well the museum villages) are all different features of architecture that illustrate different phases of the place and landscape studied, and express a relationship of the inhabitants with their landscape. We have no answer to the question raised at the beginning of the research, other than the research result itself, but we have another question. Returning to tourism, can tourism, instead of an observational relationship with landscape, promote a symbolic translation of the characteristics of the places and narratives that help us to (re) establish a closer relationship with the land and landscape, imagining and building it with an awareness of the complexity and attunement with its inherent need to be nurtured? Can colour, or its absence, trigger an awakening to the understanding of these subtleties?

Acknowledgements

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References

Berque, A. 2009. *El pensamiento paisajero*. Madrid: Editorial Biblioteca Nueva.

Conte, V. 2019. Colour and art shaping contemporary landscape dimensions. In *AIC 2019 Color and Landscape, Proceedings of the Midterm Meeting of the International Colour Association*, Buenos Aires: University of Belgrano, 417-421.

Dicionário de Estética. 1999. Carchia Gianni and Paolo d'Angelo (dir). Lisbon: Edições 70.

Gil, M. 2009. A Conservação e Restauro da pintura mural nas fachadas alentejanas: estudo científico dos materiais e tecnologias antigas da cor (Tese de doutoramento). Almada: Universidade Nova de Lisboa, Faculdade de Ciências e Tecnologia.

Tanizaki, J. 2008. *Elogio da Sombra*. Lisboa: Relógio D'Água.

Vuignier, R. 2016. Place marketing and place branding: A systematic (and tentatively exhaustive) literature review. Working Paper IDHEAP, University of Lausanne, Switzerland, [available at https://hal.archives-ouvertes.fr/hal-01340352/document].

Session 5
Colour Education - I

Josef Albers's Chromatic Perspectivism

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Abstract

This paper proposes a new path of approach to the influential colour praxis of Josef Albers, one that puts his Bauhaus-inflected pedagogy into relation with the "perspectivism" that Eduardo Viveiros de Castro identifies as a defining feature of Indigenous phenomenologies of the Americas. I simultaneously complement and complicate existing, architectural readings of Albers's artworks that connect the ambivalent volumes Figured by Tenayuca (1942-43) and related studies with archaeological sites that the artist obsessively documented on visits to Mexico undertaken with his spouse, the artist Anni Albers. I extend the recent scholarship of Joaquín Barriendos on Josef Albers's engagements with Mesoamerican architectonics as generating a "chromatic condensation of a pre-Columbian abstract visual concept." But in lieu of Barriendos's portrait of Albers as a "mystical architect of vision," I apply de Viveiros Castro's theorization of Indigenous perspectivism to propose a materialist reading of Albers's chromatic investigations, one that simultaneously recognizes Indigenous peoples as co-creators of the insights conventionally attributed exclusively to Albers.

Keywords: *Josef Albers, Interaction of Color, Perspectivism, Indigenous phenomenology, colour theory*

Introduction

Since its initial printing as a limited, boxed edition in 1963, Josef Albers's *Interaction of Color* (Fig. 1) has been a touchstone for studio-based introductions to colour research and practice. The artist's exploration of colour interaction in his iconic series *Homage to the Square* (1950-1976), in turn, constitutes a distinctive contribution to modernist abstraction. James Oles, Kiki Gilderhus and Lauren Hinkson have independently argued that Albers's exposure to pre contact Indigenous architecture and architectural ornament on travels to Latin America with his spouse, the artist Anni Albers, was formative of his subsequent artistic production and pedagogical interests (see Oles 1993; Gilderhus 2007; Hinkson 2017).

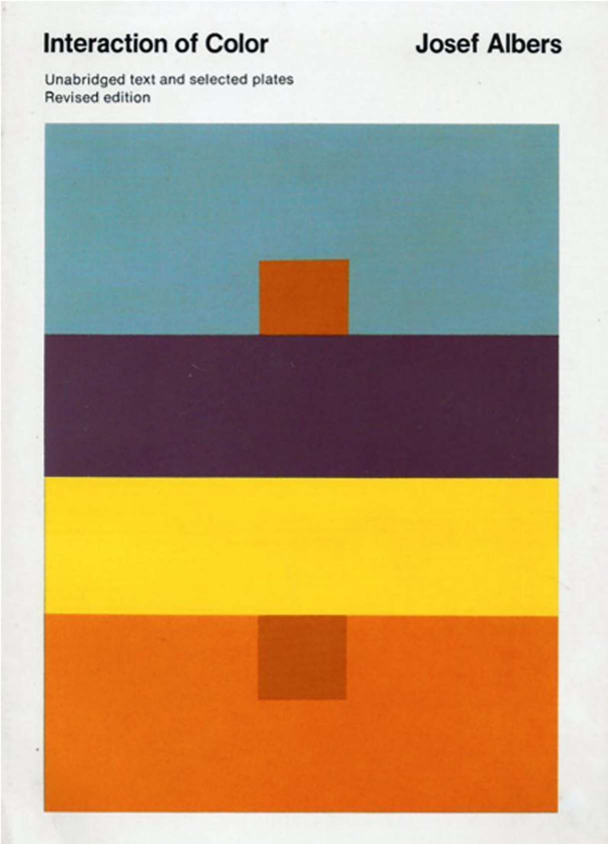

Figure 1. Joseph Albers, *Interaction of Color*, cover.

While generating valuable insights into Albers's art, this line of inquiry is limited by its architectural bias, which looks to "formal transpositions of Mesoamerican pyramid architecture" (Barriendos 2017: 34) recognizable in the contours of Albers's gestalt-like volumes, whose deceptive spatial cues deliberately frustrate perceptual resolution. As Barriendos has rightly objected, the linear and volumetric focus of these studies has the unfortunate effect of "detaching shape from color" (36), whereas Albers's own holistic discourse emphasizes the material inseparability of colour from the other components of visual expression.

Without abandoning the architectural referent mined by previous scholars attentive to the pre-Columbian inflection of Albers abstractions, Barriendos refocuses this line of research on to the metaphysical meanings unfolded by one architectural motif in particular, the *xicalcoliuhqui*, or step-fret. This polysemous and variable figure collapses several elements—stairs, spiral, hook, (pyramid) centre, and column—into a single, symbolically charged form. Barriendos argues that the *Homages* orchestrate an abstract montage of the component parts of the step-fret, thereby generating a "single chromatic superposition" (2017: 43). And yet, colour notably remains ancillary to line and volume in Barriendos's reading of the *Homages*; something merely "appli[ed]" (2020) to the primary vehicle of Albers's perceptual investigations, the architecturally-derived *xicalcoliuhqui*. While acknowledging the novel interpretive pathways opened up by Barriendos's complication of previous approaches to Albers's work in drawing attention to its Prehispanic sources, I want to look beyond the enduring architectural horizon of his analysis and its speculative metaphysics, which amplifies Jean Charlot's fanciful reading of Albers's *Homages* as encoding "a mummy's outlook from the burial chamber" (1956: 196). As an explanatory framework for Albers's engagements with the relationality of Indigenous phenomenologies of colour, architecture alone is inadequate.

Jennifer Reynolds-Kaye (2017) has relatedly studied the collection of pre-Columbian cultural belongings assembled by the Alberses as a decisive influence on the respective creative practices of Anni (textiles) and Josef (painting). In Reynolds-Kaye's perceptive analysis of the creative principles that the Alberses derived from their long standing exploration of Prehispanic culture, the step-fret motif instantiates Anni and Josef's mutual preoccupation with "the fallibility of perception" (2017: 59). In particular, Reynolds-Kaye observes that this Figure, in which "the background can be read as the foreground, and vice versa," embodies the phenomenon of contour rivalry: "the facility of line to express two things simultaneously" (59). Reynolds-Kaye proceeds to draw an illuminating analogy between the linear oscillation unfolded by the step-fret and Josef Albers's experimental ambition in *Interaction of Color* "to make one and the same color look different" (1975: 8). Reynolds-Kaye thereby triangulates the "unreliability of vision" (2017: 59) expressed by the formal instability of the step-fret with the deceptive relativity of colour explored by Albers.

I want to propose that Viveiros de Castro's theorization of Indigenous perspectivism extends Reynolds-Kaye's insights into the "contingency of perception" (2017: 60) associated with the step-fret into a phenomenological framework applicable to architectural and woven contexts alike; one that, moreover, contextualizes the "multiple perspectives" (Barriendos 2017: 40) superposed by Albers's *Homage to the Square* and related series relative to an Indigenous worldview of "relational sometimes" (Descola 2005: 25). Albers's engagement with Indigenous practices of reciprocal visuality was no mere application of a pre-existing motif; but, rather, an adaptive reuse of a cultural a priori.

Perspectivism

What is perspectivism? In brief, Viveiros de Castro proposes that "virtually all peoples of the New World share a conception of the world as composed of a multiplicity of points of view" (2014: 55). Not reducible to Western notions of relativism, this multiplicity of perspectives materializes an "immanent humanity" (53) common to human and nonhuman (as well as more-than-human) persons. As anthropologist Philippe Descola explains, this worldview results in "a single ontological class," of which all members are equally recognized as "'people'"

(2005: 24). The resulting condition of "multinaturalism," as Viveiros de Castro terms it, "presupposes … a unity of mind and a diversity of bodies" (2014: 56), the exact inverse of European relativisms that posit a diversity of mentalities as the correlate of embodied difference. Viveiros de Castro clarifies that, "all beings see ('represent') the world in the *same* manner – what changes is the *world* that they see" (2005: 53). Thus, hunter and jaguar *see* their respective worlds from a perspective of reciprocal but mutually exclusive personhood; the jaguar looking upon the hunter as non-human, all the while perceiving the sociality of their own proper habitat as an anthropomorphic "village" (2005: 38).

Viveiros de Castro's theorization of perspectivism is consistent with Nicholas J. Saunders's description of the cultural significance of colour and light in Indigenous societies as embedded in a shamanic worldview premised upon the transformational capacity of "'seeing' and perceiving" (2002: 213). Saunders posits a "pan-American 'aesthetic of brilliance'" (209) in which radiance is associated with the "mirror-image realms inhabited by luminous spirit-beings" (213) accessible via shamanic visions. This framework is consistent with the transformational ontology of perspectivism, in which, Descola writes, "everyone can undergo a metamorphosis in certain circumstances" (2005: 24). Saunders outlines the chromatic correlative of this metamorphic metaphysics: an Indigenous semiosis of immanent alterity whose sensible manifestation is shimmering iridescence.

Albers's Chromatic Perspectivism

Viveiros de Castro's description of the perspectivism ubiquitous among Indigenous societies of the Americas emerges as a compelling alternative framework for reading the reversible, superimposed perspectives characteristic of Albers's later art, as well as the chromatic relationality enacted by the didactic plates and exercises of *Interaction of Color*, as manifesting an Indigenous economy of generalized alterity. Rather than the dynamics of ascent/descent through a symbolic architectonics proposed by Barriendos, the application of perspectivism to the study of Albers's art suggests new insights into his dynamic, contextual, and deceptive phenomenology of colour, that is, the artist's fascination with "making … 2 very different colors look alike" (1975: 1) through contextual mediation.

When approached through the lens of Indigenous perspectivism, the "toggling effect" generated by Albers's use of colour noted by Reynolds-Kaye (2017: 60) is contextualized within the Alberses's investigations of Indigenous aesthetics as an expression of Indigenous peoples' "resolutely non-dualist vision of the world" (Descola 2005: 24). Strongly reminiscent of the contingent corporeality of Indigenous perspectivism—in which the appearance of human, non-human, and more-than-human persons is always relative and situated—the conditional value of colour in Albers's sensorial pedagogy and paintings is resolutely context-dependent.

As Lauren Hinkson has noted, the Alberses "aimed to revitalize pre-Columbian traditions with their own modernist art" (2017: 15). The perspectivist reading proposed here is, however, in no way intended to imply that the signature relationality of Josef Albers's approach to colour was derived from anthropological theory—something that both Josef and Anni Albers notoriously eschewed in favour of the discoveries revealed by sensuous experience (see Hinkson 2017: 19; Reynolds-Kaye 2017: 32). In any case, Viveiros de Castro's earliest work on perspectivism dates from more than a decade following Josef Albers's death. Rather, Albers would have intuited the phenomenological a priori of Indigenous perspectivism from his intensive, hands-on engagement with Prehispanic cultural belongings.

Conclusion

The radical anthropology of Viveiros de Castro opens the door to a recognition of Albers's relational colour praxis as a "coproduc[tion]" (2014: 41) with the Indigenous artists that inspired his chromatic investigations. In fact, Albers openly professed a personal identification with the Figure of the pre-Columbian craftsman as well as the cultural belongings that they produced, as both Barriendos and Reynolds-Kaye have observed. But whereas Barriendos discusses the Prehispanic craftsman as Albers's "spiritual comrade" (2017: 34), Reynolds-Kaye emphasizes the staunch anti-Primitivism of the modernist artist's approach to Indigenous conventions of relational seeing as a form of material practice. Albers, Reynolds-Kaye persuasively contends, identified with Indigenous artisans because they "were similarly concerned with issues of materials, quality, and design" (2017: 69). It was the enduring contemporaneity of Prehispanic practices of seeing that synchronized Albers's engagement with Indigenous perspectivism with a larger network of scientific investigations into colour phenomena—Gestalt, neurological, etc.—recently retraced by Vanja Malloy (2015).

References

Albers, J. 1975. *Interaction of Color*, rev. ed. New Haven: Yale University Press.

___. Truthfulness in Art. In Josef Albers in Mexico. New York: Guggenheim Museum Publications.

Barriendos, J. 2017. Devouring Squares: Josef Albers in the Center of the Pyramid. In *Josef Albers in Mexico.* New York: Guggenheim Museum Publications, 34-47.

___. 2020. Josef Albers and the Pre-Columbian Artisan. *bauhaus imaginista*, no. 2: https://www.bauhaus-imaginista.org/ARTICLES/6263/JOSEF-ALBERS-AND-THE-PRE-COLUMBIAN-ARTISAN.

Charlot, J. 1956. Nature and the Art of Josef Albers. *College Art Journal* 15, no. 3: 190-196.

Descola, P. 2005. Ecology as Cosmological Analysis. In *The Land Within: Indigenous Territory and the Perception of Environment*, Alexandre Surrallés and Pedro García Hierro, eds. Copenhagen: IWGIA, 22-35.

Gilderhus, K. 2007. Homage to the Pyramid: The Mesoamerican Photocollages of Josef Albers. In *Anni and Josef Albers: Latin American Journeys*, Brenda Danilowitz and Heinz Liesbrock, eds.

Ostfildern, DE: Hatje Cantz.
Hinkson, L. "Ruins in Reverse: Josef Albers in Mexico." In *Josef Albers in Mexico*. New York: Guggenheim Museum Publications, 14-33
Malloy, V. 2015. Introduction. In *Intersecting Colors: Josef Albers and His Contemporaries*, Vanja Malloy, ed. Amherst: Amherst College Press, 1-10.
Oles, J. 1993. *South of the Border: Mexico in the American Imagination*, 1914-1947. Washington, DC: Smithsonian Institution Press.
Reynolds-Kaye, J. 2017. Making Mesoamerica Modern: Anni and Josef Albers as Collectors of Ancient American Art. In *Small-Great Objects: Anni and Josef Albers in the Americas*. New Haven: Yale University Art Gallery, 25-72.
Saunders, N.J. 2002. The Colours of Light: Materiality and Chromatic Cultures of the Americas. In *Colouring the Past: The Significance of Colour in Archaeological Research*, Andrew Jones and Gavin MacGregor, eds. Oxford; New York: Berg, 209-226.
Viveiros de Castro, E. 2005. Perspectivism and Multiculturalism in Indigenous America. In *The Land Within: Indigenous Territory and the Perception of Environment*, Alexandre Surrallés and Pedro García Hierro, eds. Copenhagen: IWGIA, 36-74.
___. 2014. *Cannibal Metaphysics: For a Post-Structural Anthropology*, Peter Skafish, trans. Minneapolis, MN: Univocal.

Colour Connections in the Work of Fritz Seitz

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Abstract

This paper refers to the work of the late Fritz Seitz (1926–2017), artist, professor, colour scholar, graphic designer, author, and consultant. He is considered one of the most important representatives of the Deutsche Farbenzentrum (German Colour Association) from the 1960s to the early 2000s. This paper addresses ongoing research investigations of Fritz Seitz's approach to colour. It attempts to shed light on his fine art and applied art, his writings and lectures, his teaching, and how he has dealt with the phenomenon of colour.

Keywords: *Colour Education; Colour Application*

Introduction

This paper borrows its title from an exhibition introducing the work of the late Fritz Seitz (1926–2017), artist, professor, colour scholar, graphic designer, author, and consultant. He is considered one of the most important representatives of the Deutsche Farbenzentrum (German Colour Association) from the 1960s to the early 2000s. Seitz left behind an oeuvre divided into the four thematic areas of Chronolog, a visual diary, Teaching, Writings, and Works. The Willi Baumeister Foundation (WBS) in Stuttgart, Germany, preserved most of his artistic estate. Stuttgart, the greater area, and the State Art Academy of Fine Arts with its professors Adolf Hoelzel (1853-1934) and Willi Baumeister (1889–1955) form the context in which his lifelong investigations are rooted.

Fritz Seitz Exhibitions

The show "Fritz Seitz Colour-Connections" ("Fritz Seitz Farbvernetzungen"), from May 1 to August 1, 2021, at the Weissenhofwerkstatt in the Mies van der Rohe House at the historic Weissenhof Estate in Stuttgart was the inaugural display of the broad spectrum of Seitz's work. (Figures 1 + 2). The concept focused 'on colour,' connecting all his subject areas, Chronolog – Teaching – Writings – Works, and inspired the collaboration. Curated by Esther Hagenlocher, University of Oregon (UO), and Hadwig Goez, the Archive Baumeister at the Kunstmuseum Stuttgart (AB in the KM) and the WBS, and 'on colour at the Weissenhof' by Anja Kraemer, Director Weissenhofmuseum in the Le Corbusier House, and the Friends of the Weissenhof. The show's content and proximity to the State Art Academy of Fine Arts in Stuttgart addressed the larger public to discuss cross-cultural exchanges in experiential colour culture.

The solo show on Fritz Seitz's work accompanied the exhibition on Willi Baumeister, "Comb, Pastel and Buttermilk. Willi Baumeister, Adolf Hoelzel, and Fritz Seitz," at the Kunstmuseum Stuttgart, November 2020 - September 2021. Curated by Hadwig Goetz in collaboration with others[1]. On' Seitz's colour' with Esther Hagenlocher. Introducing unshown pastel drawings and studies from his "Entwurfslehre Farbe" ("The teaching of colour"), developed for nearly forty years, illustrated his hands-on approach to colour and his perfection in the material, craft, and technique.

Tracing the academic lineage of Hoelzel – Baumeister – Seitz, as Goetz writes in the brochure catalog, "Baumeisters rarely presented pastel drawings entered a dialogue with works by his teacher Adolf Hoelzel and by his student Fritz Seitz."

Complementing the shows, Hagenlocher and WBS initiated and developed the bilingual webpage (fritz-seitz.org) to attract and strive for international research and collaborations.

Anyone who wants to get to know Fritz Seitz learns about colour. Furthermore, talking about colour inevitably leads to Adolf Hoelzel. Willi Baumeister, an important painter of classical modernism in post-war Germany, studied with Hoelzel and held a chair at the State Academy of Fine Arts in Stuttgart. Baumeister's name also became a byword for leading graphic design, notably through his work for the Weissenhof Estate Exhibition in 1927.

Research project and goals

This paper addresses ongoing research investigations of Fritz Seitz's approach to colour. It attempts to shed light on his fine art and applied art, his writings and lectures, his teaching in how he has dealt with the phenomenon of colour. What is the unique and distinguishing characteristic of Fritz Seitz's work on colour?

Two steps will approach the search for this singularity in Seitz's oeuvre:

- To what extent does his approach resemble that of Adolf Hoelzel? Regarding content, Seitz's and Hoelzel's teaching show similarities, although Seitz never referred to the latter. The research traces the versatile approaches of both artists. The question arises given the widespread perception Johannes Itten, and Oskar Schlemmer carried on Hoelzel's teaching at the Bauhaus, constituting something like the "origin of the Vorkurs (foundation course)," comprising the origin of this course. Both Hoelzel and Baumeister play significant roles in developing foundation courses; their interpretations have set standards yet are less known.
- Did Seitz bring a thoroughly renewed path to colour education in the arts and allied arts (design, architecture, and interior architecture), and did it lead us to a more approachable path to colour?

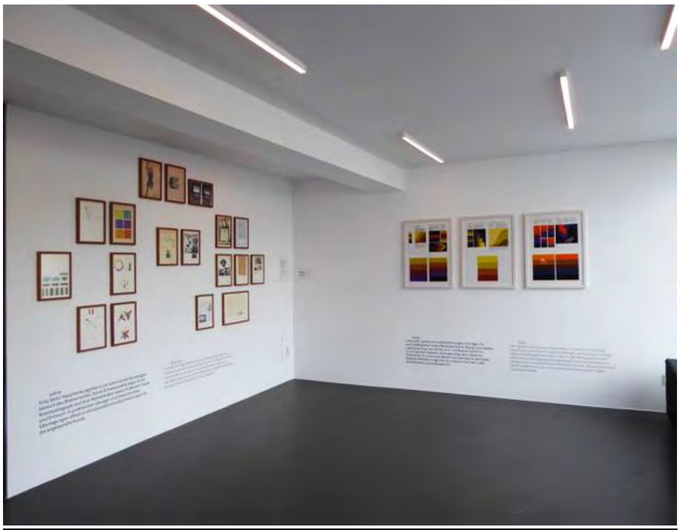


Figure 1 + 2. “Fritz Seitz Colour-Connections” at the Weissenhofwerkstatt, Stuttgart, Germany. PC: Ralph Fischer, Association member Friends of the Weissenhofsiedlung e.V.

Fritz Seitz Professor, Scholar, Author and Artist, and Consultant

Fritz Seitz belonged to the inner circle of successful Baumeister students, and, after years of working as a freelance graphic designer in Stuttgart (1950-1965), he was appointed professor of "foundation courses" at the Academy of Fine Arts Hamburg (1965-1992). Seitz dealt extensively with models for integrating foundation teaching into the four-year course of study, as he says, "to constantly support and deepen the activity in the specialized classes and departments with basic studies 'from the side.'" Colour was an integral part.

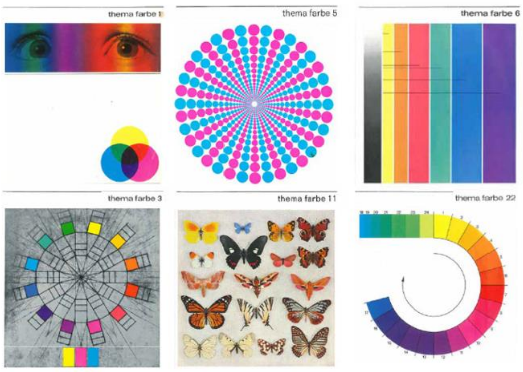
Speaking about Seitz's works, one is tempted to follow the conceptuality of the theories; however, his works do not represent writing about others, nor are they theories set into visual communication, but rather the dissolution of the boundaries between fine and applied art.

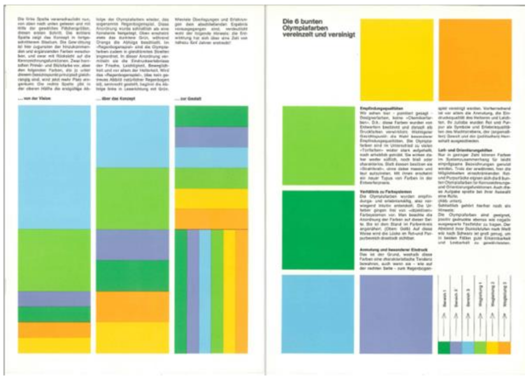
Andreas Schwarz elaborates on Seitz's expertise, in his essay on the historical development of colour contrasts (Field – Hoelzel – Itten) by introducing twelve colour contrasts. By drawing parallels between the works of the designer and the artists, Seitz demonstrated them in written and visually, i.e., suitable for warning and rescue services (aviation, seafaring, high-altitude mountaineering) or safety in the workplace, calling for attention; or international understanding system of the letter flags meaning. Yet, despite the practical everyday applications, Seitz elaborates on the pros and cons: "What speaks for the knowledge of colour contrasts is that they help us foresee and intentionally create colour effects. Their representation is universally valid and is available for every tendency of design. (...) Solid knowledge and foresight can easily lead to putting sensitivity (the sensitivity to differences) to sleep. The danger is apparent in observing the colour contrasts as "regularities" in isolation and roughly schematizing them.”

Is Seitz's work a continuation of Hoelzel's approach? Seitz did not participate directly in the continuation of Hoelzel. Nevertheless, he understood its developmental significance and drew his conclusions, concluding in a lecture at the Stuttgart Academy, 1981: “Please listen: it began in 1906 when the painter Adolf Hoelzel was appointed to your academy. Starting from here, a lot has changed in university teaching in fine arts. At that time, the teaching part, which connected the work of the specialized classes, was placed mainly in the plaster room and the figure studies room. In addition, there were nature studies, for which one had some in cupboards. Thus, the beginning was made, and a foundation was laid. With Hoelzel, this became different. (...) That happened here in Stuttgart from 1906 to 1919.”

How much did Hoelzel's preliminary work contribute to the importance of the Bauhaus needs to be explored further? Seitz continued, “But there is another student of Hoelzel, who later, in 1953, taught here at Weissenhof: Willi Baumeister. What with Johannes Itten was the formal penetration of the colour theme; with Baumeister, it was the penetration of the form theme, summarized in his ‘elementary exercises.’ But even with him, it did not remain formal. Today, almost 30 of Baumeister's students are now teachers at universities. One of them is trying to address you today, who has also dedicated himself to work on teaching foundation courses. ”In addition to his pedagogical skills, Fritz Seitz developed samples of his practical work, which also prepared his students for a broader activity putting colour studies in theoretical, practical and cultural contexts.

Seitz's numerous publications, lectures, and jury activities in visual language, graphic design, and basic design theory have made him well-known in Germany and abroad. He stands out as an exceptional theoretician, researcher, and consultant in the field of colour, primarily on behalf of well-known companies. Seitz's writings reflect an inquiry into the relationship between creative practices, theory, and the larger culture. For example, in the 1973 pamphlet “The Colours of a Great Project" (Figures 3+ 4).He describes the process of the visual design of the 1972 Olympic Games, a design system of several colours, its production, and implementation. “The following is about the visual design of the Olympic Games in Munich. It is about technical matters, about an excerpt, about partial questions. We could, therefore, "get to the point" without further ado if this very thing were not closely connected with those events that later overshadowed the course of the Games. The objective was called: the cheerful games. Thus, the work of the designers was also affected by serious events. However, in retrospect, one cannot separate these colours and their design intention from the events that overshadowed these Olympic games. Therefore, we think that every statement about the Munich Games, and especially every presentation of the design work." Photographs taken during his on-site visit and subsequent hikes in the Alps underline his exploration. Whether unconscious connections or deliberate positions to his site visit a few days before, they mirror the beauty of relationships in his work.





Figures 3 + 4. “Fritz Seitz Writings: Theme Colour. (l) The colors of a Big Project. Olympics Munich, 1972. (right)”

Figures 5 + 6. "Fritz Seitz Works: Pastel Drawings, “Polka,” 2004 (l) and “Schwamm,” 2007 (r)

Conclusions

During his retirement, he created a body of fine artwork built on his earlier work in which the knowledge and understanding of colour are palpable. Fritz Seitz's oeuvre represents an essential contribution to the field of design, applied arts, and art. It attempts to create access colour encompassing many possibilities, areas, and applications. Perhaps there are not many comparable ones. He goes beyond individual systems and theories and gives an all-encompassing background.

The goal of this research is to identify Fritz Seitz's investigations. His investment in colour lay mainly in challenging distinctions between perceived colour, as one finds on a grand scale in his art. He was guided by an inquiry into the implications of colour employed, bringing a rich and varied professional and life experience to his work. Seitz develops the idea of a humanized approach through his practice and applies his path to colour in a new way (e.g., preferred colour; colour contrasts, harmony-disharmony). Moving between theory and practice, teaching and painting, Seitz was a rare example of someone who was both an inspiring professor and a visionary, thoughtful artist, designer, and writer. He was a critical and independent thinker who constantly engaged in learning, challenged conventions, and sought to place the creative act of colour in the broadest context of human and natural phenomena. The research will also provide insights into Seitz's creative process, showing how abstract concepts and ideas are made concrete and take shape in design and art. Seitz developed a then-new generation, turning its commitment to colour by showing the process.

However, the research's interest is not in these methods for their own sake but in how they carry and express a system of values. Seitz has left behind an oeuvre that asks to be further investigated, published in English to make it accessible to a broad audience, and studied for its adaptability and versatility to the social demands of our time.

Acknowledgments:

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References:

Baumann, G. 2019. In Exhibition Catalog: *Von Hoelzel zum Bauhaus.* Galerie Schlichtenmaier Kleiner Schlossplatz. About: Eine Ausstellung zum 100-jährigen Bauhaus Jubiläum, pp. 3–6.

Lingner, M. (Ed.) 2003. Grundfragen zu den Grundlagen. Fritz Seitz und Michael Lingner im Gespräch.

Seitz, F. *Contributions To Research And Teaching*. State Academy of Fine Arts, Stuttgart , 1981, in Lingner Michael (Ed.) 1992. *Kunstvermittlung – Weltverwirklichung. Schnittstellen aesthetischer Erziehung*. Hamburg, Friedrich Forum. Beiträge zur pädagogischen Diskussion., pp.33-34.

Schwarz, A., F. Schmuck, and F. Seitz. 2003. Immer wieder Itten. Neue Ansaetze zum Umgang mit Farbe im Kunstunterricht. Publikation zum Kunstpaedagogischen Tag, Düsseldorf, pp.9+10.

Städtische Museen Freiburg. *In the Laboratory of Modernity. Hoelzel and his Circle. 2017*. Michael Imhof Verlag, Adolf-Hoelzel-Stiftung.

Stankowski, A., and K. Duschek. 1989. *Visuelle Kommunikation. Ein Design-Handbuch*. Berlin: Dietrich Reimer Verlag.

Exploring the origins of Itten's color theories using digital color mapping

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Abstract

Johannes Itten was a leading color theorist and educator of the twentieth century and his influence remains strong decades after his death. At the Bauhaus, Itten was responsible for the introductory Basic Course which included a color component and, after the Bauhaus closed, Itten continued to teach color at various institutions, and he also published several influential texts on color. Attempts have been made to identify the origins and inspirations of Itten's ideas about color and some have suggested that Itten's former painting teacher may have played a role. However, this is debatable and Itten himself referred to five color theorists as providing invaluable inspiration: "For me, the theories of Goethe, Runge, Bezold, Chevreul and Hölzel have been invaluable" (Itten, 1970).

This research applied a new approach to investigate the origins of Itten's color theory ideas within the context of a series of case studies. Using digital color mapping, this study explored patterns of similarity and difference in color collateral published by Itten and one of his key inspirations, Philipp Otto Runge. Outcomes from this research indicate that Runge may have had a stronger influence than previously acknowledged. Further case study research into the other color theorists cited by Itten may provide additional insight.

Keywords: *Johannes Itten, Philipp Otto Runge, color theory, digital color mapping*

Introduction

Johannes Itten (1888-1967), a leading color theorist and educator of the twentieth century, continues to influence color theory and color education nearly sixty years after his death. One of the founding educators at the Bauhaus, Itten was responsible for developing and teaching the introductory Basic course which all students were required to complete before turning to their area of specialized study. Color was a component of this course and Itten's involvement in color theory and color education continued after the closure of the Bauhaus. Specifically, he taught color at the Zurich University of the Arts (1938-1954) and developed color courses for the Ulm School of Design (1955).

In addition, Itten published *The Art of Color: The Subjective Experience and Objective Rationale of Color* (1961), one of several publications that underpin traditional color theory and which continue to influence color education in art and design. In *The Art of Color*, Itten provided multiple ways in which to explore the nuances of color and provided a guide to color relationships relevant to art and applied design including seven types of color contrast.

Since his death, discussion has occurred regarding the sources of inspiration that contributed to the development of Itten's theories of color and his supporting color collateral. Moving beyond this discussion, this study adopted a different approach to investigate Itten's sources of inspiration. Applying digital color mapping in conjunction with a case study, this research identified and analyzed the color data evident in a key example of Itten's color collateral and Philipp Otto Runge's color collateral, one of several color theorists that Itten noted had been invaluable to him.

Research context and aims

The literature on color reveals an ongoing series of color theories dating back centuries which feature conceptual color models and collateral such as hue circles, color charts, diagrams, and the like. Patterns of similarity in respect to conceptualization as well as supporting collateral indicate that some color theorists are influenced by earlier theorists; while others are more unique in terms of their conceptual development and associated color collateral.

In respect to Itten's color theories, discussion has occurred regarding his sources of influence and the theorists that may have inspired the development of his color theories, conceptual color models and associated color collateral. Gage notes Itten as a devoted pupil of Hölzel who incorporated his seven types of contrast into the Bauhaus syllabus (Gage, 1982). Briggs (2013) suggests, "...Itten [still] derived much of his teaching from Hoelzel's (*sic*) theories of colour harmony and contrast, and even appropriated some of Hoelzel's diagrams, including the (hue) circle based on Schopenhauer's rations, which Itten mistakenly thought were Goethe's" (p2). However, Parris suggests that it was primarily Hölzel's *methods* that inspired Itten, and it was these *methods* that Itten adopted and incorporated into the pedagogy of the Bauhaus (Parris, 1979).

Itten himself noted, "For me, the theories of Goethe, Runge, Bezold, Chevreul and Hölzel have been invaluable" (Itten, 1970). While a literature search provides some insight into the origins of Itten's color theories, notably his own declarations, it falls short in providing a definitive explanation.

This lack of clarity about sources of inspiration is relatively common among color theorists. It can be speculated that many color theorists formed their ideas about color during early training, but likely modified them to varying degrees over time in line with their evolving experiences relevant to their context in terms of time, place, praxis, and intellectual milieu. It is noted that few color theorists have clearly articulated the specific sources of their ideological and theoretical influences, and some seem keen to convey the impression that their theories are original and unique. This latter approach likely had benefits for those theorists who monetized their theories in some way, either through patented proprietary color collateral or color systems (such as Munsell) or through their consultancy practice.

Teaching proved to be a key focus and inspirational activity for Itten, who developed creative tasks and challenges for his students which both extended their learning experience and enriched his own ideas about color and design (Raleigh, 1968). Initially trained to become a teacher, Itten notes that he owes his "first educational ideas to the young, forward-looking head of my teachers' training college", Ernst Schneider at Bern-Hofwil Teachers' Academy (Itten, 1963, p6). It was here that Itten adopted the strategy of not criticizing or correcting students' creative output but substituting general discussion as a means of prompting insight instead. Itten decried the practice of celebrating 'star' students "who made the best job of copying their professors" and advocated against the thoughtless copying of Master's work without deeper exploration and critical analysis (Itten, 1963, p6). Itten encouraged students to explore and investigate in a creative and individual manner, and he "recognized *creative automatism* as one of the most important factors of artistic creativity" (Itten, 1963, p7).

In addition to his training as a teacher, Itten enrolled in extramural studies in painting under Adolf Hölzel (1853-1934) at the State Academy of Fine Art in Stuttgart from 1913-1916, where he explored color, composition, abstraction, and the importance of light-dark contrast. Itten notes, "Hölzel's lectures impressed me profoundly with the importance of the study of Old Masters. Knowledge of their working methods is useful. It heightens the awareness of order and disposition in the picture area and the feeling for rhythm and texture" (Itten, 1963, p7). It needs to be noted that Itten says 'study' not copy Old Masters, and he transferred this approach to his own teaching, with a focus on finding multiple solutions for the same artistic or design 'problem'. Itten noted, "each time principles of form, rhythm, or color [are] discussed, I asked my students to analyze relevant masterpieces to make them see how different masters solved a given problem" (Itten, 1963, p7).

According to Itten, Hölzel was not dictatorial or prescriptive in his approach but was receptive to anything that was new, and both Hölzel and Itten championed the notion of multiple solutions to artistic and design problems within an educational context that encouraged individual subjectivity and *creative automatism*. Hölzel's pedagogical approach was not only adopted by Itten, but also became a key characteristic of the Bauhaus pedagogy.

Specifically in respect to the development of his ideas about color, Itten notes, "For me, the theories of Goethe, Runge, Bezold, Chevreul and Hölzel have been invaluable" (Itten, 1970). Given this declaration, it appears that Itten's influences in respect to the development of his theories about color and the development of his color collateral remain relatively broad and it is this issue that underpins the key aim of this study. It is suggested that Itten considered these various theories about color in tandem with his experiences as a teacher and painter, blending with his own ideas about encouraging exploration and individual subjectivity.

A key aim of this research is to explore Itten's declared sources of inspiration about color – Goethe, Runge, Bezold, Chevreul and Hölzel – using a research method that does not involve conjecture or speculation, in tandem with a series of case studies. To address this aim, digital color mapping was applied to identify and evaluate color data evident in Itten's key color theory collateral with color data evident in the key color collateral of theorists mentioned by Itten. Initially, the key color collateral of Philipp Otto Runge (1777-1810) is evaluated in this first case study, to be followed by the other case studies that focus on Goethe, Bezold, Chevreul and Hölzel.

Research methodology

To address the key aim of this research project, environmental color mapping was applied. This research method is often used to identify color characteristics within a given environment and has been applied (either digitally or manually) to identify, document, and evaluate building façade color and signage as well as regional and urban color in England, France, Norway, and Sweden (Angelo & Booker, 2019; Iijima, 1995, 1997; Porter, 1997; Lenclos, 1977).

Digital technology brings benefits in terms of identification and transferability of color data, and the notion of 'environment' has been broadened to include corporate identity design (O'Connor, 2003. 2004, 2006, 2011). While there are some drawbacks to the use of digital technology to identify color data, the identification process has been found to be equivalent and relatively accurate in comparison with the non-digital, manual method. In addition, digital technology allows for the communication as well as archiving of color data across multiple software platforms and applications.

Outcomes from the color mapping process include the identification of color characteristics within a defined environment using an existing color notation system, as well as evaluating patterns of similarity and patterns of difference in respect to the three main attributes of color: hue, tonal value and chroma. The process has been found to be a reliable method for identifying and assessing color characteristics across multiple different types of environments.

In this study, color mapping was applied as an investigative tool to identify and evaluate colors evident in an example of Itten's key color collateral and a key example from one of the color theorists that Itten noted had been invaluable to him, Philipp Otto Runge. The steps involved in conducting this color mapping study are as follows:

1) Desk research was used to locate the most accessible, accurate and largest pixel-size digital images of key color collateral from both Itten and Runge. Care was taken to select images from the most reliable sources to ensure maximum color accuracy of digital images.

2) Images of color collateral were selected on the basis of their capacity to illustrate colors likely intended by both theorists and the final images selected for this study are as follows and are featured in Figure 1:

Itten's color star - Farbenkugel in 7 Lichtstufen und 12 Tönen (Color sphere in 7 light values and 12 tones), 1921. Lithograph. 74.3 x 32.2 cm. Dokumente der Wirklichkeit I/II (Weimar, 1921), fold out from inside cover. The Getty Research Institute, 85-B9544-2.

Runge's color sphere illustration (cross section) – Artist's estate, c1810; Collection, Hamburger Kunsthalle. https://online-sammlung.hamburger-kunsthalle.de/en/objekt/34294/

3) The images were downloaded using the largest file size possible to ensure maximal image accuracy and saved in a secure file location.

4) The images were uploaded to the proprietary software platform Canva. This platform was selected as it is a fast and effective platform that features a highly accurate color picker with the capacity to identify and communicate color data using hex color codes. The hex code system was selected as this specifies color according to red, green and blue components, each of which are represented by eight bits, which translates to 24 bits for the specification of color within the sRGB gamut, resulting in the capacity to specify over 16.7m color nuances. Hex codes can be converted to other common color notation systems including sRGB and NCS.

5) The color data in each color collateral image was identified and documented using hex codes. Specifically, twelve key colors were identified – the outer ring in Runge's illustration and the middle ring in Itten's illustration – as well as variations in tonal value and chroma.

6) Illustrations were created in Canva to feature both Itten's image and Runge's image in tandem with the array of color data identified from each image.

7) The resulting array of color data was examined and patterns of similarity and difference in hue, tonal value and chroma were identified.

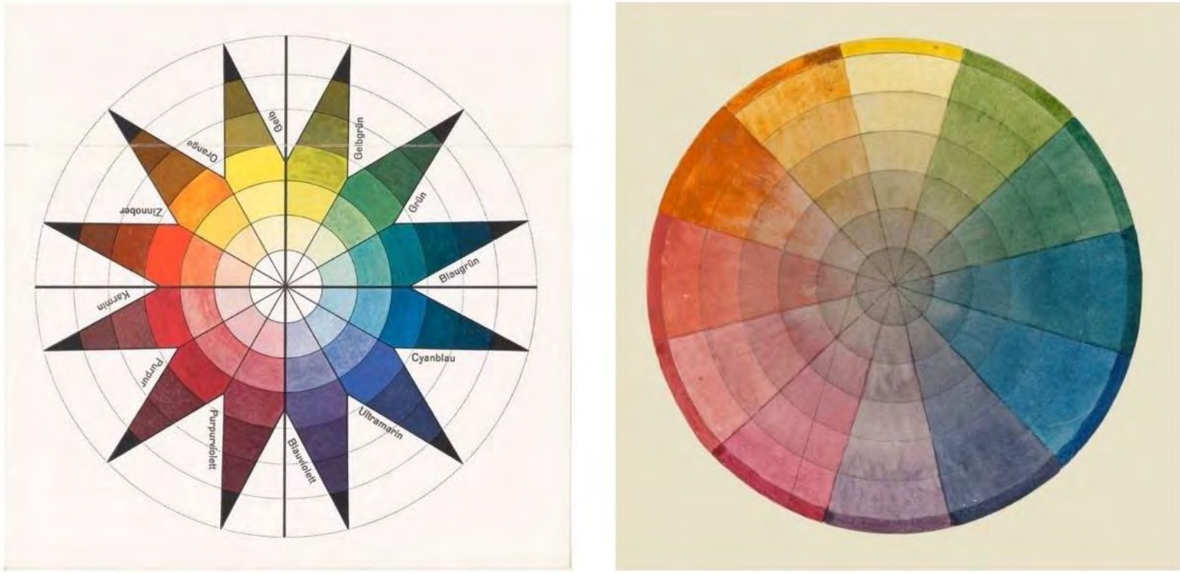

Figure 1. Itten's color star (1921) and Runge's Color sphere cross section (c1810).

Research outcome and discussion

The key aim of this study was to explore Itten's declared sources of inspiration about color – Goethe, Runge, Bezold, Chevreul and Hölzel. Color mapping was selected as the key research method as it provides color data that can be examined and analyzed.

Examination of the results of this preliminary color mapping study are compelling. Specifically, there are strong patterns of color similarity between the twelve key hues as well as their chroma levels identified in Itten's color star (1921) and Runge's color sphere cross section (c1810). In addition, there are also patterns of similarity – albeit not as strong – in respect to the first level (ring) of tonal value variations in both illustrations. Figure 2 features the illustrations of Itten (color star, 1921) and Runge (color sphere cross section, c1810) plus the array of color data identified within each image – specifically, Itten's twelve key hues and first level (ring) of tinted tonal variations (top two rows) and Runge's twelve key hues and first level of tinted tonal variations (bottom two rows).

The relative age and variable nature of digital versions of historical color illustration prohibits a conclusive evaluation of the color data; however, the similarities identified in this study are strong.

While this study does not provide a definitive answer to the specific sources of inspiration that underpinned Itten's color theories, it provides a starting point for a different perspective and an interesting basis that relies on data rather than speculation or conjecture.

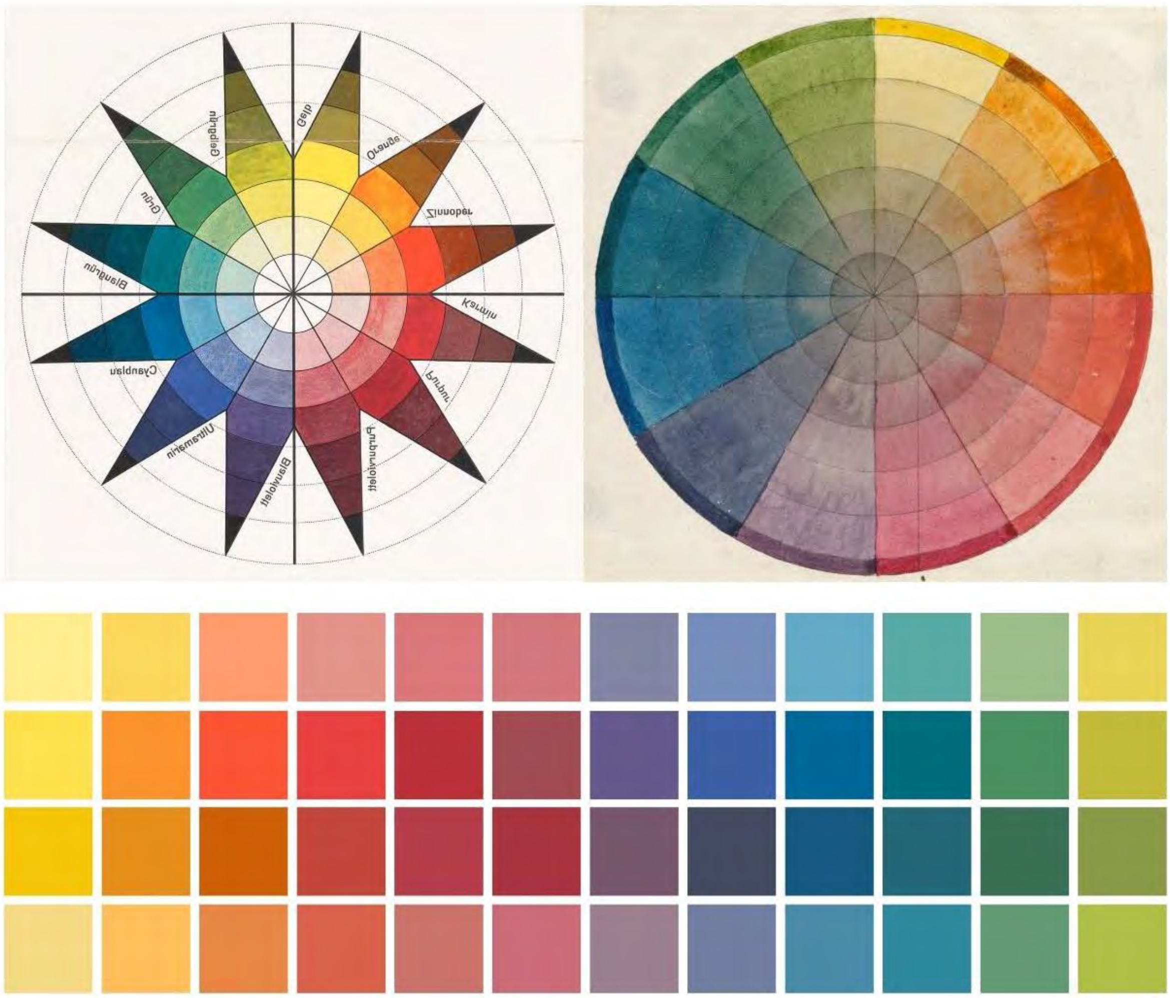

Figure 2. Itten's color star (1921) and Runge's Color sphere cross section (c1810) plus color data array.

Further research in the form of additional color mapping case studies may provide further insight. Specifically, color mapping case studies using additional color collateral from Runge as well as relevant color collateral from Goethe, Bezold, Chevreul and Hölzel are likely to increase understanding about the origins of Itten's color theories.

References

Angelo, K., and A. Booker. 2019. *Traditional Façade Neutrals are not Achromatic*. Proceedings AIC 2019, Buenos Aires, Argentina.

Aoki, K. 2016. Hölzel Circle as the Proto-Bauhaus: The situation in the Stuttgart Academy and the concept brought to the Bauhaus. *The Journal of the Asian Conference of Design History and Theory* No. 1, 41-54.

Bayer, H., W. Gropius, & I. Gropius. 1975. Bauhaus 1919 - 1928. London: Secker & Warburg

Briggs, D.J.C. 2013. *Itten's colour theory and hue system*. Accessed on April 15, 2022, from http://www.huevaluechroma.com/072.php

Gage, J. 1982. Colour at the Bauhaus. *AA Files* No. 2 (July 1982), pp 50-54.

Iijima, S. 1995. Study on the relationship between local colour attributes of streetscape and climatic elements. *City Planning Report No. 30*, Northern Japan.

Iijima, S. 1997. Cross-cultural color differences of commercial facility between Great Britain and Japan, *Bulletin of Okayama Marketing University*, 33(2): 39–51.

Itten, J. 1961. The art of color (Revised edition, 1973). New York: John Wiley.

Itten, J. 1963. *Design and form: The basic course at the Bauhaus and later* (Revised edition, 1975). New York: John Wiley & Sons.

Itten, J. 1970. *The elements of color* (translated by Ernst Van Hagen). New York: Van Nostrand Reinhold.

Kuehni, R. G. & A. Schwarz. 2008. Color ordered: A survey of color order systems from antiquity to the present. Oxford: Oxford University Press.

Lenclos, J.P. 1977. *Living in colour*, in Porter, T., Mikellides, B. (eds) Colour for Architecture. London: Studio Vista.

Lenclos, J.P. 1982. *Les Couleurs des France* in Linton, H. (ed.) Color in Architecture. New York: McGrawHill.

O'Connor, Z. 2003. Pixel perfect? Environmental colour mapping using digital technology. In S. Hayman (Ed.) *Proceedings of the 37th Australian and New Zealand Architectural Science Association Conference* (pp 686-716). Sydney Australia: University of Sydney.

O'Connor, Z. 2004. Environmental colour mapping using digital technology. In D. Miller & J.A. Wise (Eds.), *EDRA35: Annual Conference of the Environmental Design Research Assoc.,* Albuquerque USA (pp 71-80). Edmond, OK: EDRA

O'Connor, Z. 2006. Environmental colour mapping using digital technology: A case study. *Urban Design International, 11 (1),* 21-28.

O'Connor, Z. 2011. Logo colour and differentiation: A new application of environmental colour mapping. *Color Research and Application, 36 (1),* 55-60.

Parris, N.G. 1979. Adolf Hoelzel's structural and color theory and its relationship to the development of the Basic Course at the Bauhaus. PhD dissertation, University of Pennsylvania, USA.

Porter, T. 1997. Environmental colour mapping, *Urban Design International*, 2:1, 23-31.

Raleigh, H. P. 1968. Johannes Itten and the Background of Modern Art Education. *Art Journal*, 27(3), 284–302.

Reeber, S. 2011. *"Art is religion": Adolf Hoelzel's Modernism*. Master thesis, University of Missouri, Kansas City.

Runge, P. O. 1810. *Model studies for the "Color Sphere": Cross-section and longitudinal section*. Hamburger Kunsthalle. Accessed on February 19, 2020 from https://www.hamburger-kunsthalle.de/sammlung-online/philipp-otto-runge/modellstudien-zur-farbenkugel-querschnitt-und-laengsschnitt-0

Contemporary Analysis of Traditional Colour Theory

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Abstract

We define "traditional colour theory" as a loose collection of propositions about colour that disregard the findings of modern colour science beginning with Young, Maxwell, Helmholtz, and Hering, very often oversimplified and misinterpreted, taken, among others, from the writings of LeBlanc, Field, Goethe, Chevreul and popularised in Itten's *The Art of Color*. We discuss four of the major misconceptions found in the literature and, alas, widely taught in schools – from pre-school to university level. These misconceptions are those related to the "primary colours"; the hue circle (colour wheel); simple rules to establish harmonious colour combinations; and the problems associated with using vague colour categories or simple hue names, supposed to be sufficient to attach meaning and effect to colours. After pointing out the fallacies contained in these misconceptions, we conclude that 21st century colour education should break away from the shackles of traditional colour theory and treat colour as something to be experienced and enjoyed, and not just taught.

Keywords: *Colour Theory, Primary Colours, Hue Circle, Colour Harmony, Misconceptions*

Introduction

This paper is the fruit of the cooperation of members of the ISCC/AIC Colour Literacy Project (2021). Colour is a complex phenomenon whose study involves, among other fields, physics, physiology, psychology and philosophy and aesthetics, and many of the concepts related to colour are still open to debate, often to controversies even among the most experienced professionals. What we discuss below is the majority view of the CLP team, reflecting our best, current knowledge, see Arnkil (2013); Briggs (2007-, 2021); Calvo (2021); Green-Armytage (2006, 2009); Hirschler (2008, 2018); Schwarz (2012a, 2012b); Westland (2021).

We define "traditional colour theory" as a loose collection of propositions about colour that disregard the findings of modern colour science beginning with Young, Maxwell, Helmholtz, and Hering, very often simplified and misinterpreted, taken, among others, from the writings of LeBlanc, Field, Goethe, Chevreul and popularised in Itten's *The Art of Color*. Due to simplifications and misinterpretations many of these ideas lead to serious misconceptions representing a fossilized version of our understanding of colour, see e.g., Fraser (2011); Itten (1961); O'Connor (2021), Waichulis (2016).

Misconception #1: There are three primary colours, RYB Primaries

The term "primary colours" in traditional colour theory refers to various sets of colours deemed to be the fundamental components of other colours, including colours sometimes called "secondary" and "tertiary" colours. In addition to the ubiquitous red, yellow, and blue "primary colours", they may refer to the colours of a variety of sets of lights and colorants that are used to create mixtures having other colours. According to TCT "primary colours" or "primaries" are so named because "*they cannot be broken down any further and are the principal ingredients that make up all other colors*" (Bleicher, 2005:57). This definition (and the numerous similar ones abundant even in modern textbooks) can be easily refuted applying the principles of the simplest colour science.

Figure 1: Itten's colour wheel based on the red, yellow, and blue "primary colours". Mounted using the coloured sheets from [14].

The modern view is that we should not conflate colour sensations (where we may talk of the 'unique hues') and lights (which may be mixed additively) and colorants (which may be mixed subtractively). The number, hues, lightnesses and saturations or chromas of the primaries depend entirely on the mixing process and the technology to which they are applied. There are technologies using 4, 7 or even 13 defined colorants. Mainly due to economy "primary colours" are often represented as three, but with no set of three primaries in any technology is it possible to achieve the full gamut of the colours visible to humans.

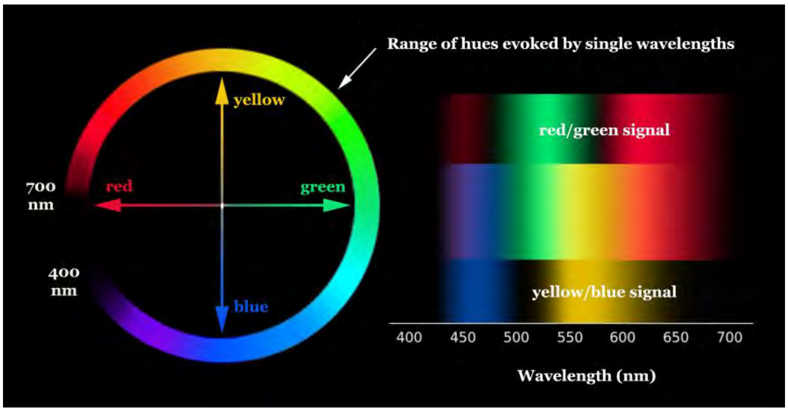

Figure 2: A. The four opponent hues or "psychological primaries", and the range of their combinations evoked by single wavelengths of light, and therefore seen in the spectrum. B. Origin of the colours of the spectrum from successive combinations of red vs green and yellow vs blue colour-opponent signals created in the brain. Briggs (2007-: Section 11.2)

Misconception #2: A single simple hue circle or "colour wheel" is all that is needed to illustrate all colour relationships

Current knowledge is that these simple hue circles hide the complexity of colour relationships.

Firstly, representation of colours of lights or objects requires a three-dimensional framework, and different three-dimensional frameworks are needed for different purposes. For colours of objects, perceptual frameworks aligned with hue, lightness and chroma, such as the Munsell system, and with hue, blackness and chromaticity, as in the NCS, each have different applications. A different framework to these is needed for colours of lights, which can be described perceptually in terms of hue, brightness and colourfulness, or hue, brightness, and saturation. Artists and designers working digitally use additional colour spaces, for example CIE L*a*b* (Lab space in Photoshop) or based on computationally simple correlates of colour attributes, such as hue, relative brightness, and relative saturation (HSB).

Secondly, there are hundreds of different hue circles, none of which represents an absolute model of hue irrespective of context. Although the order of the colours in virtually all hue circles is the same, the exact hues specified, and their number, vary from one wheel to another, as do the hues that lie opposite each other. A hue circle or colour wheel is a conceptual way of illustrating hue relationships for a specific purpose, often embodying a specific model of hue relationships. Some of the main models that have been used are:

- Traditional, for example the colour circle of Johannes Itten
- Subtractive, based on the primaries of subtractive technology, CMY
- Palette-based, structured around specific artists' paints, arranged with paint-mixing complementaries opposite each other
- Additive, based on the primaries of additive technology, for example hue angle (H) in the digital space HSB
- Opponent, for example the hue circle in the NCS
- Perceptually even, for example the Munsell hue circle
- Colorimetric, for example hue angle in CIE L*a*b*, that is, H in CIE L*C*h

Misconception #3: There are simple rules to establish harmonious colour combinations

The modern view is that this is a highly complex subject, which is still open to debate and controversy. In scientific circles it is maintained that harmony is individual and subjective, and there are no valid rules to establish harmonious combinations.

Colours are so fascinating for us humans because they not only simply ensure orientation in the world, but because they are able to affect our mood, create a certain atmosphere and evoke emotions. The way and intensity with which colours can affect us is extremely diverse. The factors that play a role in this are highly complex. Even the simple fact that everyone likes certain individual colours more than others can hardly be summed up in scientifically generalizable results, despite numerous empirical studies. The same applies to scientific studies of colour combinations that are perceived as harmonious or disharmonious. If one considers the results of all empirical studies conducted to date, with the aim of generating generalizable statements about the harmony of colours, it can be concluded that – in accordance with the everyday view – colour harmony remains primarily a matter of personal taste.

But, contrary to this everyday view based on personal experience, there is also the belief in general rules for creating harmonious combinations of colours, the latter being rooted in cultural history reaching back to antiquity.

Alfred Lichtwark (1901:16) emphasized more than 100 years ago that scientific knowledge does not form a standard for the aesthetic assessment of colours, which is why the individually drawn up colour harmony doctrines are by no means objectively valid. Rather, they only give the appearance of objectivity due to the references to physics, physiology, or psychology. In reality, however, the colour harmony doctrines are all pseudo-scientific theoretical constructs. They are therefore of little practical relevance, but are nonetheless of cultural and historical significance, since they reflect the ideas of certain epochs and cultures, see Arnkil (2015); Schwarz (1999); Westland (2007).

It is due to Goethe's influence that the two incompatible areas (colour as a subjective matter of taste and objective rule) are still mixed up today or not clearly separated from each other. On the one hand, Goethe (1810: § 758 – 901) emphasizes the fact that colours have an effect on people, and, at the same time, he lists the basic potential effects of colour combinations, which also include colour harmony in the form of rules. Since then, the relationship between subjective judgments of taste and (pseudo-) scientific theory formation has become lopsided. This has not only led to numerous empirical investigations into the harmony of colours with hardly usable results (see above), but was also taken up in colour education, where the teaching of rules about the harmonious combination of colours can still be found in the context of today's colour education.

Misconception #4: Using vague colour categories or simple hue names are sufficient to attach meaning and effect to colours ("red is arousing", "blue is calming"

The modern view is that this is also a highly complex subject, which is still open to debate and controversy. Every colour may have multiple or even contradictory meanings depending on the context. In dealing with colour, one has to be aware that it is a pre-verbal phenomenon. Recent research (Divers, 2020) pointed out that to draw meaningful conclusions on the meaning and effect of colours mentioning single hue names is not sufficient. In addition to the hue dimension the other colour attributes, such as value and chroma (or similar) and their combinations also play, often an even more significant role.

The perception of colour is able to convey meanings and evoke emotions and these can both contribute to the success of colour in art and design applications. However, the literature can sometimes insufficiently differentiate between meanings (which are cognitive) and emotions (which are affective). More seriously, the meanings that colours have often vary with context and culture and even between individuals. The simple idea, for example, that 'red means this and blue means that' that is represented in many popular infographics is not supported by practice. The meaning that red might convey in one context (e.g., when used on a yoghurt pot) can be very different from the meaning that red conveys in a different context (e.g., when used on a stop sign).

Designers usually understand the effect of context on meaning and are able to use colour effectively. There are also differences between cultures. For example, in many Asian countries in some circumstances red can be associated with good fortune and this relates to a number of cultural practices that use red objects; however, there is little evidence that red is associated with good fortune in Western Europe where it is green that can be associated with good fortune through the imagery of the green shamrock. For colour preference, Palmer and colleagues have suggested that colour preferences may stem from our colour associations; in general, we may prefer colours that we associate with objects and ideas that we find attractive and have much less preference for colours that we associate with objects and ideas that we find unattractive. This leads to a general agreement about colour preferences (for example, blue is universally liked by the majority of people) because we live in shared environments and share many cultural ideas but allows for differences between individuals (for example, some people dislike blue). Thus, although within a given context and culture we might share many colour meanings, there will always be the possibility that some individuals might have different associations or responses for a colour because of their individual life experience.

Conclusion

Traditional Colour Theory owes its popularity to being *vague, simple, and easy to explain;* however, this **simplification makes the theory inaccurate**, and this inaccurate theory is widely taught and publicised.

In the 21st century colour education should break away from the shackles of traditional colour theory and treat **colour as something to be experienced and enjoyed, and not just taught**. The ISCC/AIC Colour Literacy Project is exploring new approaches to colour education as a multidisciplinary system of connections between science, art and design, industry, technology, and culture. Fluency with the language of colour sharpens our visual intelligence, expands our perceptions, and enhances our ability to communicate. 21st century colour literacy is not just for scientists and artists — it is for everyone.

References

ISCC/AIC 2021. Colour Literacy Project. https://colourliteracy.org/ Accessed on 22 November 2021.

Arnkil, H. 2013. *Colours in the visual world*. Helsinki: Aalto University School of Arts, Design and Architecture.

Arnkil, H. 2015. The art of colour harmony: the enigmatic concept of complementary colours. In: *Proceedings of the AIC2015 TOKYO - Color and Image*. pp. 974-979.

Bleicher, S. 2005. *Contemporary color theory & use*. New York: Thomson Delmar Learning.

Briggs, D. 2021. *Colour online*. https://sites.google.com/site/djcbriggs/colour-online Accessed on 22 November 2021.

Briggs, D. 2007-. *The dimensions of colour*. http://www.huevaluechroma.com/ Accessed on 22 November 2021.

Calvo Ivanovic, I. 2021. Observation, Reflection and Collaboration - Colour Design Training Itinerary, a Framework for the Future of Colour Education. *CSA National Conference "Colour Connections"*. Sydney, 21 March 2021.

Divers, E. 2020. Beyond hue: the affective response to value and chroma. In: *Proceedings of the International Conference of the Color Society of Russia* | 1–5 December 154 2020 | Smolensk, Russia. https://www.ellendiversdesign.com/research Accessed on 22 November 2021.

Fraser, T., and A. Banks. 2011. *Colour in design: Pocket Essentials*. Lindon: Ilex Press.

Goethe, J. W. von 1810. Zur Farbenlehre. Tübingen: Cotta 1810 (Engl. Transl.: Charles Lock Eastlake: *Goethe's Theory of Colours*. London: John Murray 1840).
Green-Armytage, P. 2006. The value of knowledge for colour design. *Color Research and Application*, Volume 31, Number 4, August 2006, pp. 253-269.
Green-Armytage, P. 2009. *Seven kinds of colour*. In: Porter, T., Mikellides, B. (eds.) Colour for Architecture Today. Abingdon: Taylor and Francis
Hirschler, R. 2008. Teaching colour wheels and complementary colours. In: *Colour – Effects & Affects. Proceedings of the AIC Interim Meeting in Stockholm* June 15-18, 2008. Paper # 098.
Hirschler, R. et al. 2018. How much colour science is not too much? *Color Research and Application*, 43:977–992 https://doi.org/10.1002/col.22275
Itten, J. 1961. *The art of color* (1st English edn, tr. Ernst van Haagen). Reinhold Publishing Company, New York.
Itten, J. 1976. *The elements of color*. Study Material. New York: Van Nostrand Reinhold Company.
Lichtwark, A. 1901. Die Erziehung des Farbensinnes (The education of the color sense). Berlin: Bruno u. Paul Cassirer.
O'Connor Z. 2021. Traditional colour theory: A review. *Color Research and Application* 46:838-847 https://doi.org/10.1002/col.22609
Schwarz, A. 1999. Die Lehren von der Farbenharmonie (The doctrines of color harmony). Göttingen: Musterschmidt
Schwarz, A. 2012a. Problemkreis Farbkreis – Bemerkungen zu Ittens „Kunst der Farbe". Teil 1. Impulse. *Kunstdidaktik*. 11/May 2012. pp. 45-61.
Schwarz, A. 2012b. Wahrnehmungsfilter Farbkontraste - – Bemerkungen zu Ittens „Kunst der Farbe". Teil 2. Impulse. *Kunstdidaktik*. 12/November 2012. pp. 36-53.
Waichulis, A. 2016. https://anthonywaichulis.com/itten-munsell-cable-theory-and-a-kiss/ . Accessed on 2 April 2022.
Westland, S. 2007. Colour harmony. *Colour: Design and Creativity*, 1 (1) 1-15. https://aic-color.org/journal-issues
Westland, S. 2021. *Colourchat. Colour theory in 2 minutes.* https://colourware.org/category/colour-theory-in-2-minutes/ Accessed on 22 November 2021.

On Colour Bibliography for Design Discipline: a Study to the References Proposed by 34 Colour Courses

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Abstract

This paper is part of a doctoral research which inquired on the current issues of colour education, documented by several authors during recent years. The study presents an analysis of the bibliographic references proposed in the syllabus of 34 colour courses taught in design programmes during the last decade (2010-2020). The courses analysed were taught in English, Spanish or Italian in different countries (Latin America, North America, Europe, and Oceania). The analysis concentrated on: (i) identifying the most referred authors and sources for all courses analysed; (ii) identifying the most cited books in all languages (English, Spanish and Italian); (iii) studying the year of publication of all the referred sources; (iv) performing a comparison of the most cited sources in English and Spanish; and, (v) individuating the inclusion of women authors' works as part of the sources suggested for the courses. The bibliography was analysed to understand what sources support the delivery of the contents provided by colour courses and to identify novel, innovative and updated materials, or bibliographical resources for the support of a didactic itinerary on colour for design.

Keywords: *Colour Education, Colour Bibliography, Colour in Design, Literature Review*

Introduction

This study is part of a doctoral research for the proposal of an innovation on colour education for design and other creative project-based disciplines, which inquired on the current issues of colour education, documented by several authors during recent years. As one of the main data collection actions, the PhD research proposed a comprehensive analysis of 103 colour courses taught within design programs of higher education institutions from different countries (Latin America, North America, Europe, and Oceania) during the last decade (2010-2020). This research action sought to define the state of the art of the inclusion of colour training within design higher education, identify the main didactic strategies implemented, and recognise the main critical aspects to face when proposing an innovative framework for colour training.

The analysis focused on formalised and autonomous training moments for colour in design, colour courses. It did not consider colour lessons inside courses on other subjects. In order to study the different aspects that make up the didactic experience of a course, it was decided to take advantage of a common instrument present in most higher education institutions, the syllabus. The syllabus corresponds to an initial statement made by the teacher about the outline of an academic course. Generally, the syllabus contemplates a list of formative objectives of the course, the topics to be covered, the proposed activities, and the evaluation criteria to be applied, among others. In this sense, the syllabus is a summary facilitated by teachers to students so that they have all the necessary information for the course. The courses' syllabi provided a significant amount of relevant data about the inclusion and teaching of colour within design programmes and institutions. The sample considered courses' syllabi in English, Spanish and Italian.

The analysis criteria were divided into two main categories: the formal aspects of the courses that provide the context in which the course is taught (i.e. course level, duration, entry profile of students, specific disciplinary area, location, type of institution, language) and the didactic strategies implemented by teachers (i.e. learning outcomes, knowledge structure, teaching and learning activities, bibliography), which provided key elements to keep and main critical aspects to improve in the light of an innovative framework for colour training in design. The specific aspect of the courses' bibliography, declared by teachers, is presented in this paper.

Methodology & Data Collection

Usually found at the end of the courses' syllabi, the bibliography is presented as a whole under the names of *'Course Bibliography'*, or *'Main Bibliography'*, or well, divided into *'Mandatory* or *Main'* and *'Complementary* or *Suggested'* references. The analysis sought to determine the most cited references when teaching colour, to understand what sources support the delivery of the contents provided by the courses and to identify novel, innovative and updated materials, or bibliographical resources for the support of a didactic itinerary on colour.

Data collection regarding bibliography was only possible in 34 courses where this information was available, corresponding to 33% of the total courses analysed. The rest of the courses did not provide bibliographic references on the syllabus. The total number of nominations of bibliographic sources is 305, with an average of 9 sources per course. As some of the sources can be found in the bibliographic list of more than one course, the total number of unique authors' names corresponds to 157, and the total number of unique books or sources is 153, as in some cases the sources had more than one author. The first step of the analysis was to identify the most referred authors and sources for all courses analysed. Regarding authors, the 10 most cited authors in all languages are seen on Table 1.

Authors	Number of Nominations
Albers, Josef	18
Itten, Johannes	17
Sanz, Juan Carlos	15
Gage, John	13
Birren, Faber	8
Eiseman, Leatrice	8
Batchelor, David	6
Berns, Roy	6
Batchelor, David	6
Tornquist, Jorrit	6

Table 1. Top 10 most referred authors in all languages, English, Spanish and Italian.

Concerning the authors' work or titles of the sources, the most cited books in all three languages (English, Spanish and Italian) can be seen in Table 2. Titles appear in the original languages the sources were cited the most in the syllabi, and some English titles were included (in italic) by the researcher, to facilitate the recognition of books that already have a translated version published in that language.

Title of the source	Author's Name	Year of 1st Publication	Nº of Nominations
Interaction of color	Albers, Josef	1963	18
The Art of Color: The Subjective Experience and Objective Rationale of Color	Itten, Johannes	1961	11
Colour and Culture: Practice and Meaning from Antiquity to Abstraction	Gage, John	1999	9
El lenguaje del color	Sanz, Juan Carlos	1985	7
Colore e luce, Teoria e pratica	Tornquist, Jorrit	1999	6
Art and Visual Perception: A Psychology of the Creative Eye	Arnheim, Rudolf	1954	5
Psicología del Color	Heller, Eva	2007	5
Chromophobia	Batchelor, David	2000	4
Creative colour	Birren, Faber	1961	4
Principles of Colour, A Review of Past Traditions and Modern Theories of Color Harmony	Birren, Faber	1969	4
Storia dei colori *History of Colours*	Brusatin, Manlio	1983	4
Les Matériaux de la couleur *Colour: Making and Using Dyes and Pigments*	Delamare, François Guineau, Bernard	1999	4
Colour and Meaning: Art Science and Symbolism	Gage, John	1999	4
Theory of Colours	Goethe, J.W.V.	1810	4
A Color Notation	Munsell, A.H.	1905	4

Table 2. Top 15 most referred books in all languages, English, Spanish and Italian.

Regarding the year of publication of all the referred sources, data collection results are illustrated in Figure 1.

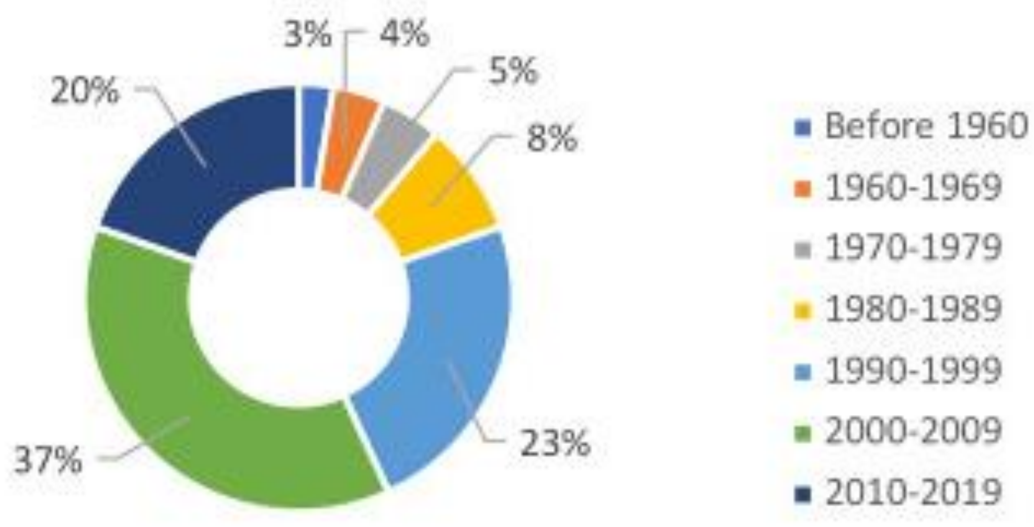

Figure 1. Overview of the distribution of the bibliographic sources according to their decade of publication

Going into the detail of the specific languages, in the case of English, courses taught in this language indicated 110 authors' names for 98 unique bibliographic sources. In the case of the Spanish language, courses addressed 54 authors' names for 51 unique bibliographic sources. Courses taught in Italian indicated 5 authors' names for 4 unique bibliographic titles.

Accordingly, a comparison of the most cited sources in English and Spanish can be seen in Tables 3 and 4. Additionally, some titles also appear in Spanish (in italic) to illustrate the original nominations to titles found in the syllabi collected in that language.

English		Spanish	
Author's name	**Nominations**	**Author's name**	**Nominations**
Itten, Johannes	15	Sanz, Juan Carlos	15
Birren, Faber	8	Albers, Josef	11
Eiseman, Leatrice	8	Gage, John	7
Albers, Josef	7	Heller, Eva	5
Batchelor, David	6	Tornquist, Jorrit	5
Gage, John	6	Ortiz, Georgina	5
Berns, Roy S.	5	Brusatin, Manlio	4
Finlay, Victoria	4	Ferrer, Eulalio	4
Münsell, Albert H.	4	Goethe, J. W.V.	4
Pastoureau, Michel	4	Kandinsky, Wassily	4

Table 3: Overview of the 10 most referred authors in English and Spanish language.

In Table 4 below, the year of the first publication of the sources is included to trace their relevance and topicality. Additionally, some titles also appear in Spanish (in italic) to illustrate the original nominations to titles found in the syllabi collected in that language.

References in English language			
Title of the source	**Author's Name**	**Year of 1st Publication**	**Number of Nominations**
The Art of Color: The Subjective Experience and Objective Rationale of Color	Itten, Johannes	1961	10
Interaction of Color	Albers, Josef	1963	7
Chromophobia	Batchelor, David	2000	4
Creative color	Birren, Faber	1961	4
Principles of Color; A Review of Past Traditions and Modern Theories of Color Harmony	Birren Faber	1969	4
Colour and Culture: Practice and Meaning from Antiquity to Abstraction	Gage, John	1999	4
A Color Notation	Munsell, A.H.	1905	4

References in Spanish language			
Title of the source	**Author's Name**	**Year of 1st Publication**	**Number of Nominations**
Interaction of Color *La interacción del color*	Albers, Josef	1963	11
Colour and Culture: Practice and Meaning from Antiquity to Abstraction *Color y cultura; la práctica y el significado del color de la antigüedad a la abstracción*	Gage, John	1999	7
El lenguaje del color	Sanz, Juan Carlos	1985	7
Colore e luce, Teoria e pratica *Color y luz, teoría y práctica*	Tornquist, Jorrit	1999	5
Psicología del Color	Heller, Eva	2007	5
Diccionario Akal del Color	Sanz, Juan Carlos & Gallego, Rosa	2001	4
Theory of Colours *Teoría de los colores*	Goethe, J.W.V.	1810	4

Table 4. A comparison of the most referred sources in English and Spanish.

Finally, it was of particular interest for the researcher to individuate the inclusion of women authors' works as part of the sources suggested for the courses. From the total number of unique authors (157), 21,7% correspond to female authors (34). The most referred women authors in general, in English and Spanish in specific, and the number of nominations can be seen on table 5.

All Languages		English		Spanish	
Author's name	Nº of nomin.	Author's name	Nº of nomin.	Author's name	Nº of nomin.
Eiseman, Leatrice	8	Eiseman, Leatrice	8	Heller, Eva	5
Finlay, Victoria	5	Finlay, Victoria	4	Ortiz, Georgina	5
Heller, Eva	5	Livingstone, Margaret	4	Gallego, Rosa	4
Livingstone, Margaret	4	Walch, Margaret;	3	Finlay, Victoria	1
Walch, Margaret	3	Sloan, Patricia	2	Varichon, Anne	1

Table 5. Most referred woman authors in all languages, and in particular in English and Spanish

Main Findings & Discussion

Although according to literature, one of the reasons for the issues of colour education was linked to the implementation of outdated colour theory in schools, the courses' bibliography showed that most of the references proposed as mandatory and complementary sources (80%) have been published within the last 30 years (1990-2019), highlighting that **the contents supporting the courses are mostly updated.** However, the research showed that 9 of the 15 most referenced books were published before 1990, which indicates that **teachers still rely very much on classic or well-known books,** such as Albers' or Itten's work. It should also be noted that of the 153 sources cited for all languages, only 7 contain the word *'design'* in their title (*diseño* in Spanish, *design* in Italian), showing an evident lack of reference to sources covering specific disciplinary content. Nevertheless, other creative areas such as architecture or art obtain a more significant presence in the titles of the suggested sources.

A further finding regarding sources: the **consideration of references other than books** in the syllabi (e.g. conference papers, journal articles, audio-visual materials, websites and digital applications, etc.) **was practically non-declared** in the courses analysed, which leads to some hypothesis; (i) although most colour teachers are also researchers and scholars, the scientific production they generate (i.e. research articles and papers) is not permeating the training environments and therefore, is not arriving to students; (ii) colour teachers still rely on traditional printed bibliography and/or they find difficulties in identifying reliable digital mixed media materials to refer to in their courses. Evidently much remains to be done in integrating new and diverse sources of knowledge in the teaching of colour.

Regarding the authors, it is interesting to note that the most cited author in English (Johannes Itten) does not appear in the top 10 of authors cited in Spanish, although his publications can be found in that language. However, one of his main works (*The Art of Color*) is part of the list of Spanish-language references, although with a smaller proportion consisting of 2 nominations. Other relevant authors with works published in English (e.g., Faber Birren, Albert H. Munsell or Roy Berns) do not appear in the Spanish reference list, probably due to difficulties to find their works (or reliable translations of them) in that language. On the other hand, none of the Spanish-speaking authors present in the Spanish bibliographic list was referenced by the courses taught in English. In this sense, the case of Juan Carlos Sanz is notorious, a recognized author with a large number of high-level publications in Spanish, and to whom the Spanish-speaking courses refer significantly. **This language barrier raises a reflection regarding the access to colour knowledge** by design students and proposes a differentiation of colour bibliography: there is a 'universal or shared' colour bibliography, as some authors are inside the most cited sources for both languages, English and Spanish; and a 'language-based' colour bibliography, as some of the most cited authors in one language do not even appear in the bibliographic list in the other language, and vice versa.

Still, regarding authors, only one female author (Leatrice Eiseman) appears as part of the 10 most referred authors, and less of a quarter of the referred authors are women. However, it should be noted that the significant nomination of Eiseman could be highly influenced by the fact that, at the time of this study, she was the Director of the Pantone Color Institute, a division of Pantone Inc, one of the best-known companies in the field of colour management. She has published 8 books on colour, all of which refer to the Pantone system and have been sponsored and distributed by the company world-wide.

However, the **gender disparity** concerning the people recognised as the primary references when it comes to teaching colour is not reflected in the same way when it comes to the teachers who give the courses. In fact, of the total of 98 teachers in charge of the courses analysed, 52% are women. Despite this, it should be noted that the result of this effort led by the female majority of teachers to the recognition and consideration of more and more women authors is still limited in the design and colour teaching community.

References

Calvo Ivanovic, I. 2022. *Colour Design Training Itinerary: A Framework for the Teaching and Learning of Colour in the Design Discipline.* [PhD in Design Research Thesis, Politecnico di Milano]. POLITesi - Digital archive of PhD and post graduate theses.

Csillag, P., A. L. Lupinacci, & R. Hirschler. 2018. Overview of Colour Education in Brazilian Universities: a Focus on Design Courses in the State of São Paulo. *Journal of the International Colour Association,* (22), 4–14.

Janssens, J. & B. Mikellides. 1998. Color research in architectural education - A cross-cultural explorative study. *Color Research and Application*, 23(5), 328–334.

Minah, G. 2008. Colour as Idea: The Conceptual Basis for Using Colour in Architecture and Urban Design. *Colour: Design & Creativity,* 3(2), 1–9.

Motamed, B. & R. Tucker. 2016. The etymology of a colourful design language: How do we determine what informs an architect's colour choices? *Art, Design and Communication in Higher Education,* 15(2), 191–208. https://doi.org/10.1386/adch.15.2.191_1

Mottram, J. 2018. Identifying colour use and knowledge in textile design practice. In: *Progress in Colour Studies,* L. W. MacDonald, C. P. Biggam & G. V. Paramei (Eds.). London: John Benjamins Publishing Company, 371–389.

Smedal, G. & A. Svedmyr. 1989. Who needs to learn what about. *Proceedings of the 6th Congress of the International Colour Association*, 197–198.

Session 6
Colour in Architecture - II

"Thinking pink in architecture" - survey on perception and preferences of pink color by architecture students from the "millennial generation."

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Abstract

The article's primary goal is to present the author's online survey results. The study aimed to investigate what architecture students think about pink-colored buildings and if the popularity of so-called "millennial pink" affected their current perceptions and general preferences of that color. The study showed that the color pink is no longer stereotypically perceived by the students and that it is treated in the same way as any other hue in architecture. Pink was usually appreciated and positively assessed, especially in the buildings where it was consistent with the function and architectural style of the object. As the survey shows no prejudice behind pink, thus the young generation of architects could usher in a new era of pink in architecture. It is, however, difficult to state unequivocally if the popularity of "millennial pink" played a significant role in this change in pink's identity. Although the survey participants were limited only to architecture students from just one University, the results may contribute to a broader discussion on the role and future of pink color in architecture.

Keywords: *Pink, Millennial pink, Color in architecture, Color preferences*

Introduction

The pink color has a big variety of associations, sometimes quite adverse. It is being described as romantic, gentle, sweet, feminine, tender as well as childish, artificial, garish, and vulgar. The perception of this color is also not unequivocal and it is deeply rooted in the observer's cultural background. It is also very much dependent on a particular nuance, which varies from delicate pastels and corals to saturated and bold “shocking” pink amaranths.

In Western cultures pink is strongly feminized and eroticized for almost one century, and it becomes a kind of a symbol of womanhood, gender norms, and femininity (Blegvad 2019, Bideaux 2019). Because of those long-standing associations, today it is often identified with stereotypically understood femininity and goods intended only for girls (not only little ones). It is color of Barbie, princesses, and unicorns. At the same time, some artists want to counteract this and redefine the meaning of pink, giving it more mature and even revolutionary connotations. One of these “new” approaches to pink, which are no longer connected to popular gendered symbolic inherited from the twentieth century, is formed by so-called “millennial pink”, which refers to a specific range of pale pink tones. It was named after “Millenials”, a generation of young people born between 1990 and 2000. “Millenial pink” became popular towards the end of the year 2015 and thanks to the internet spread widely throughout the world of fashion, art, and design (Bideaux 2019). Additionally, in 2016 Pantone presented “Rose Quartz” as one of two colors of the year, which was in line with this mood and attitude.

But what about pink and architecture? Kaye Blegvad wrote in “The Pink Book” (Blegvad 2019), that pink is a very “out-of-the-ordinary” color for architecture and because of that pink buildings convey a sense of wonder and the extraordinary. Despite this, in Western architecture, the varied shades of pink are often discounted for any significant use in architecture, due to its strong previously mentioned associations. Of course, there are notable pink buildings in the history of architecture, but there are not too many of them. Let's mention iconic buildings of Mexican architects Luis Barragan (Casa Pedregal 1950, Cuadra San Cristóbal 1966, Casa Gilardi 1976) and Ricardo Legorreta (Camino Real Hotel, 1968) (Martinez 2018) or Spaniard Ricardo Bofill (La Muralla Roja, 1973). We also do have examples of American pink hotels from the 1920s, like e.g. “Pink Lady” - The Don CeSar Beach Resort and Spa in Florida by arch. Henry H. Dupont (1928) or "The Pink Palace of the Pacific" - The Royal Hawaiian Hotel by arch. Warren and Wetmore built in Hawaii (1927) (Massello 2017).

You can also find suggestions that the trend for "millennial pink" had some connection with Wes Anderson's 2014 movie “The Grand Hotel Budapest”, set in a fictional hotel, painted in several shades of pink (Bartkowska 2021). But at the same time, some buildings fit the stereotypical meaning of color. For example, let's mention candy-pink facades and interiors of The Barbie Dreamhouse Experience available to visit in 2013 in Berlin (Germany) or house for events Eaton Studio in Tiptree (Great Britain) painted pink in 2012 to attract guests with a controversial look. Thus, it seems that the color pink has multiple facets also in architecture. If so, the question can be asked, if the popularity of “millennial pink” in any way changed/affected the current approach of architects to pink color for buildings and spaces?

As building facades take up fashionable trends with a certain delay so, of course, it is difficult to look for a sudden increase in the number of objects painted pink. But some tendencies can be observed while searching most popular websites, covering architectural news and projects from around the world, especially: Archdaily (www.archdaily.com), Divisare (www.divisare.com), and Dezeen (www.dezeen.com). New ways of using pink can be observed e.g., in residencies, where this color no longer represents only the extravagant life of the owner or fulfilled the dream of being a princess, becoming instead a mature architectural color.

To check whether these observations result from the change in the perception of pink, as a lecturer at the Cracow University of Technology (Poland), I decided to survey students from the Faculty of Architecture, who are mostly representatives of the millennial generation. The main purpose of the article is to present the results of this color study.

Method

To conduct the research, an online questionnaire was prepared in Google Forms, in which the respondents were asked about diverse aspects concerning pink color, both in general and in architecture.

Survey Structure

The study consisted of four parts. In the first part, the participants provided their data - gender, nationality, year of birth, and field of study.

The second part concerned general preferences for the color pink. The participants answered the question if they liked the color pink and if they knew the term "millennial pink." In this part, the participants were also asked to evaluate on a scale of 1-5 (1 - definitely not; 2 - rather not; 3 - hard to say; 4 - rather yes; 5 - definitely yes) the representativeness of selected groups of colors for the term "pink" (6 groups of 4 nuances) (Figure 1) and "millennial pink" (6 groups of 6 nuances) (Figure 2).

The third part was about the color pink in architecture. First, the participants answered the general question of whether they like pink in architecture, indicating one of 5 possible answers: Yes, I think the pink buildings are awesome!; Yes, but only some shades and in specific realizations (it depends on the context); It's hard to say (I have no particular preferences in this regard); I'm not fond of it, but I appreciate some projects in this color; No, I don't think this is the right color for buildings. The students were then asked to choose from among 13 functional categories the types of buildings that they thought could be painted pink (assuming, of course, the style of the buildings and the context of the place).

The next step was a detailed assessment of 21 buildings presented in order from oldest to newest (photo + description). At first, the study participants were to answer whether they were familiar with a given object and liked the building and its color. Then they rated on a scale of 1-5 (1 - it doesn't fit the character and style of the building at all; 2 - it rather doesn't fit (a different color would have been better); 3 - it neither fits nor does it (I have no opinion); 4 - it rather fits (I have nothing against it); 5 - fits well and emphasizes the character of the building) the degree of color matching to the character, style, and function of the building.

The fourth part was summarizing. Participants were asked if they liked the research, if it increased their knowledge of pink color, and if it influenced their thinking about pink in architecture. It was also possible to leave comments for the survey.

Colors selection

According to the NCS system, twenty-nine pink colors were selected for the second part of the survey. Then, the selected colors were sorted into twelve groups of pink shades - 6 x 4 colors and 6 x 6 colors, combining nuances with different hues (more salmon or more purple), saturation (more or less saturated) and lightness parameters (lighter or darker). A division of colors into groups is presented in Figures 1 and 2, respectively.

group 1	group 2	group 3	group 4	group 5	group 6
0515-Y90R	0515-R10B	0530-Y90R	0530-R20B	0550-R	1050-R20B
0515-R	0515-R20B	0530-R	0530-R30B	0550-R10B	1050-R30B
0520-Y90R	0520-R10B	0540-Y90R	0540-R20B	1050-R10B	1060-R20B
0520-R	0520-R20B	0540-R	0540-R30B	1060-R10B	1060-R30B

Figure 1. Color groups to evaluate the level of representativeness for the term "pink"

group A	group B	group C	group D	group E	group F
0515-Y80R	0515-R	0530-Y90R	0530-R10B	0540-R	1050-R10B
0515-Y90R	0515-R10B	0530-R	0530-R20B	0540-R10B	1050-R20B
0515-R	0515-R20B	0530-R10B	0530-R30B	0540-R30B	1050-R30B
0520-Y80R	0520-R10B	0540-Y90R	0540-R10B	0550-R	1060-R10B
0520-Y90R	0520-R20B	0540-R	0540-R20B	0550-R10B	1060-R20B
0520-R	0520-R30B	0540-R10B	0540-R30B	0540-R20B	1060-R30B

Figure 2. Color groups to evaluate the level of representativeness for the term "millennial pink"

Buildings selection

Twenty-one pink buildings, both traditional and modern, were selected for the study. The main selection criterion was the greatest possible variety of function, form, and aesthetics of objects. Therefore, the final list includes very different buildings: sacred, administrative, museums, single and multi-family houses, hotels, shops, a school, and an equestrian club. The objects also represented different architectural styles and different ways of using pink color. The buildings selected for the study are shown in Figure 3.

Figure 3. Selection of the buildings (collage by Justyna Tarajko-Kowalska)
1 - City Palace (1727, Jaipur, Indie); 2 - The Chesme Church (1780, arch. Jurij Felten, St Petersburg, Russia); 3 - Casa Rosada (1898, Buenos Aires, Argentine); 4 - Da Nang Cathedral (1924, Vietnam); 5 - Casa de Serralves (1925-44, arch. José Marques da Silva, Porto, Portugal); 6 - The Don CeSar Beach Resort and Spa "Pink Lady" (1928, arch. Henry H. Dupont, Florida, USA); 7 - Cuadra San Cristóbal (1968, arch. Luis Barragan, Mexico); 8 - La Muralla Roja (1973, arch. Ricardo Bofill &Taller Arquitectura, Calpe, Spain); 9 - Casa Gilardi (1975, arch. Luis Barragan, Mexico); 10 - Sanitary Facility for IJBZ Children's Camp 'Lake Barleben' (2002, arch. AFF architekten, Magdeburg, Germany); 11 - The Group of schools in Reims (2005, arch. Dominique Coulon and associés, Reims, France); 12 - Casa de los Milagros - House of Miracles (2006, arch. Danilo Veras Godoy, Xalapa Veracruz, Mexico); 13 - Make it right House (2007, arch. Frank Gehry, New Orleans, USA); 14 - Palazzo Chupi (2007, by artist Julian Schabel, New York, USA); 15 - Barbie Flagship Store (2009, arch. Slade Architecture, Shanghai, China); 16 - Eaton House Studio (2012, Tiptree, UK); 17 - CF-house (2013, arch. Christian Calle Figueroa, Cuenca, Ecuador); 18 - The Grand Budapest Hotel (2014); 19 - His house and Her house (2017, arch. Wutopia Lab, Shenzen, China); 20 - Monte House (2019, arch. TACO taller de arquitectura contextual, Mexico); 21 - The Webster (2020, arch. David Adjaye, Los Angeles, USA).

Results

The author collected the data presented in this article in April 2022 for around one month. During that period, 127 students took part in it, 104 females (81.9%) and 23 males (18.1%). They were born between 1993 and 2002 (93.7% between 1997 and 2001). Most of the survey participants came from Poland (115 - 90.55%). Twelve people (9.45%) were from other countries: Belarus, France, Germany, Mexico, Romania, Russia, Spain, and Ukraine. They were primarily students from the Cracow University of Technology, Faculty of Architecture. Their field of study mainly was Architecture (85.8%), but also Landscape Architecture (12.6%), and Urban Planning (1.6%). The results were categorized and organized according to the division of the study itself.

Results of part I

In the first part on the general preferences for pink color, to the question "do you like pink?" most replied in the affirmative. The total number of answers "definitely yes" (31.5%) and “rather yes” (40.2%) was 71.7%. 20.5% answered "hard to say", while "rather not" only 7.9%. There were no "definitely no" answers.

Then, the participants rated on a scale of 1-5 six groups of four colors each for their representativeness of the term "pink." When assessing all the presented color groups, the dominant answers were "rather yes" and "definitely yes." Their percentage ranged from 52.5% to 74%.

Group 4 of hues R20B and R30B with high lightness and high saturation was considered the most adequate for the term "pink" (the total number of "definitely yes" and "rather yes" answers was 74%). Group 5 came second (70.9% of the answers to "yes"). The third place was taken by groups 1 and 2, with 65.4% of the answers to "yes." The fourth place was taken by group 6, in which the number of responses to "yes" reached 53.5%. For this group, the percentage of answers to "no" was also high, accounting for 27.5%. The least representative group for the term "pink" turned out to be group 3, where the percentage of "yes" answers was 52.7% and "no" 25.2%. In the assessment of this group, a significant 22% of participants also chose the answer "hard to say."

When asked about their knowledge of the term "millennial pink," a small majority of the respondents answered "no" (63%). Then, the students were asked to indicate which of the presented six groups of six shades are, in their opinion, the most representative of the term "millennial pink." It was possible to select any number of groups. None of the groups received a clear majority of votes. The highest number of votes (39.4%) was obtained by group A, followed by group B (26%), C (22%), D (18.9%), and the least number of votes by groups F (10.2%) and E (7,9%).

Results of part II

In the second part of the survey, on the color pink in architecture, when asked, "do you like pink in architecture?" most answered in the affirmative. 63% answered "yes, but only some shades and in specific realizations (it depends on the context)." 18.9% were enthusiastic about the color pink, indicating the answer "Yes, I think the pink buildings are awesome!". Only 3.94% of the respondents did not have any particular preferences in this regard, and only 1.6% answered that pink is not a color suitable for buildings.

The respondents were then asked to choose from 13 functional categories those types of buildings that, in their opinion, could be painted pink (assuming, of course, that their style and the context of the place were appropriate). Restaurants and cafes (78.7%), as well as community centers and museums (70.9%), were considered to be the most suitable functions for pink color. A high percentage of responses was also given to hotels (58.3%), theaters and cinemas (57.5%), kindergartens and nurseries (53.3%), as well as shops (52.8%). Private houses received 48% of responses, and multi-family houses - 35.4%. Secondary schools obtained 30.7%, industrial buildings 25.2%, hospitals and clinics 22%, and sacral buildings - churches and chapels 19.7%. The lowest percentage of responses, 13.4%, was obtained by administrative buildings and headquarters. 16.5% of the study participants chose the answer "all of the listed" and only 1.6% the answer "none of the listed."

In part concerning the detailed assessment of buildings, the vast majority of the 21 objects presented were new to students. The most known building was the La Muralla Roja residential complex, whose recognizability was declared by 56.69% of respondents. The top five most well-known objects also included: Grand Hotel Budapest - a fictional building from the movie directed by Wes Anderson (51.9%); stables and equestrian club Cuadra San Cristóbal (33%); Barbie Flagship Store (29.9%) and museum of contemporary art Casa de Serralves (22%). Most of the presented buildings were liked by students (12 objects were favored by more than 58% of respondents). They also appreciated their color (the colors of 16 buildings were pleased by more than 50% of respondents). The ranking of the most preferred buildings included: La Muralla Roja and the fashion store The Webster, which were liked by 91.3% of respondents. The following positions were taken by: Cuadra San Cristóbal - 89.8%, Casa de Serralves and Monte House - 84.2%, Jaipur's City Palace - 81.9%, School complex in Reims - 80.3%, and Barbie Flagship Store - 79.5%.

The least appreciated were houses: Casa los Milagros - 30.7%, Make it Right House - 22%, and Eaton House Studio - only 7.1%. Color's ranking looks very similar, as the participants usually preferred the colors of those objects, which they also appreciated as buildings. So, the respondents most liked colors of The Webster and Cuadra San Cristóbal - 93%, as well as La Muralla Roja - 89%. They were also pleased by the colors of Monte House and Casa de Serralves - 85%, Jaipur City Palace - 83.5%, Barbie Flagship Store - 81.1%, and School complex in Reims - 80.3%. On the other hand, the color of Eaton House Studio was the least liked - only by 13.4% of respondents.

In the assessment of the degree of color matching to the character, style, and function of the building, the highest scores were received by: The Webster - 96.8% (the total percentage of responses 4 and 5); Barbie Flagship Store - 91.3%; La Muralla Roja, Cuadra San Cristóbal and Monte House - 90.5%; Casa de Serralves - 89%; Jaipur City Palace - 85%; School in Reims - 81.1% and His and Her House - 78.74%. The color of Eaton House Studio was rated as the least appropriate to the building - 59% (the total percentage of responses 1 and 2), followed by two sacral buildings of Da Nang Cathedral - 38.6% and The Chesme Church - 37.8%, and Palazzo Chupi - 35.4%.

Results of part III

In the third part, the respondents expressed their opinion on the study itself. Most of the respondents appreciated the survey. The total number of answers "definitely yes" (80.3%) and "rather yes" (17.3%) was 97.6%. "It's hard to say," answered one person (0.8%) and "rather not" two (1.6%). There were no "definitely no" answers. 86.6% of the respondents said that their knowledge of pink had increased thanks to the survey ("definitely yes" - 55.9%; "rather yes" - 30.7%; "hard to say" - 10.2%; "rather not" - 3.1%). 81.9% also confirmed that the survey influenced their thinking about pink in architecture ("definitely yes" - 55.1%; "rather yes" - 26.8%; "hard to say" - 10.2%; "rather no" - 4.7% "definitely not" - 3.1%).

Conclusions and discussion

The results of the first part of the study confirmed that the spectrum of colors referred to as "pink" is vast and covers both pure shades of red (R) as well as those with an admixture of yellow (Y80R, Y90R) or with a blend of blue (R10B, R20B, R30B). In the case of the colors representing the term "millennial pink," the research confirmed that it is not one specific nuance but rather a group of them (see also Bideaux 2019). The largest number of indications for group A proved that these are rather salmon and peach shades (Y80R, Y90R, and R) than lavender and violet (R10B, R20B, R30B) and that these are relatively light colors with low saturation (0515, 0520).

The second part of the study showed that pink is no longer stereotypically perceived by the students. In the buildings where the color was consistent with the function and architectural style, pink was appreciated and positively assessed. Even the use of pink following its stereotypical associations was accepted (e.g., Barbie Flagship Store or His house and Her house) if it was made in a way that does not depreciate the architecture of the building. On the other hand, the objects in which the use of the color pink was characterized by kitsch (e.g., Eaton House Studio) were assessed less positively. There are also some functions for which pink is not perceived as suitable. These are, in particular, administrative and government buildings, as well as sacral ones.

So this means that the color pink is treated in the same way as any other hue in architecture. It is difficult to state unequivocally if the popularity of "millennial pink" played a significant role in this change in pink's identity. Although most of the respondents did not know this term, they must be familiar with products in this color that are common on the market. The results of the third part of the study also suggest that the architects of the older generation may be partly responsible for the hitherto stereotypical perception of pink in architecture. Students not knowing pink objects were also not aware of the possibilities of pink, and thus having no inspiration, they do not use it in their projects. Nevertheless, the study shows no prejudice behind pink and that the young generation of architects could usher in a new era of pink in architecture. The beginnings of this evolution can already be observed in recent architectural realizations, which may become an inspiration for future adepts of architecture (e.g., The Webster). Although the survey participants were limited only to architecture students from just one University, the results may contribute to a broader discussion on the role and future of pink color in architecture.

An additional, more general, observation is that the color of the buildings was, in the vast majority of cases, assessed better than the building itself, regardless of whether the building was liked or not. The number of undecided people also decreased (answers: "it's hard to say"). This may suggest that the preferences for colors are more specific and more straightforward to define than for forms. Also, the color of objects, despite a strong relationship with the building's form, function, and structure, can to some extent be assessed independently.

Acknowledgements

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Appendix A

Detailed results of the study can be found at https://drive.google.com/drive/folders/1GbNGLj-wP8wwS5rAg0d57zwTo7jjN3gL?usp=sharing

References

Bideaux, K. 2019. Millennial pink: gender, feminism, and marketing. A critical Analysis of a color trend. *Color Culture and Science Journal, 11(1), 82-89.* https://doi.org/10.23738/CCSJ.110110

Blegvad, K. 2019. The Pink Book: An Illustrated Celebration of the Color, from Bubblegum to Battleships. San Francisco: Chronicle books.

Martinez, A. 2018. The true story of how Mexican Pink was born. *The Mazatlan Post.* Online: https://themazatlanpost.com/2018/12/16/the-true-story-of-how-mexican-pink-was-born/ (accessed: 5 December 2021)

Massello, M. 2017. 5 Famous Architects Who Loved Millennial Pink Before it was Cool. Apartment Therapy. Online: https://www.apartmenttherapy.com/5-famous-architects-who-loved-millennial-pink-before-it-was-cool-246584 (accessed: 10 January 2022)

Bartkowska, P. 2021. Transformacja różu – od kiczu po millennial pink. *Internity Home*. Online: https://internityhome.pl/odkrywaj/trendy/transformacja-rozu-od-kiczu-po-millennial-pink/ (accessed: 10 January 2022)

Colour and Modern Architecture in Southern Chile

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Abstract

The period called "second modernity" in architecture in southern Chile had its peak between 1960 and 1980. During such a period, colour appears in many works in the form of ceramic, and vitreous and coloured glass coatings, endowing cities with an atmosphere never seen before. This article focuses on iconic works in the southern cities of Concepción, Chillan, and Valdivia, which have colour in their facades and interiors, in the form of coatings or coloured light. While these materials are no longer manufactured in the country due to lack of demand, the buildings remain nostalgic for a period of urban chromatic splendour of great quality.

Keywords: *Architecture, Colour, Modernity, Chile.*

Introduction

The modern period in architecture, often considered as originating during the first half of the 20th century in Europe, had great Figures. The names of Walter Gropius, Mies van de Rohe, Le Corbusier, Gerrit Rietveldt, and many more, are already iconic and part of an immeasurable list. From the point of view of colour, this architecture flourished in a multiplicity of materials and coloured spaces. The colourful work of expressionist architect Bruno Taut (Fernandez, 2108), for example, is recognized worldwide, as is the coloured light work of Le Corbusier. Three of his most important works are: the chapel of Ronchamp, the convent of Le Tourette, and the parish of Saint Pierre in Firminy (Schielke, 2015).

The development of modern architecture, both in North and South America, followed its own course and paths, and was recognized as an oeuvre in itself; reinterpreted, and distinct. In South America, it has been called "Appropriate Modernity" or "Other Modernity", divergent and diverse, with a strong sense of belonging (Fernández-Cox, 1990). In Venezuela, for example, the Central University campus in Venezuela, Caracas (1950-1960) is a prime exponent of Latin American modernity where colour plays a fundamental role. Its author, architect Carlos Raúl Villanueva, invited great artists such as Alexander Calder, Fernand Leger, Victor Vasarely, Jean Arp, and Wilfredo Lam, among many others, to participate in this project. In Brazil, the city of Brasilia (designed by architect Oscar Niemayer) is another example of the interpretation of the modern movement in South America. In the metropolitan cathedral Nossa Senhora Aparecida (1958-1971), the impressive stained-glass windows cover the entire circular space shedding coloured light to the interior and creating an atmosphere of deep spirituality.

International art movements have always arrived in Chile several years or even decades late. Considering that it is a highly centralized country, this delay is particularly marked in Chile’s regions. Santiago de Chile has important works that reinterpret modernity and incorporate colour; however, in this work we will focus on the southernmost part of the country, specifically in the cities of Concepción, Chillan, and Valdivia.

In 1960, a huge earthquake hit the south of Chile (9.5° in the Richter scale, the largest recorded worldwide to date), with its epicentre in Valdivia. The quake activated the development of an architectural and urban process that we have called "Second Modernity" or "Mature Modernity".

The colours of modernity

At this stage, modern architecture and colour burst with force in the buildings and public spaces of southern cities through coatings in the form of ceramic and glazed tiles, glass, and coloured light. So far, our research has identified at least four means of incorporating colour through these coverings, all of which are discussed in this paper: IRMIR and FANALOZA; Muriglas; REVICOL, and coloured light.

A. IRMIR and FANALOZA (Fábrica Nacional de Loza) ceramic tile cladding

The modern architecture under which the cities destroyed by the 1960 earthquake were rebuilt largely introduced this cladding, both in buildings and public spaces, providing colour and glazed finishes that have characterized the architecture of the 1950-1970 period. Of the broad spectrum of works that use this architectural resource in the country’s south, here we mention the Forum of the Universidad de Concepción (1958), the Sports Coliseum of Valdivia (1966), and the building of the Student Affairs Office of the Universidad Austral de Chile, in Valdivia (1962).

● The Forum of Universidad de Concepción is at the heart of the university campus and one of the main modern-coloured public spaces in the country’s south. The sunken plaza meets –as a backdrop– a large 38.5m long multicoloured ceramic mural, 2.4m below the main level (Berríos, 2017). The blue-green-yellow gradient design provides the space with an atmosphere that accentuates the freshness of the pool (Figure 1).

Figure 1. Forum and water wall at Universidad de Concepción, Chile (author: GCB and ECJ, 2022).

● The Valdivia Sports Coliseum is one of the country's main indoor stadiums (Muñoz et al., 2000). By introducing ceramic murals in a sculptural wall of coloured ceramic reliefs, the intent of integrating arts and architecture is patent. Blue, light blue, grey, grey, white, and yellow compose a contrast of value, saturation, and warmth-coldness that provides the wall curves with movement and depth. The design is framed by an upper red line corresponding to the edge of the roof.

● The Student Affairs' Office building at Universidad Austral de Chile in Valdivia is one of the most significant modern works in the country's south.[1] The building features large windows that open onto the landscape and a rigorous treatment of cladding surfaces, both outdoors and indoors. On the exterior, stone-clad walls contrast with blue ceramic tile cladding. The interior features dark native wood for the ceilings, stone walls in neutral colours, white marble for the pillars, light yellow for the floors, and a large blue ceramic baseboard (Figure 2).

Figure 2. Student Affairs' Office Building at Universidad Austral de Chile, Valdivia (author: GCB, 2022).

[1] This work is sponsored by the "Vicerrectoría de Investigación, Desarrollo y Creación Artística", de la "Universidad Austral de Chile".

B. Muriglas glass mosaic tiling

Coating based on small tesserae of coloured glass. Often, different colours and varied designs were combined on the walls, even in murals developed by renowned national artists. Below is a description of the building of the "Caja de Previsión de Empleados Particulares" (Private Workers' Social Security Facility) of Concepción (1959) and the building of the "Caja de Crédito Prendario" (Public Pawnbroker) of Valdivia.

The modern building of the "Caja de Previsión de Empleados Particulares" of Concepción was one of the many modern buildings in the south of the country that used coloured Muriglas tesserae as cladding. On the exterior, the orange Muriglas almost covers the entire facades, making the building standout in contrast with the green of the trees and the grey of the other facades. Indoors, the muriglass (tiny coloured glass tiles) is arranged in the staircase space, hall, and corridors. The indoor design is a "quality contrast" pattern with a cold-blue background, with warm accents of oranges, reds, and yellows (Figure 3).

Figure 3. Building of the "Caja de Previsión de Empleados Particulares" of Concepción (author: GCB, 2022).

The building of the "Caja de Crédito Prendario" of Valdivia, is a work of great rationality that stands out for the introduction of coloured muriglass in its accesses and recessed balconies, both in walls and pavements. Browns and yellows are used in a particularly outstanding surface for the intentional management of light, generating coloured and illuminated surfaces of great geometric abstraction. The indoor design is a "quality contrast" pattern between a less saturated brown background and extremely saturated yellow light points (Figure 4).

Figure 4. Building of the "Caja de Crédito Prendario" of Valdivia (author: ECJ, 2022).

C. REVICOL coloured glass cladding

In the 1960s, coloured glass was another architectural resource widely used in modern architecture in Chile. These glasses were manufactured in the country by the company REVICOL (Revestimientos Vidriados de Color). To achieve a certain level of privacy and to avoid the exposure of household activities to the street without sacrificing indoor light, coloured glasses were often used in the parapets. This practice was also used in different public buildings.

The Immaculate Conception School building (1964), in the city of Concepción, is one of the paradigmatic buildings of the Second Modernity architecture in the city. The upper floor corridors are treated in their parapets with red glass, irradiating towards the main facade, the corridors' indoor space, and the building's common areas. These coloured glass coverings completely renewed the image of modern architecture developed in the city in the 1960s. Above all, however, they contributed to a new conception of indoor space, where coloured light is treated as a design material (image 3). Indoor, a horizon of transparent red light is created, which at certain hours of the day deploys a luminous carpet of the same colour (Figure 5).

Figure 5. "The Immaculate Conception School" building (author: GCB, 2022).

D. Coloured light

The novel conceptions of architectural space proposed by modern architecture in the 1960s –such as double or triple height spaces, new indoor-outdoor spatial relationships, spatial fluidity, or the expression of materials in the built space, among others– gave rise to a new way of understanding architectural space. In this context, it could be argued that coloured light became a design material, something that radically transformed the production of modern indoor spaces.

An example is the building of the COPELEC (Electric Cooperative) in the city of Chillan, revealing the strong expressiveness of raw reinforced concrete (béton brut). The treatment of coloured light appears as a constant in the entire work. Light is treated as a project material and represents one of the building's highest and most outstanding architectural design marks. The rough, textured raw concrete walls are bathed in blue, red, green, yellow, and white light, which also tint indoor spaces through organically shaped skylights and coloured acrylic plates (Figure 6).

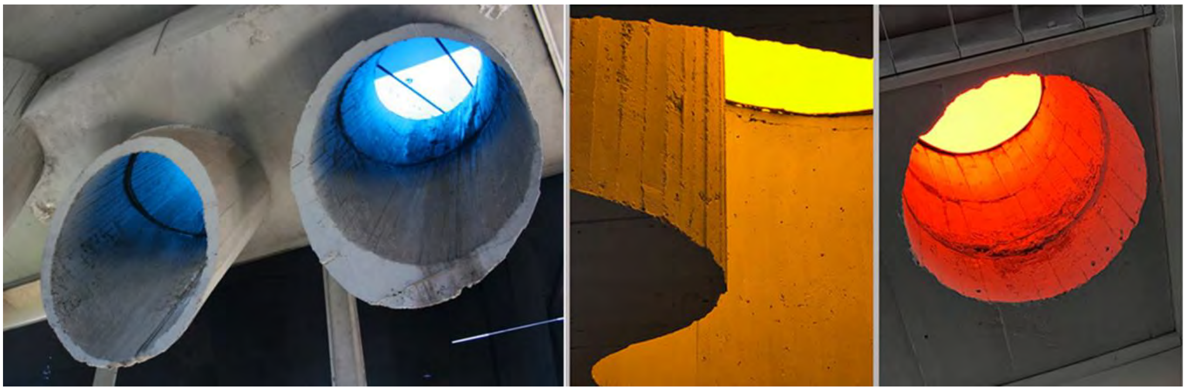

Figure 6. COPELEC building in Chillan (author: GCB and ECJ, 2021).

Conclusions

The second modernity took place in Chile as an introduction to a palette not only of an unprecedented chromatic richness, but also of a varied haptic and visual quality in the surfaces, given by the brightness and translucency of its materials, providing it with nobility and durability. These materials, although more expensive than paint, were convenient in terms of cleaning and maintenance. In addition, the colour did not fade over time, providing great durability.

An important aspect was the architectural and political moment facing the country in the 1960s and 1970s. Featuring strong State involvement in the construction of housing and public buildings, coloured coatings became popular. The decline in their use matched the beginning of Augusto Pinochet's Dictatorship in 1973. Notwithstanding, IRMIR and Muriglas were largely demanded for the construction of the new Santiago subway from 1975 onwards.

Unfortunately, trends go away and the material was left aside in the 1980s, when the companies winded up due to lack of demand.

The works carried out during this period have remained as icons of a limited time in the history of Chilean architecture, seen with nostalgia today by a group of architects and scholars. Our expectation is for this work to contribute to making colour visible in architecture and urban space.

References

Berrios, C. 2017. *Emilio Duhart, elaboración de un espacio urbano. Ciudad universitaria de Concepción.* Lom Ediciones/ Universidad del Bío-Bío.

Fernández C. 1990. *Arquitectura y Modernidad Apropiada: tres aproximaciones y un intento.* Taller América Ltda. Editorial Universitaria, Chile. Santiago de Chile,

Gasparini, M. et al. 1991. *Obras de arte de la ciudad universitaria de Caracas*. Montes Ávila Editores; Venezuela.

Muñoz, M. et al. 2000. *Premios Nacionales de Arquitectura, Chile*. Ediciones Universidad del Bío-Bío, Concepción, Chile.

Fernández, B. 2018. *Le Corbusier y el lenguaje del colour*. Noviembre 2018. Accessed 5 May, 2022. https://www.plataformaarquitectura.cl/cl/906557/le-corbusier-y-el-lenguaje-del-colour

Schielke, T. 2015. Light Matters: Le Corbusier y la Trinidad de la Luz. Febrero 2015. Accessed 5 May 2022. https://www.plataformaarquitectura.cl/cl/762849/light-matters-le-corbusier-y-la-trinidad-de-la-luz

Color and collective housing. Color at the service of the 20th century heritage. Case study of the Harlequin of Grenoble

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Abstract

The Cité de l'Arlequin, the Harlequin, opened on the Jean Verlhac Park, in Grenoble, France, is a major architectural and urban project of the 60's and 70's. Based on innovative social ideas, it fits into the landscape with a very particular aesthetic and a claimed polychromy. Today, in parallel with the major urban renewal project, the facades of the Harlequin are rehabilitated. This article studies the history of this remarkable heritage of the 20th century and the methods of its revival, enriched by the expertise of an agency of colorists consultants.

Keywords: *city, modern architecture, color plan, urban utopy*

Introduction

The Cité de l'Arlequin, the Harlequin, marks a "pivotal" moment in the history of social housing.The creation of the "Villeneuve", which has 2,200 housing units, including 920 low-income housing, entrusted to the Atelier d'urbanisme et d'architecture (AUA)*, is based on innovative and social ideas at the end of the 1960s: high density, reduction of social segregation, priority to collective life, green spaces and parks, separation between pedestrians and cars, simultaneous construction of housing and neighborhood amenities, urban image as opposed to outlying residential neighborhoods.

The Harlequin is the first district created between 1970 and 1973. So called in reference to its colored facades aimed at reducing its monumental appearance. Today, his space of experimentation marks the city of Grenoble and becomes a pioneering place that must be valued. The district becomes the first social housing district rehabilitated in High Environmental Quality.

A color palette was produced by the agency, expert in color design, Nacarat Color design, for all buildings from number 10 to 170. A prescription tool for the renovation project for the facades of the Harlequin and the gallery. It is used by condominiums and social landlords. A palette of materials completes this study. This communication, in the form of a case study, explains the role of color in the enhancement of a collective housing district labeled as a remarkable heritage of the 20th century.

1.1. *The Harlequin of yesterday, bringing color to a modern utopia project*

It takes the form of an "urbatecture" almost a kilometer and a half long. It brings together housing and facilities served by a street running under the buildings, the gallery. It was awarded the Remarkable Contemporary Architecture label in 2003. When it was first built in 1972, these homes for homeownership were rented at moderate or normal rent to elderly, working people or young couples. They are now divided between condominiums and social landlords.

The buildings, historically dressed in polychrome facades (which gave its name to the built complex, The Harlequin) and of decreasing height, are made up of broken lines at one hundred and twenty degrees, with ramifications. The ground floors on two levels called "streets" constitute a long gallery reserved for pedestrian traffic. The vertical circulations serving the floors overlook this “Harlequin gallery”.

It is in volume that the Harlequin stands out: its polychrome mass and its linearity from 6 to 15 floors over 1.5 km long, comprising 1,875 apartments and two residences for the elderly.

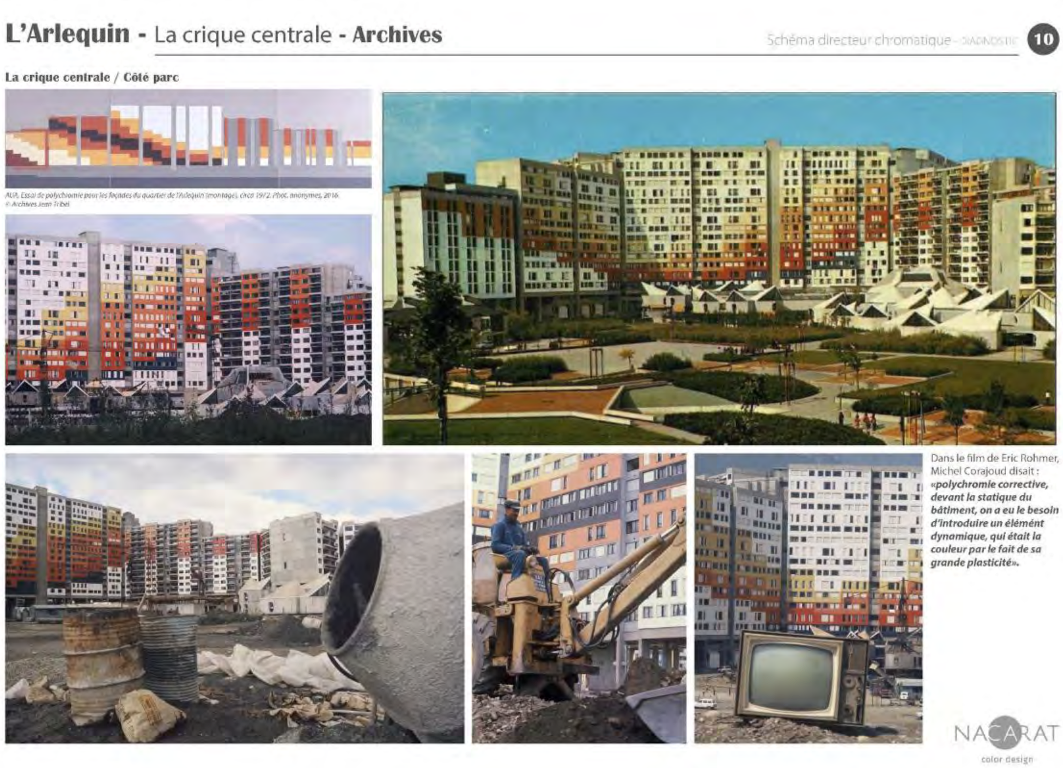

Figure 1. The central cove of the *Harlequin*, archives research, circa 1972, Nacarat Color Design

To the west facing the Belledonne range (French Alps massif), to the east, facing the Vercors massif, the building stands out in the middle of the plain like a new mountain: the differentiated screeding is inspired by the profile of rocky ridges. At the heart of this complex, a park covers 22 hectares, it is made up of grassy mounds that can reach 10 meters in height. The massive and polychrome silhouette of the building delimits part of the park by draping it and playing on its borders. The gallery, an integral part of the megastructure, contributes to the complexity and richness of the Harlequin.

1.2 A district where Art has always had its place

Within *the Harlequin*, Art has always been present. Through both the early integration of works of art and frescoes on and around the buildings of the Villeneuve Park, but also via the workshops set up from the birth of the district and accessible to all its inhabitants (wood workshop, weaving workshop, ... and workshops organized by the inhabitants in the "social" spaces, shared spaces where the inhabitants could themselves organize collective and artistic activities).

For the children, it is again from its birth that the district offers them collective creation workshops, outside school hours, in school premises. Art still invites itself to the Villeneuve through its colored facades.

At the Villeneuve, it is the Atelier d'Urbanisme et l'Architecture (AUA) who initiated this approach, unique in its kind, to elaborate upstream a common reflection between architects and artists. This was complex, and the two entities had difficulty working together, perhaps due to the complexity of the architectural design of the buildings, but this initiative left a lasting mark on the territory as a place of experimentation and research around arts and color.

> Corrective polychromy: in front of the statics of the building we had the need to introduce a dynamic element, which was the color because of its great plasticity.

This sentence, stated by Michel Corajoud in a film by Eric Rohmer, "The shape of the city", in 1975, is fundamental because the consideration of color as the basic frame of the facade design allowed the *Harlequin* to fit into its landscape environment, but also to claim its identity for the century to come.

The built complex has two structural and formal identities:

- On one side, a light curtain wall type facade with a vertical frame made of aluminum profiles fixed to the concrete beams of the facade. The composition of the curtain wall facades combines colored vertical bands, horizontality of the slab nosings, vertical openings in the bay windows and sliding shutters. A weaving effect is thus obtained. The random positions of the shutters, depending on their use, offer a moving vision that reinforces the dynamics of the whole.

- On the other side, a prefabricated concrete facade and aluminum joinery. The molding alternates bays with rounded corners, balconies with full or empty railings. The composition is more classic than that of the first typology created with colored verticals with a set of one or two elements.

1.3 The gallery and the park

Inspired by « The Image of the City » of Kévin Lynch in 1960, the gallery also recalls « The City in space » by Frederick Kiesler (1925). It is the spine of the serpent. At the same time a sheltered street, reserved for pedestrians, places of exchanges, shops, vertical and horizontal circulations: it serves the whole from North to South, punctuated by the vertical services of the housings. It creates the link between the street, the car parks, the mineral to the East and the park, the vegetal, to the West.

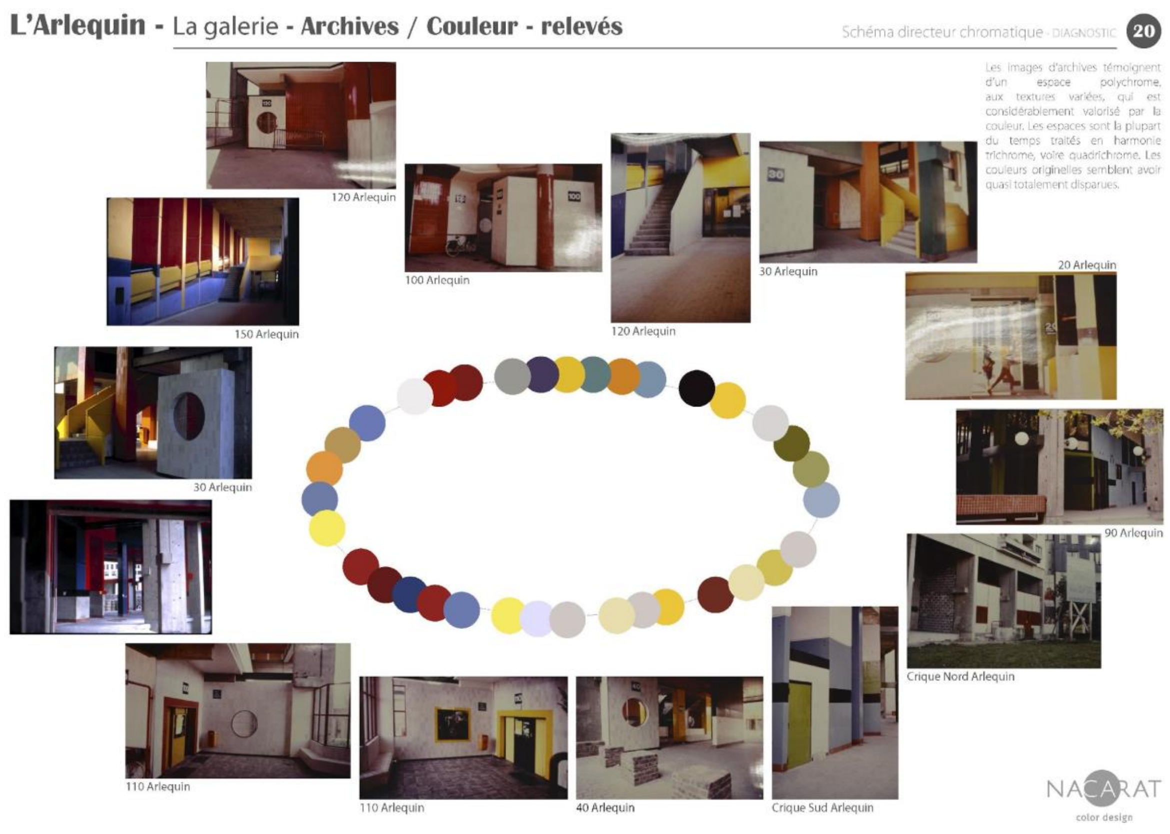

Figure 2. The gallery. archives (circa 1972) and chromatic highlights, Nacarat Color design, 2022

Here again, the sinuous shape allows for a multiplicity of views and routes. As an integral part of the megastructure, it contributes to the complexity and richness of the Harlequin. The polychromy, set up by Michel Corajoud, Henri Ciriani and Borja Huidobro contributes to the unequaled strength of this place. The gallery made the Harlequin famous. The area of the park is 14 hectares, making it the second largest park in the city after the Paul Mistral Park. Again with the idea of breaking the large scale and making the space more complex, the development of mounds or hills made of building embankments, large structuring lines, make possible to diversify the views.

As it was initiated in 1963, urban aesthetics, color and prescription materials can be linked in the urban space, and become the unifying elements of a new quality of life. Conversely, poor management of these elements, or a complete “graying” of the facades of the Harlequin could be the starting point for the construction of a district that cannot take its second flight. Giving back its colors to the Harlequin, by reinventing it for the years to come, is a strong signal for its current and future inhabitants.

2. The Harlequin of tomorrow, a challenge for a building classified as a remarkable heritage of the 20th century.

2.1 History at the service of the project

For the Colorists, a work of quantitative and qualitative surveys of the current colors, the building, and its direct environment by the realization of duplicates of ground, was enriched by numerous archival research. Images from reference books, old postcards, author pyrographs, press articles and cinematographic works shot in situ, have supplemented the information found in the municipal and departmental archives. A work of synthesis by the realization of chromatic maps made it possible to make intelligible the collected data intelligible.

2.2 A process of co-construction

In parallel with this detailed diagnosis, a series of workshops with the co-owners was carried out, with the aim, first of all, of allowing everyone to express themselves and to understand the expectations of the inhabitants.

An urban walk, color chart in hand, at the foot of the buildings was thus organized. The colorists then conducted workshops for the discovery and manipulation of materials and color, with the aim of co-constructing the future history of this collective habitat. To do this, the field diagnosis carried out by the colorists was presented to the inhabitants, and they were able to express themselves on how the first rehabilitations (in the 1990s) then those undertaken in 2019-2020, had played a role on the identity of the district, turning its back, too, with its original polychrome history. A new charter then was created, and two color-material palettes were designed by the colorists, one in line with the historical palette, with bright colors, and the other softer inspired by the landscape colors of the Jean Verlhac Park (Figures 3 and 4).

2.3 The new Harlequin palettes

The new palette for Arlequin corresponds to the multiple challenges of the project: harmonizing and integrating the architecture into its urban and landscape environment, making a link with the history of the building and its DNA, supporting identification in collective spaces, upgrading the Harlequin to allow it to evolve in phase with the major urban renewal project in which it is part.

Figure 3. The details on the city side, the range of materials prescription, Nacarat Color design, 2022

The entire architectural megastructure of the Harlequin is concerned by the mission in order to provide a global and coherent vision. A particular attention is paid to the visual dialogue between the building and the Jean Verlhac park. Beyond the aesthetic and urbanistic issue, which allows through color to make a link in the urban space, and to *the Harlequin* in order to regain its splendor, another issue is emerging for the district.

Figure 4. The details on the park side, the range of materials prescription, Nacarat Color design, 2022

It is a question of carrying an image of renewal for a living space that is too often devalued and little recognized for the quality of life that it can offer to its inhabitants, the quality of its architectural spaces and its landscaped spaces.

These two palettes guide and accompany the choices, one on the city side, and the other on the Park side for the rehabilitation of the Harlequin.

A final co-creation workshop invited the co-owners to compose with the new palette: groups formed by condominium worked together to create the color range of their future building in a logic of continuity with the other numbers of serpentine architecture.

Acknowledgements

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References

Joly, J. et Parent, J-F. 1988. Paysage et politique de la ville : Grenoble de 1965 à 1985. Grenoble : PUG.
Marrey, B. 2004. Guide Rhône-Alpes de l'architecture du XXe siècle. Paris : Ed. URCAUE-Picard.

The colors in the housing buildings in the neighbourhood of Boa Viagem, Recife, Brazil

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Abstract

Analyzing the wealthier classes' multifamily buildings in Recife, Brazil, it was noticed an almost unanimous use of a chromatic palette formed by tones of beige, brown, grey, white, and black. Thus, this research questioned to what extent the use of this chromatic palette, called classic, in the south zone Boa Viagem neighbourhood buildings, and what conditioned their choice over the decades. And there is a relationship between the use of this palette as a symbolism chosen to value classicism as an aesthetic option, historically adopted from the European Neoclassical Movement, with rebounds in Recife. The methodology was based on the method used by M. M. Loder, which consists of photographing the facade and digitally removing the colours of the building's body and its details and thus setting up tables with the colour palette of each building. The ongoing research concludes that most of the colours observed correspond to the so-called classic palette, with less constant variations that explore light shades of blue and green. Other reasons, in addition to the symbolic ones, such as the indicative use of glass for east facades, as well as the economic ones, also account for its use.

Keywords: *Color, Architecture, Facades, Classicism, Composition*

Introduction

This research is an integral part of ongoing doctoral Architecture and Classicism studies and aims to deepen discussions regarding the aesthetic dimension of housing architecture in the city of Recife, Brazil. Analyzing the wealthier classes' multifamily buildings in this city, it was initially noticed an almost unanimous use of a chromatic palette formed by tones of beige, brown, grey, white, and black, more specifically in the buildings concentrated in the south and north neighbourhoods of the area. The Boa Viagem neighbourhood, located in the south zone, mostly concentrates on buildings with coatings in these shades.

Another facet of this phenomenon is about the choice of this palette is related to a symbolism chosen of valorization classicism as an aesthetic option by the wealthier classes, which historically adopted the use of these colours from the

Neoclassical movement of the 18th century, with origins in France and England, and rebounds in the city of Recife.

Thus, this research questions to what extent the residential buildings in the Boa Viagem neighbourhood make use of this chromatic palette, as well as investigate what has conditioned the option for this palette in these buildings over the decades.

Classic colours in the Boa Viagem neighbourhood

The neighbourhood of Boa Viagem, 7.53 km2 long, has been consolidated over decades as a stronghold of the wealthier class of Recife. Located in 1707, due to the construction of the chapel of Boa Viagem, the neighbourhood until the 19th century was an isolated area, and until 1906 it had only 60 houses. Until 1950 the neighbourhood remained a place for vacationers and some fishermen. The wealthier classes had their summer homes there. Remarkable buildings such as Casa Navio imitated the Queen Elizabeth Ocean liner (Cavalcanti, 2016) and eclectic little castles expressed the aesthetic whims of the most fortunate and referenced the architecture of the great cultural centers of Paris and London.

With the inauguration of the Agamenon Magalhães bridge in 1953, bringing the neighbourhood closer to the central regions of the city, the construction of the first skyscrapers in 1957, and the progressive vision of the neighbourhood due to the beach, hotels and the first shopping center in the city in the 1980s, the neighbourhood developed more and more. The great flood of 1975 was an important event for the wealthy classes to flock to this neighbourhood, not affected by the floods, who will have their permanent homes in the multifamily building typology, more coherent with modern urban life.

These buildings demonstrate an almost unanimous use of a chromatic palette formed by the tones of beige, brown, grey, white, and black, the object of this research. Several reasons can justify the use of this palette, among which we focus on the aesthetic choice made by users and builders. In addition to the influence of European eclectic architecture, influences from the neoclassical aesthetics prevailing in Europe are pointed out for the residences of the more affluent. It is known that since the 19th century the classicist aesthetic ideals of France, England and the United States, countries that first developed industrially, influenced the wealthier classes in Brazil and Recife, as a symbol of civility, good taste, and modernity. Previous studies by the authors identified the use of the aforementioned palette, called classical, as derived from European centers since 17th century Palladianism, and described in the works of Annie Sloan and Kate Gwynn.

Also noteworthy is the appreciation of white by historians such as Johann Joachim Winckelmann in the 18th century, by the Purism movement, and by the modern architecture of the early 20th century. References to the predominant use of white in housing were also reported during the colonial period in Recife until the mid-19th century, by Louis Léger Vauthier: "[...]as brancas fachadas das residências, salpicadas por numerosas janelas de madeira pintadas de verde e adornadas com algum filete amarelo e ocre." (Reynaldo, 2017:100). And, by Henry Koster, Maria Dundas Graham Callcott, Louis-François Tollenare, and later on, in the 20th century, by Gilberto Freyre, for whom the 19th century houses, "Numerosas parece que eram caiadas de branco." (Freyre, 1996:208).

These references throughout the history of architecture in Europe and Brazil may be contributing to the appreciation of these colours by local society, and consequently their acceptance and preferences for use in buildings. Other reasons, in addition to the preference of the target audience for this chromatic palette, are being researched, such as economic reasons, given that white and neutral ceramic tiles have a more commercially competitive value.

Methodology

For the development of the research on the colours that are used in the multifamily buildings of the Boa Viagem neighbourhood, it was necessary to develop a method, for which that of Loder (2013) could be corroborated, and given the analysis of the proposed theme, it was necessary to divide the five-step search.

The first stage consisted of delimiting the area to be worked on, and with the help of Google Maps and ESIG, a digital service of geographic information in Recife, the neighbourhood was divided into five large zones, with each zone being named according to its Z(n) number, as can be seen in Figure 1.

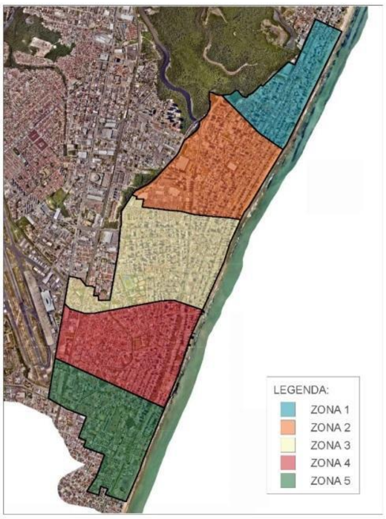

Figure 1. Map Zones / Source: ESIG, edited by the authors, 2022.

The second stage consisted of dividing each predefined zone into blocks. Each block was defined with a letter of the alphabet as shown in Figure 2.

In the third stage, the plots of each block were marked, which were enumerated to facilitate the recognition of the location.

Figure 2. Block and Lots Map / Source: ESIG, edited by the authors, 2022.

In the fourth stage, a photographic survey of the facades of the buildings was carried out. Initially, the survey was restricted to the facades that are on Avenida Boa Viagem, which is located by the sea. The photographic survey was carried out in loco, between 10:30 am and 11:00 am so that the sunlight did not fall perpendicularly on the facades, increasing the brightness of the coatings and so that they did not generate shadows that could harm the intended appearance of the colours.

The capture of colours was done in three fields, one called the body, which comprises most of the facades of the buildings, the other field called details, which comprises the smallest parts of the facades, and a third field defined by the fenestrations, normally in aluminum and glass frames.

From these records, the colours present in each facade were identified. The colour palette for each building was set up, with the help of Illustrator Software, as shown in Figure 3. With this process, the images generated in the survey obtained the nomenclature Z1/ A/L1, facilitating the cataloging and the grouping of information.

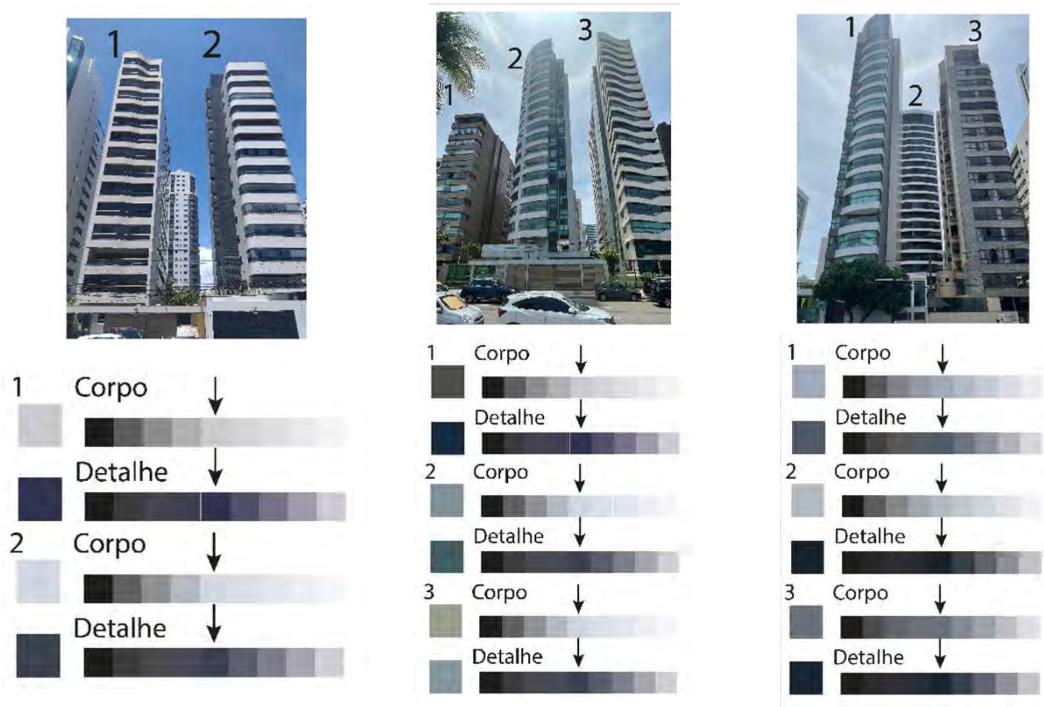

Figure 3. Color Palette / Source: Authors, 2022

In the fifth stage, an analysis of the colours presented in the palette of each building was carried out. The chromatic groupings were evaluated, that is, the combinations between the colours of the body of the building and the colours of the details of the facades, so it can be seen the occurrence of the chromatic palette called classic in all the buildings surveyed so far in what concerns to the body and details, with small variations in the fenestrations.

Finally, it would be possible to add a sixth stage in which interviews with the construction companies would be carried out to identify the reasons that led to the adoption of these colours, which is supposed to be due to the high cost of colours other than white. In this sixth stage, there is a direct correlation with Loder (2013), however, the difference is that in the research by Loder (2013) the questioning is made to the residents and in this stage, it will be made to the builders.

Conclusion

It is concluded with the studied sample that the facades of the buildings are mostly white or gray in their various shades, with details of blue, green, or beige.

However, it is possible to notice some exceptions to the rule when the buildings have their body in shades of brown.

It is noticed that both the body colours and the colour of the details and frames have mostly neutral and cold colours, with blue and green tones prevailing for the windows. In addition, some properties have an achromatic colour palette, with their main colour being white and their details, such as the frame or guardrail, being black.

It was also possible to notice that in the neighbourhood there are still single-storey buildings, like houses, but they follow the chromatic patterns perceived in the neighbourhood. Also, the frames, with the different shades of glass, have great participation in the final aesthetic aspect of the buildings, since, due to the east orientation to receive the best insulation and ventilation, most of the facades are covered by the frames, being the rest of the building's body effectively with the coatings in the indicated shades.The adoption of the so-called classic colour palette has been confirmed in the studied sample, given that all the buildings were presented in shades of beige, brown, gray, white and black. This reality is consistent with the neighbourhood's history of having developed as a zone of preference for the middle and upper-middle classes and is classified as an elite neighbourhood, which has demonstrated, throughout Recife's history, its symbolic preferences.

References

Calvacanti, C. B. 2016. *O Recife e seus bairros*. Recife: Poço Cultura.

Farina, M. 1990. *Psicodinâmica das cores em comunicação*. São Paulo: Edgar Blucher.

Freyre, G. 1996. *Sobrados e Mocambos: Decadência do Patriarcado Rural e Desenvolvimento Urbano.* Rio de Janeiro: Editora Record.

Guimarães, L. 2000. *A cor como informação: a construção biofísica, linguística e cultural da simbologia das cores*. São Paulo: Anablume.

Loder, M. M. 2013. *Cor e habitação: um estudo dos aspectos cromáticos das fachadas de conjuntos habitacionais da cidade de Pelotas.* RS. Pelotas.

Reyhnaldo, A. 2017. *As catedrais continuam brancas. Planos e projetos do século XX para o centro do Recife*. Recife: Cepe.

Session 7
Colour Education - II

Colour preferences and use in textiles design and decoration amongst students

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Abstract

Colour is the most important and exciting element of design that catches one's attention for fabric selection. Colour plays important roles in the designing and production of textiles artefacts. It gives life to the textiles product as they become what they are because of their inherent colours. Batik and tie-dye making are textiles products that predominantly depend on colours (dyes) for their decoration. It is an aspect of textile production on which students exhibit a wide range of creativity in fabric decoration. Various tints and shades of colours are uniquely characterized by blended schemes in their productions. So, how do students describe their works? How appropriate are the colours they choose for dyeing their works? Why do they prefer specific colours for decorating their fabrics and what influences their choice of colours? These are the key questions guiding this inquiry into the preferences and uses of colours by student-designers in their freestyle fabric designs and decorations. The study found that students' preferences for the choice of colour for their batik and tie-dye works are influenced by the Ghanaian colour symbolism, the cultural environment, and purpose and uses for which the designs were made.

Keywords: *batik, tie-dye, textile colours, design, symbolism.*

Introduction

Colour is one of the most versatile elements in art that undeniably gives vision to a designed artwork. It is the lens through which designs are perceived. No element of design is as exciting or as confusing as colour. However, it is the most important and exciting element of design that catches one's attention and sets the stage for fabric selection. Understanding how colour behaves the way it does, determines more skilfully and expressively it is used for designing. In Ghanaian cultural settings colour plays a major role in everything that is designed. Colour is represented as part of the culture and each colour performs some specific functions that contribute to the maintenance and sustenance of life and living.

Individual colours and colour groupings have symbolic meanings and significance founded on Ghanaian historical, philosophical, and spiritual values.

Colour plays a vital role in the Ghanaian setting. It affects thoughts, mood, and emotion. It can make one either happy or sad. It can sway thinking, change actions, and cause reactions. It can irritate or soothe the eyes, raise blood pressure, or suppress appetite (Cherry 2019).

As a powerful form of communication, colour is irreplaceable in human activities and an inseparable tool from culture and tradition. In the Ghanaian context it is a strong medium of communication and one which is linked closely to the history and environment. Indeed, our sense of colour is perceived through our environment which has its symbolism in our cultural milieu. With this regard, colour becomes very important in the day-to-day activities of the individual. As confirmed by Ayiku (1998) (cited in deGraft-Yankson, 2020), for the Akan people to use colour symbolically and ground colour meanings within Ghanaian historical, philosophical, and spiritual values therefore seems very plausible. Persistently, the traditional Akan people have recognized the social/physical and religious/spiritual relevance of colours and have used them in ways that impact beneficially on their lives. The overall implication is that, beyond their visual qualities, colours command great social relevance as well. Colour can be described as the biggest tool for expressing information about a situation in the cultural setting among the people of Ghana notably the Akan people who form the majority ethnic group in Ghana. (deGraft-Yankson, 2020)

These concepts are translated into every artistic product that must deal with colour. Textile products are no exception. Dyeing, (batik & Tie-dye), printing, embroidery, crocheting artifacts etc. produced under textiles are what they are because of their inherent colour. A textile work is deemed aesthetically pleasing due to its inherent colour application. Colour influences a wide array of open themes when it comes to dyeing. In Ghanaian tradition, colour plays an important role in fabric design and decoration. Ghanaian printed fabrics come in so many colours, which are carefully selected in terms of their meaning, association, and usage (Amissah. 2018).

The production of batik/tie dye fabrics in Ghana, although not indigenous has come to be accepted as a fabric production method as well as one of the easiest ways of starting business (Frimpong, 2009). Its introduction came along with materials and methods which are not necessarily Ghanaian. However, the techniques and skills have found themselves into the school curriculum which is studied at all levels of the Ghanaian educational sector. It is through this, that the craft is studied as a component of textiles education in the Department of Art Education, University of Education, Winneba. Students are taken through the various production techniques and skill in batik and tie-dye making. They produce very interesting designs with elegant colours which come in various tints and shades that uniquely are characterized by the blended colour schemes that are visible in the after the dyeing process. Batik and tie-dyeing also influence a wide array of open themes when it comes to dyeing.

The choice of colour for textiles design basically hinges on certain factors that the artist deems appropriate to use. The designer must be able to explain the concept and appropriateness of the chosen colours through aesthetic discourse. Most often, the best explanation a student may give to describe a chosen colour for making batik or tie-dye is either "I like the colours" or "they are nice" or "they are beautiful". These are not appropriate responses to describe aesthetically pleasing artefacts. There is therefore the need, to explore what influences their choice of colours for the works they produce by finding answers to; How students describe their works, how appropriate are the colours they choose for dyeing their works, why they prefer specific colours for decorating their fabrics, what influences their choice of colours of their works. Responses to these will reveal what informs the colour choices and preferences of student-designers in their freestyle textiles fabric design (batik and tie-dye) and decoration.

Methodology

The study employed a qualitative inquiry approach to solicit views from textiles students on colour application and decoration in their batik and tie-dye productions. Qualitative inquiry was used as it focuses on the discovery, description of experiences and view of research respondents. (Given, 2008; Acquah, 2015). The census sampling technique was used to select twenty-five (25) third-year textiles students from the Department of art Education, University of Education, Winneba for the study. Data was collected through interviews and observations and the analysis was done descriptively. Annum (2014) defines interview as an interaction in which verbal questions are put forward by the interviewer to bring out oral responses from the interviewee. Observation is a way of gathering data by watching behaviour, events or noting physical characteristics in their natural setting (Pilot and Becks, 2008, Kothari, 2004). The researcher actively took part in the situation under study as he was constantly with the students at the dyeing studio, observed processes, conducts and behaviours of the students as they went through the batik and tie-dyeing production. Students were asked to describe their fabrics (batik and tie-dye) based on choices, preferences, and influences of specific colours they apply in the execution of their products.

Results and Discussions

The interpretation and analysis of data collected for the study was intended to provide the necessary basis for the findings and conclusions reached. It is organised based on three themes: description of works as aesthetic objects; appropriateness and preferences for the choice of colours for fabrics decoration; and Influences and uses of chosen colours.

The description of works as aesthetic objects

Respondents gave detailed descriptions of their works, outlining the various elements and principles of design as used in their designs. Two works are presented for the aesthetic discourse, one batik product and one tie-dye product. These are presented below:

Batik work

Figure 1. Batik work showing the various colours used in the colouration.

The colours identified in the work are white, green, yellow, and purple colours. The white colour depicted in the design showing some brush strokes and spots of varying shapes is associated with cotton or white clay (kaolin) in our Ghanaian setting. The cotton is for the fibres used in the production of the white cloth. White symbolizes purity, victory, joy, virginity, and spirituality, as its state of being faultless before God. The rendition of yellow in the fabric is associated with the richness of the colour and represents the fat of a chicken and gold metal. It connotes riches, abundance, and prosperity of individuals and the state. It also symbolizes royalty, continuous life, warmth, and the rule of God or a king. Yellow has been used to initiate beautiful patterns in the cloth. The depiction of green in the fabric is associated with vegetation. It symbolizes newness or youthfulness, vitality, fertility, and growth. It represents productive farms and the hope for a bountiful harvest.

The background colour of the cloth is a mixture of blue and red, giving a purple effect to the fabric. Purple is not directly associated with anything in the traditional Ghanaian society and therefore has no much connotations. Blue in the Ghanaian tradition is associated with the sky and water, which signifies a state or quality of being serene, calm, tranquil and peaceful. It also connotes fidelity, female tenderness, and other attributes pertaining to love and affection. Water is life. Its association with blue makes the blue colour a symbol of fertility for the earth, humans, and animals. White is widely used in everyday life activities, most especially in marriage and funeral rites. It also symbolizes love and fertility.

The red colour is associated with blood. It is used to symbolize a state of alarm, danger, unrest, fear, anger, hatred, aggression, violence, and conditions relating to death, calamity, or disaster. It is also used as a sign of danger to warn people away from certain situations. These two colours put together give a feeling of love and protection. The total rendition of these creates a feeling of harmony and unity among the colours in relation to their visual quality, symbolic meaning, association in nature, and their usage. These were the views that informed the student's preference and choice of colours for the art piece.

Tie-dye work

Figure 2. Tie-Dye Work.

The resist technique used in this tie-dye was aesthetically manipulated in a unique manner to create curved-like lines and exquisite textures to harmonize each other. The design depicts cloud-like shape in a repetitive manner arranged to juxtapose and create a harmonized path of movement throughout the fabric to suggest the dynamics of life. The unique choice of colours of the fabric attracts and sustains the attention of the viewer. The use of red, tint of blue, violet, white and shade of red (brown) matches well to portray the unity and strength embodied in the fabric as a reflection of behaviours in traditional Ghanaian societies. Red is perceived as a natural colour which in the Ghanaian setting, is associated with blood, sacrificial rites, shedding of blood, passion, and lust. Red is therefore used as a symbol of heightened spiritual and political mood, sacrifice and struggle, sadness and danger or warning.

In the traditional societies, red is used in the shrines for sacred purposes, festivals and during funeral rites to connote sorrow and bereavement. Blue is associated with the sky, the abode of the Supreme creator and the ocean. It is therefore used in a variety of ways to symbolize serenity, stability, inspiration, good fortune, spiritual sanctity, and health. It can also be associated with life, harmony and love related ideas. (Violet is also an associated colour used in rituals and healing purposes. It is also associated with feminine aspects of life. It represents the strong and beautiful nature of womanhood. Violet clothes are mostly worn by females in the Ghanaian society).

White is associated with the shell of the egg, cotton and from white clay (kaolin) used in spiritual purification, healing, sanctification and festive rites, marriage, and outdooring occasions. In some situations, it symbolizes contact with ancestral spirits, deities, and other unknown spiritual entities such as ghosts. It symbolizes perfection, faith, innocence, vitality, softness, and cleanliness. Brown is an earthly colour that symbolizes dependability, comfort, strength, growth, and a sense of being grounded. It may be used to represent dullness and predictability. It is associated with spirits of the land. Traditionally, it is believed that living things spring up from the soil and are considered as the base for fertility and growth. All living creatures depend on the earth for survival and food. The fabric can be used for many occasions that includes festivals, traditional marriages, rites, church, work etc.

The above narratives are examples of how the students aesthetically presented their views on the works they created. The discourse indicates that all the students followed the same pattern in their discussion. They provided the meanings and significance of the colours as used in the Ghanaian traditional context. No specific name is attributed to any of the colours as the tints and shades of the colours remain the same. 'Yellow is yellow' and 'green is green' despite the different tints and shades as indicated in the fabric. This affirms deGraft-Yankson's, (2020), assertion that, from the Akan perspective, colour hardly discriminates among shades, tones, and value. Therefore, the conventional properties of colour as presented by the western colour scheme have little or no bearing on the description of colours among the traditional Akan people. Due to this it was not difficult for any of the students to ascertain specific vocabulary that can conveniently be used to describe colours in the Ghanaian language.

Appropriateness and Preferences for the choice of colours for fabrics decoration

Students gave their views on the above theme. One of them wrote that: "I do not have any preference for any specific colour. I usually work with the colours (dyes) that are available at any time I work. To me, there is nothing like appropriateness of colour. Colours available are utilised and interesting designs are produced from them. Once the colours can be related to culture and tradition, it is okay to work with". From the above, though the student debunked the idea of appropriateness in his submission, the cultural and traditional relations identified makes the choice of colours used at any point in time appropriate. Many of the students were of the view that appropriateness and preferences for colour choice in their designs come by themselves as batik and tie-dye processes produce a variety of interspersed backgrounds. Once the resultant colours can easily be identified within the environment the colours are considered appropriate. It was also realised that the outcome of the colours creates interesting designs.

Influences and uses of chosen of colours

Almost all the students agreed that the choice of colours for the execution of their design works were influenced by the colour's association in nature, the philosophical or spiritual meaning they possess and how relevance the colour may have in the community and the society. This confirms Ayiku (1998), (cited in deGraft-Yankson (2020), who in prescribing tenets for the study of colours in Ghanaian schools, outlines three complementing approaches thus: The first is by finding out what in nature a particular colour is associated with or represents; second by finding out its meaning, that is, the historical, philosophical, or spiritual ideas it symbolizes; and third, by exploring its uses or social relevance. This has greatly affected how colour is perceived and addressed in the educational set-up in Ghanaian schools. Many of the students are of the view that colour significance and symbolism cannot be left out in the quest to create textiles designs. The designs based on the colour combinations should relate to the socio-cultural values of the society. Another student asserts that; 'batik and tie-dye design fabrics are produced for use on many occasions that includes festivals, traditional marriages rites, church, work etc. and therefore, whatever design is produced finds its use in the society'. In the view of the student, batik and tie-dye fabrics are made for utilitarian functions. Colour influences and uses are therefore relevant to their creation because no matter the outcome of the design it will be put into an appropriate use.

Conclusions

The study found that colours as used in the designing of batik and tie-dye fabrics cannot be in isolation from the cultural and symbolic meanings associated with the people. It is part and embedded in the lives of the people. It was also found that fabrics are worn to occasions based on the symbolic meaning of the colours in the prints. Colours control the emotional aspects of the people who wear such designs. There is also a lack of vocabulary in expressing ideas in terms of colour significance except to relate them to the things found within the environment which have symbolic meanings in most ethnic groups in Ghana. It was also realised that some colours do not have meanings in Ghanaian culture as they cannot be associated with the environment. The study concludes that students' understanding of colour concept, preferences and uses are different from the western world which has for many years influenced the educational milieu in Ghana. The study recommends that students should be encouraged to appreciate their culture and traditions as they play an important role in understanding the use of colour in their environment.

References

Acquah, E. 2015. *The response of art teachers in Ghana to Ghana's cultural policy*. (Doctor of Philosophy in Dissertation). Urbana-Champaign: University of Illinois.

Amissah, E. R. K. & Lecther-Teye, S. M. 2018. Artistic and Cultural Significance of Ghanaian Printed Fabric Designs. Current Trends in Fashion technology & Textile Engineering, 2, (4), 1-7.

Annum, G. 2014. *Research instruments for data collection*. Kumasi, University Press.

Ayiku, R. K. 1998. Symbolic meanings in the Ghanaian arts: A step towards developing cultural literacy, Ph.D. thesis, Montreal: Concordia University.

Cherry, K. 2019. Colour psychology: Does it affect how you feel?, *Verywell Mind Cognitive Psychology* Post, 28 May, https://www.verywellmind.com/color-psychology-2795824. Accessed 12 March 2022.

deGraft-Yankson, P. 2020. Of the Akan people: Colour and design education in Ghana, *International Journal of education through art* Volume 16 Number 3 © 2020 Intellect Ltd Article.

Given, L. M. 2008. *The Sage encyclopaedia of qualitative research methods*. Los Angeles, California, Sage Publications.

Kothari, C. R. 2004. *Research Methodology: methods and techniques* (2nd Ed) New age International Publisher.

Polit, D.F. and Beck**,** C.T. 2008. *Nursing Research Generating and Assessing Evidence for Nursing* Practice 8th Ed., Wolters Kluwer Health/Lippincott Williams & Wilkins, Philadelphia, 796.

Two Voids in the Language of Colour

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Abstract

In this paper we highlight the lack of generally understood terms for two key colour concepts. First, there is not a commonly understood term for the totality of colours we can perceive or imagine. Terms currently under consideration to fill this void are the 'colour universe' and the "universal gamut'. Second, although the measurable attributes of colour are well defined, there is not an equally well-defined term for dividing the colour universe by sets of colours of different hues that share similar perceptual characteristics, such as pale, dark, or muted colours. We propose the term 'colour character' and argue that the adoption of this, or another more suitable term, possibly NCS 'nuance', would be helpful in describing colours since it is this aspect of a colour's appearance, more than its hue, that is useful in communicating meanings.

Filling these two voids in the language of colour is a critical step in a paradigm shift that expands our understanding of colour beyond the rainbow hues. Naming these concepts will not only assist in the teaching of colour in early childhood education but could also advance colour awareness in the public at large.

Keywords: *Colour Education, Colour Language, Colour Sorting, Colour Systems, Colour Variations*

Introduction

In order to expand our understanding of colour beyond the rainbow, we need an easily understood term that describes the full range of perceivable colours in an imaginary three-dimensional space. For the purposes of this paper we will use the terms 'the colour universe' or the universe of colour.

For centuries people have categorized the colour universe according to hue. This basic mental construct, or Hue Paradigm (Divers, 2020), has permeated how we think, how we teach and how we conduct research on colour. But there is another way to categorize colours that have no name - dividing the universe of colours based on variations of the vivid hues, such as "dark", "pale", "muted" and "vivid" instead of hue. In recent years the evidence has begun to point to the fact that this type of sorting colour actually elicits a more consistent emotional response from people than does hue (Valdez & Mehrabian, 1994, Divers, 2020).

Expanding our foundational understanding of colour beyond the rainbow colours is a paradigm shift. Paradigm shifts such as this one often require new language and this is where we are, searching for 1. a term such as the universe of colour and 2. an umbrella term to identify the colour categories, which divide the universe of colour, not according to hue, but according to ___? ___.

Limitations of Vocabulary

At the AIC 2021 congress we presented a paper in which we drew attention to the limitations of our vocabulary in relation to colour (Green-Armytage and Maggio, 2021). We pointed out that the emphasis in early colour education is on vivid colours with little attention paid to the extensive range of other colours 'beyond the rainbow'. We introduced a sorting set of 45 colours consisting of nine hues, each with a vivid, light, dark, and muted variation plus a nine-step grey scale from white to black. We used the term 'hue family' rather than the single word 'hue' since young children, especially, are not familiar with the word 'hue' but they can easily recognise the relationships between colours of the same hue and can readily associate that with the concept of 'family'. As we tested the sorting set, we became aware of two particular voids in the language relating to colours.

First, we do not have a commonly understood word for the totality of perceivable colours. It is possible to think of a seamless continuum of colours in a kind of cloud with colours getting paler towards the top, darker towards the bottom, more vivid towards the outside of the cloud and more muted towards the centre. From within this cloud individual colours have been singled out for the various colour order systems, but there is no single definitive term that encompasses all the colours that we can perceive or imagine.

Second, we found a void in the language for describing sets of colours that share perceptual similarities unrelated to hue. While all systems start by sorting colour by hue, there is no stand alone word, commonly understood, that can be used to describe the sorting of colours into 'pale', 'dark' and 'muted' variations of each hue family. There are examples of this type of sort, as illustrated in Figure 1, but we do not have a name for it. Sort by ___?___.

Considering Possible Terms

Instead of one term, most colour ordering systems use two terms in addition to hue to describe colours – 'blackness' and 'chromaticism' in the NCS; 'value' and 'chroma' in Munsell. But there are a few examples of organizing similar variations across hues. The ISCC-NBS Dictionary of Color divided hue planes into over 20 variations (Figure 1a). In Japan, the Practical Color Coordinate System (PCCS. Japan Color Research Institute. 1991) and the Hue and Tone System (Kobayashi. 1986), both based on Munsell, use the single English word 'tone' for the combination of value and chroma (Figure 1b).

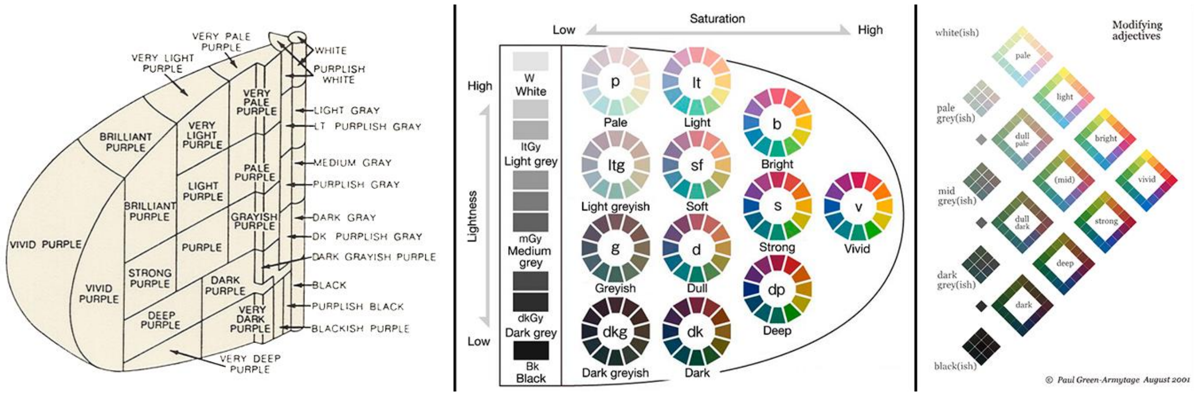

Figure 1. Examples of organizing colours by similar variation of hue. **1a.** ISCC-NBS (1955) **1b.** PCCS (1991) **1c**. Green-Armytage (2001).

Tone is not a suitable term for our purpose in that it already has two kinds of meaning in relation to the visual arts. Monochrome illustrations – drawings in pencil or charcoal as well as photographs in 'black and white' – are sometimes referred to as 'tonal' illustrations. Faber Birren (1969) uses the term 'tone' together with 'tint', 'shade' and 'full color' to characterise the appearance of colours and their rough positions in a triangular hue plane. Birren (1969: 51) defines these four terms as: "Color and white combine to create *tint*. Color and black combine to create *shade*. Color, white, *and* black combine to create *tone*."

For our sorting set we also limit the key variations to four distinct sets. We refer to Birren's 'tones' as 'muted colours'. His tints, shades, and full colours we call 'pale', 'dark' and 'vivid' colours respectively. This allows the terms 'tint', 'tone' and 'shade' to be used for the shift in appearance of any colour, not just vivid colours, toward white, grey, and black.

We have made one change to the terminology we introduced in our previous paper. We have replaced 'light colours' with 'pale colours'. This is to avoid any confusion that might arise from our use of the term 'lightness' as the equivalent of Munsell 'value'.

In the NCS the term 'nuance' refers to the combination of blackness and chromaticity that locates a colour in the triangular hue plane of that system (Hård and Sivik. 1981). Paul Green-Armytage (2002: 861-864) divided NCS colours into 'zones' with the same nuance (Figure 1c). The word 'nuance' is defined in the Oxford English Dictionary (1989) as: "1. A subtle variation or difference in meaning, expression, feeling etc. … 2. *Spec.* a. A subtle shade of a basic colour: a slight difference or variation in shade or tone." If nuance were more widely used with that second meaning it would fill this void in the language, but at present it is too closely associated with the NCS system where it is defined specifically in relation to the scales of blackness and chromaticity.

What is missing from everyday language is a term that could apply to similar colour variations in any system. To identify this aspect of a colour's appearance in our presentation at AIC 2021 we used the term 'colour character'. We may find a more acceptable term, but for now we are using that term. We can now describe a colour in terms of its character and its membership in a hue family. We can talk about a colour as a vivid red, a muted green etc. And we can use a simple notation: vR for vivid red and mG for muted green.

Meanings communicated by colour variations

Having a term like 'colour character' to fill this void is particularly desirable given that it is often this aspect of a colour's appearance, more than its hue, that communicates meanings. This is clear from the work of Lars Sivik (1977), who uses the NCS and his 'iso semantic maps' to plot colour connotations. This was also a key finding from the research of Ellen Divers (2020).

In a study conducted by Osvaldo da Pos (2007), participants were asked to put together a combination of three colours that 'best fit' pictures of faces expressing basic emotions. Colour combinations for faces expressing happiness and sadness are shown in Figure 2.

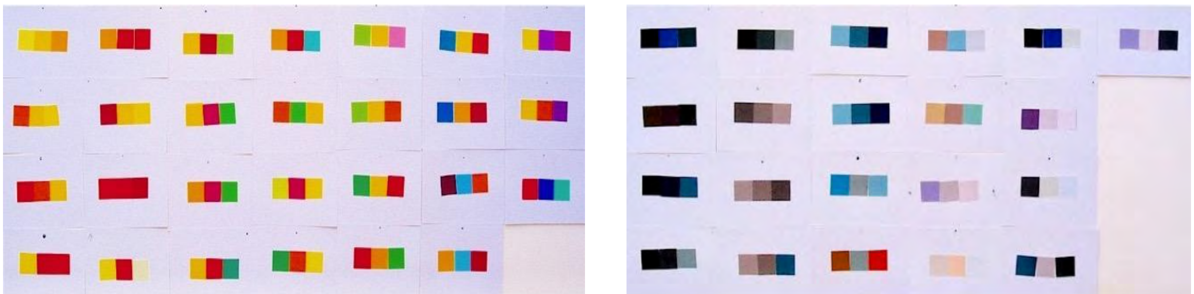

Figure 2. Colour combinations that best fit pictures of faces expressing happiness (left) and sadness (right}.

While hues clearly play a part here with red, orange, and yellow being 'happy colours' while blue and violet are 'sad', it is significant that the happy colours are also vivid while the sad colours are dark and muted. More research is needed on the connection between meaning and 'character.'

Shigenobu Kobayashi's research into colour meanings are incorporated in his *Color Image Scale* (Kobayashi 1981). Students at Edith Cowan University have used three-colour combinations to 're-invent' parts of the Color Image Scale. Colour combinations produced by the students to communicate 'lively' and 'peaceful' are very similar to those proposed by Kobayashi. Here it is definitely the 'characters' that play the key role (Figure 3). Lively colours and peaceful colours come in a wide variety of hues, but lively colours are vivid while peaceful colours are pale and muted.

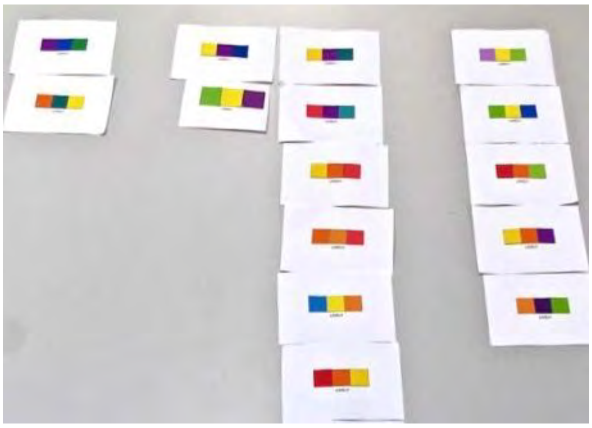

Figure 3. Some of the colour combinations produced by students to communicate 'lively' (left) and 'peaceful' (right).

The Colour Literacy Project

The Joint ISCC/AIC Colour Literacy Project is a four-year project to review the status of colour education, test prototype materials, and develop curricula for a new, experiential approach to learning about colour. A major goal of the project is to expand beyond the concept of basic colour terms and beyond traditional colour theory by introducing new ways to think about and explore colour in all its variations.

Volunteer teachers are helping us to understand the kinds of colour categorization activities that will be effective in primary schools. The teachers have used our prototype sorting set of coloured tiles and had no problem sorting colours into groups of the same hue. They were also able to sort colours into groups where all the colours are pale, dark, muted, or vivid (Figure 4).

Figure 4. Colours organised by teachers into hue families (left) and groups of the same character.

After they organised the tiles into groups of the same character we asked them to write words for the meanings they derived from the groupings (Figure 5). The words they wrote provided further evidence that meanings are associated not just with a colour's hue but especially with this other aspect of a colour's appearance – its 'character' or whatever word we use to identify it.

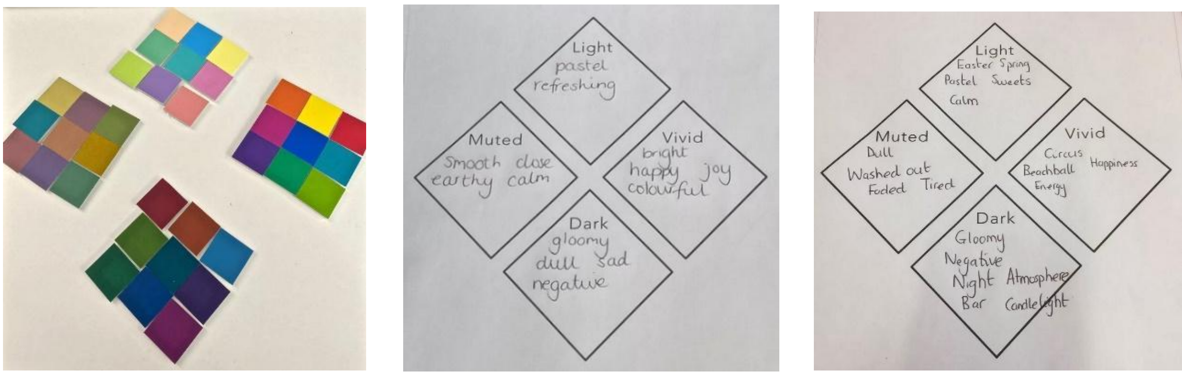

Figure 5. Colours organised by character, and words for the meanings suggested by the colours.

Following the workshops, some of the volunteer teachers introduced our foundational concepts into their classrooms. After working with their students, the most frequent request was for more definitive terminology. The teachers reported that students could see the distinctions between the colours and became frustrated by not having the words to describe what they could see. And, without the terminology, the teachers were at a loss how to help.

Conclusion

For the purposes of the Colour Literacy Project, we need to identify acceptable words to fill two voids in the language of colour for prototype testing with teachers and students in the upcoming 2022-2023 school year. First, the proposed term for the totality of colours we can perceive or imagine is the 'colour universe'. Second, the proposed term for dividing the colour universe into sets of colours of different hues that share similar perceptual characteristics is 'colour character'. We invite suggestions and hope that people will weigh in on our choices of 'colour universe' and 'colour character' and/or propose more suitable alternatives for these two key concepts in colour education. We believe that this expansion beyond the rainbow will build awareness of both the totality of perceivable colours and the appearance characteristics of colours apart from hue.

References

Birren, F. 1969. *Principles of Color*. New York: Van Nostrand Reinhold Company.

Da Pos, O., and P. Green-Armytage. 2007. Facial Expressions, Colours and Basic Emotions. *Colour: Design and Creativity*. 1 (1):2, 1-20.

Divers E. 2020. Beyond Hue: The affective response to value and chroma. In: *The International Scientific Conference of the Color Society of Russia*: *Selected papers.* Smolensk: Smolensk State University Press.

Green-Armytage, P. 1980. Violets aren't Blue: Colour Sensations and Colour Names. in *Arts in Cultural Diversity*, Condous, J., J. Howlett, & J. Skull, eds. Sydney: Holt, Reinhart, and Winston.

Green-Armytage, P. and M. Maggio. 2021. Beyond the rainbow: a new sorting set for teaching colour. In *Proceedings of the International Colour Association (AIC) Conference 2021*. Milan: Gruppo del Colore (Associazione Italiana Colore)

Green-Armytage, P. 2002. Colour Zones – Explanatory diagrams, colour names and modifying adjectives. In *Proceeding of the International Colour Association (AIC) Congress 2001*. Bellingham, Washington: SPIE- The International Society for Optical Engineering.

Hård, A. and L. Sivik. 1981. NCS – Natural Colour System: A Swedish Standard for Color Notation. *Color Research and Application*, vol. 6, no 3, 129-138.

Japan Colour Research Institute. 1991. *PCCS Harmonic Color Charts 201-L*. Tokyo: Japan Color Enterprise co., Ltd.

Judd, D.B. and K. Kelly. 1955. The ISCC–NBS Method of Designating Colors and a Dictionary of Color Names.

Kobayashi, S. 1981. The Aim and Method of the Color Image Scale. *Color Research and Application*, vol. 6, no 2, 193-107.

Kobayashi, S. 1987. *A Book of Colors*. Tokyo: Kodansha International.

Simpson, J.A., and E.S.C. Weiner contributors. 1989. *Oxford English Dictionary*. Oxford: Clarendon Press.

Sivik, L. 1977. The Language of Colour: Colour Connotations. In *Colour for Architecture*. Porter, T., and B. Mikellides, eds. London: Studio Vista.

Valdez, P., and A. Mehrabian. 1994. Effects of Color on Emotions. *Journal of Experimental Psychology,* 4, 394-409.

A Shillito Student Portfolio from the Mid-1940's

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Abstract

We illustrate and describe a remarkable portfolio of colour exercises and notes produced at the East Sydney Technical College (now the National Art School, Sydney) by Helen Jean Burgess (1926-2018) while she was a student in the Design diploma course in 1943-47. The portfolio comprises a woven fabric cover and 36 loose boards in three sections, "Shillito Theory", "Ostwald Theory", and "Munsell Theory". Forty-four typed sheets are attached to the reverse sides of 24 of the boards. The first includes Shillito's distinctive double-primary hue classification, but the remainder in their entirety closely paraphrase or copy verbatim passages from just seven texts, namely Henry Barrett Carpenter's Suggestions for the Study of Colour (1915, 1923), Maitland Graves' The Art of Color and Design (1941) and five texts on the Munsell and Ostwald systems. We compare the influences evident in these sheets with lecture notes recorded thirty years later by one of us (Eva Fay) as a student at the Shillito Design School and find that these also closely paraphrase or copy verbatim most of the same sources, including Graves and especially Carpenter, with minor additions including some passages from Birren, but no text we can attribute to Itten or Albers.

Keywords: *Colour theory, colour education, Phyllis Shillito, double primary palette*

We illustrate and describe a remarkable portfolio of colour exercises and notes produced at the East Sydney Technical College (now the National Art School, Sydney) by Helen Jean Burgess (1926-2018) while she was a student in the Design diploma course in 1943-47. The portfolio is important as an early record of the colour curriculum of Phyllis Shillito, who was a major influence on the teaching of colour theory and application in Australia, both directly from the 1920's to the 1970's, and indirectly through former students of hers who went on to become prominent educators in the design disciplines and the fine arts. The catalogue entry for the item at the Caroline Simpson Library & Research Collection in Sydney includes a biographical note on Helen Jean Burgess.

The Burgess portfolio comprises a woven fabric cover and 36 loose boards in three sections, "Shillito Theory" (13 boards), "Ostwald Theory" (12 boards) and

"Munsell Theory" (11 boards). Thirty of these boards feature renderings in gouache that range in complexity from a simple nine-step value scale to intricate Ostwald and Munsell pages that each required careful mixing in gouache of dozens of colour chips. The portfolio also includes six annotated transparent overlays, three pen and ink versions of Munsell and Ostwald diagrams, and 44 part-sheets or full sheets of typed text attached to the reverse sides of 24 of the boards. We have examined these sheets and found that almost in their entirety they closely paraphrase or copy *verbatim* passages from a total of just seven texts. These texts comprise Henry Barrett Carpenter's *Suggestions for the Study of Colour* (Carpenter, 1915, 1923), Maitland Graves' *The Art of Color and Design* (1941) and five texts on the Munsell and Ostwald systems and theories of colour harmony.

The notes in the "Shillito Theory" section of the Burgess portfolio are all closely based on Henry Barrett Carpenter's *Suggestions for the Study of Colour*, except that in places Shillito's 15-hue classification (see below) replaces Carpenter's hue terms. The plates in this section illustrate "Simple Harmonies" and "Discords" in the sense that these constructs were defined by Carpenter, plus "Pure Colours, Tints and Shades", "Contrasts and Tints", a grey scale, and two "colour wheel" diagrams designed by Shillito. The "Shillito Wheel" (Plate 2) illustrates a distinctive 15-step palette-based hue scale that was Shillito's own invention. On this plate the fifteen hues comprise six "primary colours", each corresponding to a specified pigment, plus three "secondary" and six "subsecondary" colours (called "Sub-Primary" colours in some other Shillito student portfolios), all physically mixed from facing pairs of the six "primary colour" paints. Double-primary palettes like this are used as a practical remedy for the limited colour gamut obtainable from any set of just three "primary" red, yellow, and blue paints, and became very widely used for this purpose by painters from the 1960's onwards, but very few earlier examples are known to us apart from those by Shillito and her students. A rare exception is a diagram of six primary colours and three secondary colours illustrated by Pellew (1918, p. 79).

The 15-step hue scale remained part of Shillito's colour curriculum through to the late 70's, when it was used as the basis for several additional exercises in gouache (see Fay, 2021, pp. 15, 16, 20). The arrangement must therefore have been quite well known at that time and could well have inspired later instances of "double-primary" palettes, although we are not aware of any direct evidence to support this. The "Tertiary Wheel" (Plate 10) is another original Shillito design lacking clear antecedents. With its radiating triangles grouped in hierarchical orders and its concentric bands lightening in tone radially there are some very tenuous resemblances to a diagram by Adams (1862). The "Tertiary Wheel" was another fixture of Shillito student portfolios through to the end of Shillito's teaching career, with some variation in the number of concentric bands and in the degree of differentiation of the two orders of radiating triangles.

The typed notes in the "Ostwald Theory" section include eighteen pages of excerpts from J. Scott Taylor's *A Simple Explanation of the Ostwald Colour System* (Taylor, 1935), plus pages derived from Ostwald's *Colour Science* (Ostwald, 1931, 1933) and Judson's *A Handbook of Colour* (Judson, 1935). The more elaborate gouache plates in this section (Plates 20-23) appear to derive from Ostwald's colour atlas *Der Farbkörper* (Ostwald, 1919), and some other illustrations (Plates 16, 18, 19) can be traced to *Colour science*.

The typed notes in the "Munsell Theory" section derive from T. M. Cleland's *A Practical Description of the Munsell Color System* (Cleland, 1921), Maitland Graves' *The Art of Color and Design* (Graves, 1941), and an article on *Color Organization* (Sackett, 1938) from the journal *Printing Art*. The two Munsell plates in double-hue-page format (plates 31-32) do not match editions of the Munsell *Atlas* or *Book* known to us, but one closely matches a Munsell chart by the Allcolor Co., Inc., New York City, illustrated in an article on colour science in *Life Magazine* (17 [1], July 3, 1944, p. 47).

The "Munsell Theory" section also includes gouache renderings (Plates 33-35) of three pages from Graves' *The Art of Color and Design* (1941, pp. 137, 156, and 162 respectively), which had been published just a few years earlier. These pages illustrate Graves' concepts of "value keys" ("High Minor", "Low Major" etc.) and "value chords", which he devised as a means of systematically classifying tonal distributions in compositions in relation to the Munsell value scale. Graves' textbook proved to be highly influential and his concepts of "value keys" and "value chords" still find application today in both fine art and design. Exercises rendering Graves' "value key" and "value chord" diagrams and applying these concepts to design exercises were retained throughout Shillito's teaching career (for later examples, see Fay, 2021, pp. 37-38), and Eva Fay, who studied at the Shillito Design School in the late 1970's, recalls Graves' book was made available in some of the classes where his classification was discussed.

A pdf of full-page images of all of the Burgess plates and text pages, annotated with the sources we have identified for each, is available at http://www.huevaluechroma.com/Burgess.pdf

We believe that the typed sheets in the Burgess portfolio are likely to be typed-up lecture notes. One of us (Eva Fay) still possesses the notes that she copied down during lectures at the Shillito Design School in 1976-77, including the complete colour component from Years 1 and 2 of the course. (Year 3 was spent applying the colour theory in practice on design projects). Our examination of these lecture notes from 30 years later shows that they closely paraphrase or copy *verbatim* most of the same sources, including Graves and especially Carpenter. Many subject headings and long passages are taken nearly *verbatim* from Carpenter's book, including notes under the headings "Harmonies" (including "simple harmony" and "extended harmony", as in Carpenter, Ch. III, "Harmony"), "Contrasts" (including "reduced contrasts", as in Ch. IV, "Contrasts"), "Discords" (cf. Ch. V, "Discord"), "Broken colour" (cf. Ch. III, "Harmony", p. 25, "The breaking of a colour …"), "Differences in tone and its effect upon colour" (cf. Ch. IX, "Differences in Tone and its Effect Upon Colour"), "Colour reactions" (cf. Ch. XII, "Reactions"), "Harmonizing jarring or irritating colours" (cf. Ch. X, "To Harmonize Jarring Colours"), "Use of intermingled colour" (cf. Ch. XI, "The Use of Intermingled Colours"), "Colour schemes affected by conditions of lighting" (cf. Ch. XIII, "Colour Schemes Affected by Conditions of Lighting", "Dirty colour" (cf. Ch. XV, "Dirty Colour"), "Colour in dark situations" (cf. Ch. XIV, "Colour in Dark Situations"), and "Black and white" (cf. Ch. XVI, "Black and White"). Fay's notes also include a few additional topics including "Symbols of Colour" (*verbatim* from Graves), "Colour Psychology" (mainly after Birren, 1955, 1961, with a passage *verbatim* from Cheskin, 1947), and a handout on the Bauhaus manifesto.

Surprisingly we found no passages we could attribute to the colour theory texts of Itten or Albers of the early 1960's. These texts were already highly influential in contemporaneous teaching institutions internationally and in Sydney, but their similarities with the Shillito colour curriculum, noted by O'Connor (2013), are very broad compared to the direct links we identify here.

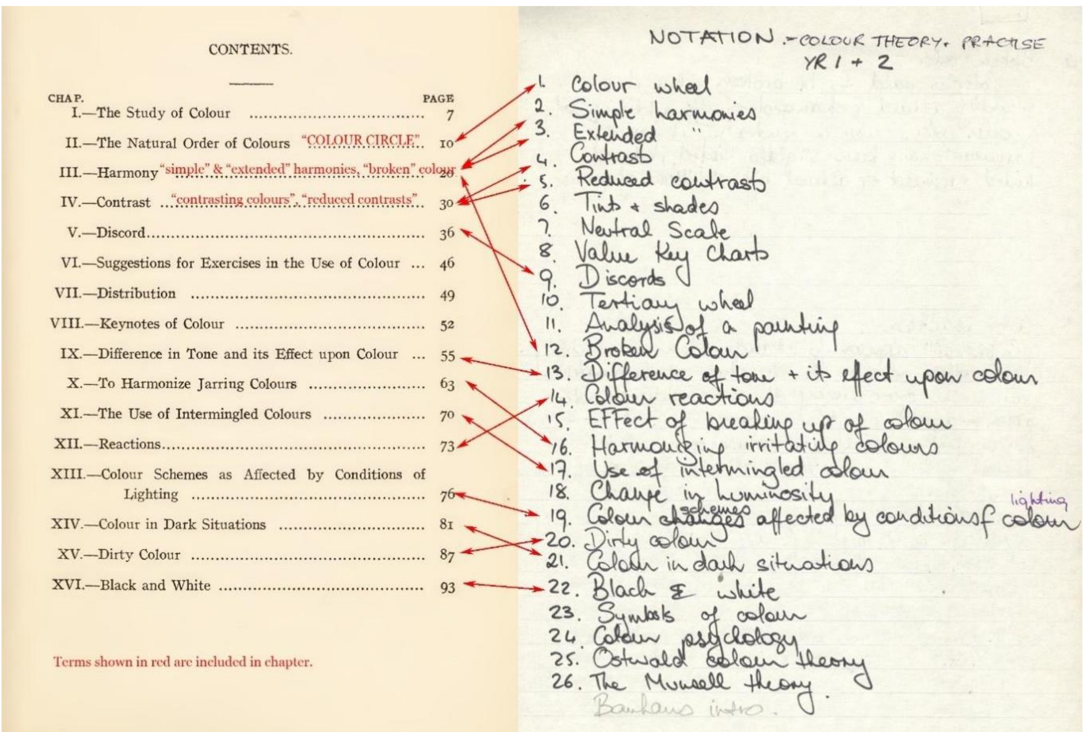

Figure 1. Left: Contents page of Carpenter's *Suggestions for the Study of Colour* (2nd edn, 1923). Right: Scan from Eva Fay's "Colour" lecture notes from the Shillito Design School in 1976-77 showing the list of lecture topics for this component of the course. Scans of all of Fay's notes are available at http://www.huevaluechroma.com/Fay.zip.

The Burgess portfolio stands out from later Shillito portfolios by the exceptional emphasis on carefully mixed Munsell and Ostwald atlas pages and diagrams, and by the exceptional quantity of accompanying text. A slightly later colour theory portfolio by Barbara Abbott held at the Powerhouse Museum, Sydney, has generally similar content, including closely comparable but less numerous typed notes, but the Munsell component is reduced somewhat and there are more numerous colour design exercises, some of them applying Ostwald notations. Shillito's colour exercises from the 1970's (discussed by O'Connor, 2013, and individually described and illustrated by Fay, 2021), show that Shillito's colour teaching continued to emphasize the intimate grasp of colour relationships that can be obtained through many hours of meticulous practical colour manipulation in paints, but now largely in rendering more creative colour design exercises in place of the copies of the Ostwald and Munsell hue pages in the 1940's. We hope that by making documents like this available we will assist future investigators in establishing the extent of comparable training temporally and regionally; certainly, today it seems very rare outside realist painting ateliers.

Another aspect of the Shillito colour curriculum that compares very favourably to much colour education today was the level of attention paid to a systematic, three-dimensional understanding of colour organization. In the 1940's, this was presented in the context of the two major scientific colour order systems used in art and design at the time, alongside Shillito's own palette-based hue system. By the late 1970's the Ostwald system had declined in influence globally, and three-dimensional colour organization at the Shillito Design School was presented primarily in terms of the Munsell paradigm of hue, lightness ("tone") and chroma ("intensity"), but we have little doubt that today Shillito would discuss both the Munsell and the NCS frameworks.

The concepts Henry Barrett Carpenter set out in his book *Suggestions for the Study of Colour* evidently formed the backbone of the Shillito's colour theory classes from at least the mid 1940's to the late 1970's. In fact, given that Carpenter was headmaster of the Rochdale School of Art, Manchester, only a short distance from the Halifax Technical College in South West Yorkshire where Shillito studied and also taught classes before coming to Australia, it seems likely that Shillito knew of Carpenter's book from the beginning of her teaching career. Carpenter's book was one of a number of popular texts for artists and designers that built on concepts derived from Ogden Rood's *Modern Chromatics* of 1879, which was in turn a popularization of the new scientific view of colour ushered in by Helmholtz, Maxwell and others beginning in the 1850's. Other such texts include Emily Vanderpoel's *Color Problems* of 1901 and Albert Munsell's *A Color Notation* of 1905, but Carpenter's approach to colour theory stands out for its emphasis on learning by practical exercises and experimentation. Carpenter expressed the hope that his key concepts, which were presented to Shillito students more or less *verbatim*, would be of use to students of fine art as well as diverse fields of design, and we are very pleased that this has been confirmed by an artist and art teacher of the standing of Jocelyn Maughan OAM (see Fay, 2021, Foreword).

We'd like to emphasize that what we have been documenting here are only the sources of the colour theory component of Shillito's comprehensive curriculum, which spanned numerous design disciplines. Eva Fay recalls Shillito in the 1970's as a unique, motivating, and inspirational educator, who knew how to guide her students to observe, experiment, discover, and search for alternative answers, to prepare them for the fine art field or the commercial world of both in 2D and 3D design. Shillito's mature method of teaching was unique in that apart from doing exercises in colour theory classes like those documented here, and having critical discussion at that point, the colour application to each design exercise was also followed up with further critiques in the design and design application section of the curriculum. Eva Fay recalls that even though the course was very structured, students were often given minimal instruction and learnt principles of colour application by experimentation, discovery, observation, and discussion. Gradually the students gained an informed colour confidence to solve challenging colour issues and an astute sensitivity to colour with a critical eye for nuances.

Acknowledgements

We thank Michael Lech, Curator of the Caroline Simpson Library & Research Collection in Sydney, for giving us permission to take and publish photographs of the portfolio (see Figure 2 below).

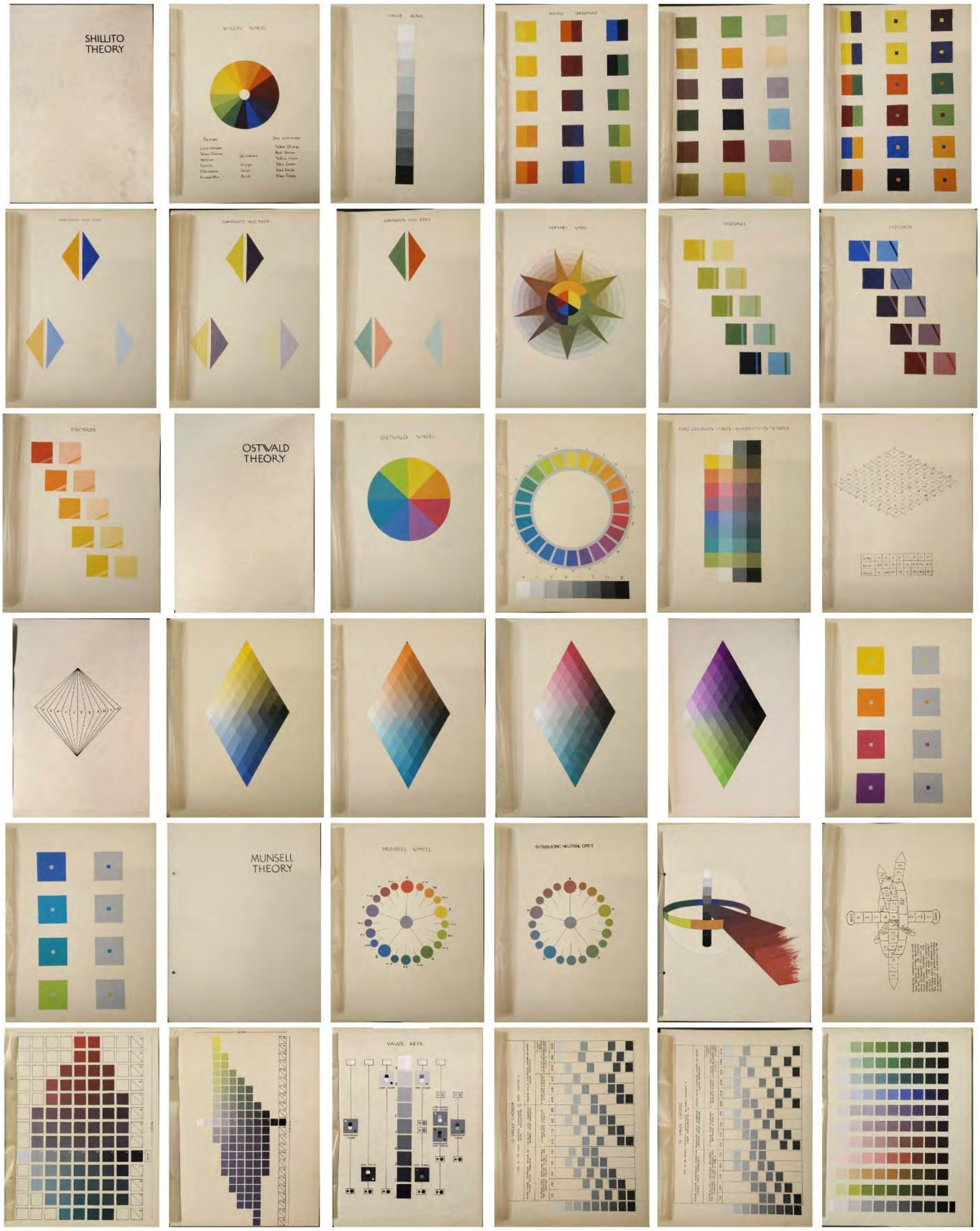

Figure 2. Burgess portfolio, Plates 1 -36.

References

Adams, R. 1862. *Die Farben-Harmonie in ihrer Anwendung auf die Damentoilette*. Leipzig: Verlagsbuchhandlung von J. J. Weber.

Birren, F. 1955 . *New horizons in color*. Reinhold Publishing Corporation, New York.

Birren, F. 1961. *Color psychology and color therapy*. Citadel Press, New Jersey.

Briggs, D.J.C. and Fay, E. 2022. "*Shillito – Ostwald – Munsell" by Helen Jean Burgess (1926-2018)*. http://www.huevaluechroma.com/Burgess.pdf

Burgess, H.J. *Helen Jean Burgess: arts and crafts teacher*. Record number: 45031 Call No: CSL&RC MSS 2014/5 http://collection.hht.net.au/firsthht/fullRecord.jsp?recnoListAttr=recnoList&recno=45031

Carpenter, H.B. 1915. *Suggestions for the study of colour*. HB Carpenter School of Art: Rochdale; 1915. Available online at https://archive.org/details/suggestionsforst00carp

Carpenter, H.B 1923. *Suggestions for the study of colour* (2nd edition). HB Carpenter School of Art: Rochdale. Available online at https://archive.org/details/b30009339

Cheskin, L. 1947. Colors, what they can do for you. Liveright Publishing Co, New York.

Cleland, T. M. 1921. A practical description of the Munsell Color System with suggestions for its use. In A Grammar of Color, The Strathmore Paper Company, Mittineague, Massachusetts. https://archive.org/details/gri_c00033125006531145/page/n17/mode/2up

Fay, E. 2021. *Shillito Design School. Australian colour education in the 70's*. Blurb.com. https://au.blurb.com/b/10737055-shillito-design-school-australian-colour-educatio

Graves, M. E. 1941. *The art of color and design*. New York: McGraw-Hill. Available online at https://archive.org/details/artofcolordesign00grav

Judson, J. A. V. 1935 - A handbook of colour: including the Ostwald theory and its practical application. Dryad Press, Leicester.

Kent, C. J. 1995. *Phyllis Shillito (1895-1980): A review*. Master's thesis, Faculty of Design, Architecture and Building, University of Technology, Sydney; 1995. https://opus.lib.uts.edu.au/handle/10453/32317

Munsell Color Company 1929. *Munsell Book of Color, Standard Edition*. Munsell Color Company, Inc., Baltimore, Maryland.

O'Connor, Z. 2013. The Shillito Design School: Australia's link with the Bauhaus. *The International Journal of Design in Society*, 6 (3), 149-159.

Ostwald, W. 1919. *Der Farbkörper*, Unesma.

Ostwald, W. 1931, 1933. *Colour science*. Translated with an introduction and notes by J. S. Taylor. Winsor & Newton, London.

Pellew, C. E. 1918. *Dyes and dyeing*. Robert M. McBride & Co, New York. https://archive.org/details/dyesdyeing00exmorich

Sackett, D. 1938. Color organization: A treatise on methods of color organization, specification and harmony. *Printing Art*, Volume 67, Issue 4, pp. 26-32. Dartnell Publications, Minnesota.

Taylor, J. S. 1935. A simple explanation of the Ostwald colour system. Winsor & Newton, London.

Colour, Light & Environment: An Experiential Course

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Abstract

This paper/presentation documents and reflects upon a unique introductory course for pre-architecture students as a contribution to the discourse on architectural colour studies. Three collaborating faculty present and reflect upon the key goals, approaches, and outcomes developed over ten years of teaching the course. A hands-on studio course for second-year undergraduates in Environmental Design, 'Colour, Light & Environment' attunes students to noticing and considering how colour, light and materiality work together in spatial settings. Offering opportunities for personal and physical experimentation and exploration, the course opens phenomenological understandings of spatial experience, cultural awareness of colour meanings, and sensitivity to colour needs and desires. Students learn that these arise from and respond to local geography and meteorology, spatial temporality, cultural context, programmatic needs, and diverse users. The authors provide examples of student work and highlight key aspects of environmental colour/light learning that have emerged as significant through the years of developing the course and its diverse projects.

Keywords: *Environmental Design, Architecture, Colour Education, Spatial, Embodied Experience*

Introduction

Colour and light are interwoven in architectural settings and require complex knowledge for best use, but focused and extended learning opportunities about spatial colour and light are limited. Readings and digital modelling have limitations for coming to understand how colour and light work in spatial settings. Practice-based decision-making within real world contexts requires nuanced understanding, gained through experience. Interconnectivity between mind/body and surrounding environment is felt, emotional, embodied. Personal, social/cultural meanings, locational, and temporal factors are among variables that do not lend themselves well to reductivist approaches. While colour and light are ever more called upon to deliver 'appropriate' spatial affect/effect, the ambient and fluctuating energy of space/place requires thoughtfulness, not formulaic decision-making. Good colour/light designers must rely on their own phenomenological experience, weighing many factors.

This presentation of a unique environmental colour-light course contributes to a significant but limited discourse about the importance of opening up colour understanding and learning through informed and sensitive design processes (see Arnkil and Pyykkö, 2018; Motamed and Tucker, 2018; Weber and Kanthak, 2017; Poldma, 2009). Technology now offers designers unprecedented capacity to utilize colour-as-material and colour-as-light in myriad forms and applications. Ensuing implications for personal and social health/wellbeing require attention and knowledge for responsible use. Personal, social, and cultural colour understandings are important for developing diverse perspectives and ways of knowing. First stage colour courses for designers can be eye-opening, delightful, potent learning experiences that open up the colour/light/environment conversation for all.

The Course: Colour, Light & Environment

The authors have worked collaboratively over several years, developing an introductory Environmental Design (ED) studio, *'Colour, Light and Environment'*. In the 1990's the course took up an exploratory and hands-on approach, as developed by Doreen Balabanoff and subsequent collaborator Stuart Reid, in the Faculty of Design at OCAD University. Co-authors Sharyn Adler Gitalis and David Pearl successively joined the faculty teaching the course, contributing to further evolution and enrichment of course content. Here we document the course objectives, projects, and outcomes, as potentially valuable to the future of architectural and interior design education.

As there were multiple sections of the course, collaboration across sections was important – projects, exercises and references were discussed/modified annually. As practicing artists/designers, we felt strongly that students should learn of the ongoing relevance in professional practice of *physical model-making* – a means of gaining real-world experience to better understand material and perceptual factors and nuances arising within architecture. Studying form, material, light, shadow, and colour interacting in real space, over time, is an effective practice-based research strategy for designers, which digital modelling/rendering and photo representation cannot replace.

Personal skills in experimentation, physical making, observation, notation, and presentation work were augmented by guided sharing of ideas and research skill development. Research literature becomes fascinating once students find particular practical or conceptual interests. Project evaluation criteria include the *quality* of *concept*; *imagination/creativity; research/process*; *craftsmanship; and cultural resonance/awareness.* Students in the course begin a richly imaginative journey towards purposefully using colour/light to create spatial value – ambience, mood, meaning, identity – with awareness of the need for sensitivity to programmatic use and geographic and cultural factors.

In the sections below, we provide brief introductions to the three main projects, with a glimpse of student works, and note several focal topics arising within the projects.

Project 1A Playing with Light: Achromatic Architectural Studies

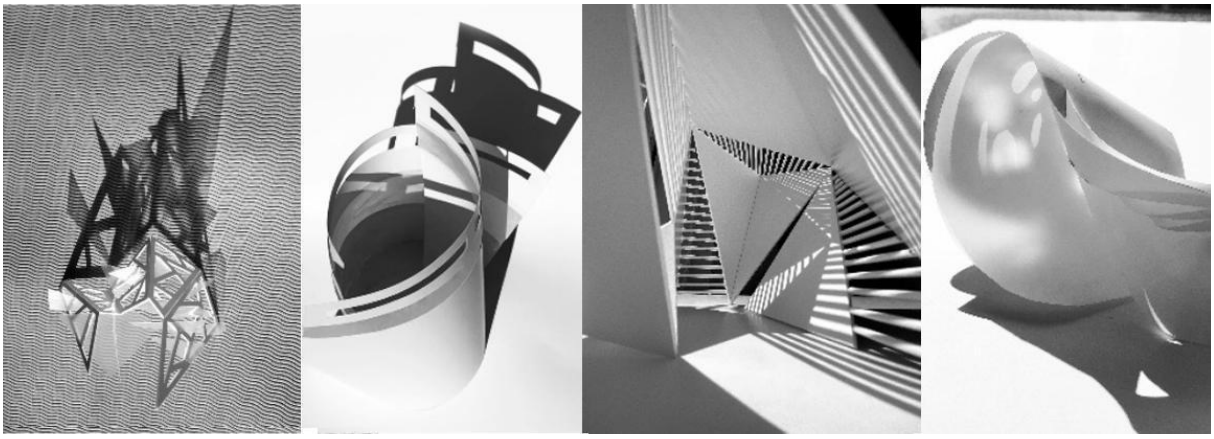


Figure 1. Examples of student work: exploration of form, light, shade, shadow, temporality

A white model: students manipulate, observe, and focus on aspects of achromatic Light and Shadow: 1) discovering/remembering that *without something to fall upon, light is invisible*; 2) understanding *time* as a key aspect of architectural space; 3) noting impact on legibility and simplicity/complexity in perception of space and form; 4) finding value in creating rich sensory experience; 5) exploring creation of poetic meanings and emotional resonances.

Aperture and form together create light and darkness

The perceptual and poetic interaction of form and light is a crucial revelation for students. Students have a rich learning experience through making, manipulating, photographing, discussing many different kinds of models, and learning to look *inside them* at different times of day.

Temporality of spatial settings

A key intention is that students come to recognize *time* as a significant aspect of architecture and human experience. Temporal awareness brings ideas about connection to place and cosmos, to nature, weather, seasons, daily cycles of warm and cool light temperatures. These are connected to understanding embodied experience and salutogenic design.

Project 1B Colour & Light in Space: Phenomenological Studies

Adding colour without 'purpose', students play with spatial colour, utilizing the same or similar white model. Experimentation and discovery in the classroom are visible, shared, pondered, discussed. The value of 'serious' play is noted as a valuable aspect of the design process. Related student readings, presentations, and exercises aid with developing understanding.

Figure 2. Phenomenological studies.

Sensitivity to colour

Students discover a myriad of unexpected effects/affective implications of architectural colour as material and as light. From now on they will see more colour/light in the world: weight, depth, temperature, emotional resonance, reflectance, luminosity, coloured shadows, ambient glow…

Colour is felt

Students experience viscerally that colour, whether material or immaterial, is felt with the mind/body, that it influences us in an emotive, embodied way that is not simplistic.

Colour: how to think about it and manifest it

Some students think only of paint, others of transparency or light projection. The range of possibilities appears *through* working, and might include coloured shadows, reflected light, gradation related to enclosure. Awareness emerges that many materials are already *coloured* (wood, brick, fabrics, landscape), and that all surfaces can be influenced by light, shadow, other adjacent or reflected colour.

Colour research as agency

The value of both intuitive experimentation and rigorous, systematic process/research methods becomes apparent. Once a colour idea, concept, or dilemma takes hold, deepening research is important. Students bring fascinating research to light in relation to their projects; new insights/discoveries abound. In this way, the course opens up the agency and intelligence of students, and opportunities for students learning from one another, supported by the faculty, for a personally meaningful learning experience.

Project 1C Considering Colour, Context and Meaning

We now add a dual challenge to a similar (still abstract, white) model: adding colour based on 1) program/use and 2) geographical location/cultural context. Two students per class choose the same program, but different locations, researching both elements. Insight development leads to deeper research. The final design remains an abstract representation but holds many articulated meanings.

Figure 3. Children's Hospital program, place left to right: Nunavut (Canada), India, Serbia, Cairo.

Paying attention to colour in culture: relationships with nature and tradition

Students find that cultural colour is connected to local climate, weather, light quality, and materiality (bodies of water, vegetation, earth colours)…that colours of place are connected to a sense of identity/belonging. Ambient energies that feel 'right' in a context may be related to familiar meteorology, long-held traditions/events, cultural artifacts/materials, even developing local trends.

Appropriateness of colour to use and comfort

Students discover/remember that colour can be used intentionally to provide meanings, legibility, comfort. Some projects find students considering how animal vision is different from humans, or how sick children are different from palliative care patients or opera-attendees. What are the concepts and people one must consider, to provide spatial colour that supports functional use, but also considers how people feel? Students learn that contextual cues, evidence-based knowledge, and empathic approaches hold value for making colour decisions.

Project 2 Urban Colourscape

Embarking on a completely different adventure, students choose from a list of Toronto neighborhoods with diverse characteristics and cultures, working in small groups to visit, document, and consider them as local colour projects. They are asked to devise a colour palette grounded in local colour use and cultural identity, name the colours, and suggest how a palette might be used to enhance the colour language – e.g., local rules for facade colours/materials, doors/windows, landscaping, etc.

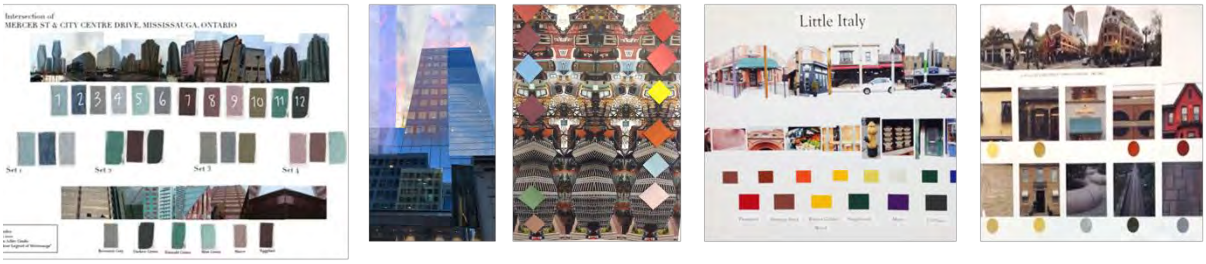


Figure 4. Urban Colour Presentation Boards.

Considering permanent and impermanent materiality and relation to identity

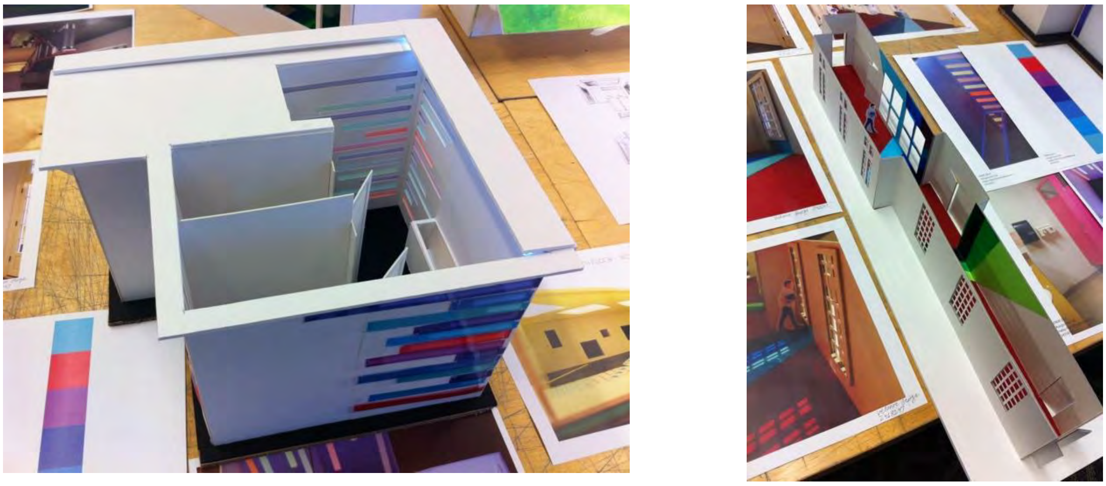
Students consider what is 'built in' to the urban environment (foundational, material colour) and what is 'added on'. Images captured offer opportunities to discuss colour opportunities and problems that arise in urban contexts. The project opens up discussions about how urban colourists can transform and/or support specific urban contexts, a new idea for most students.

Urban colour providing feelings and memories

Students newly experience and consider urban colour as embodied experience and memory. Colour is discussed as polysensorial: an impression, a sensation, an expression of feeling, a journey or story. Colour awareness brings consideration of a neighborhood's persona, sometimes, desires, problems.

Project 3 Campus Colour Installation

The final project asks students to find a site of interest and develop a site-specific colour installation/reinvention. The visual and verbal presentation includes a scale model and a presentation board, or more recently a slide presentation, with notes pertaining to site, concepts, and research. As a preparatory exercise, students present a relevant artist's or designer's colour/light work to the class, so that all students can benefit from a wide array of concepts and ways of working.



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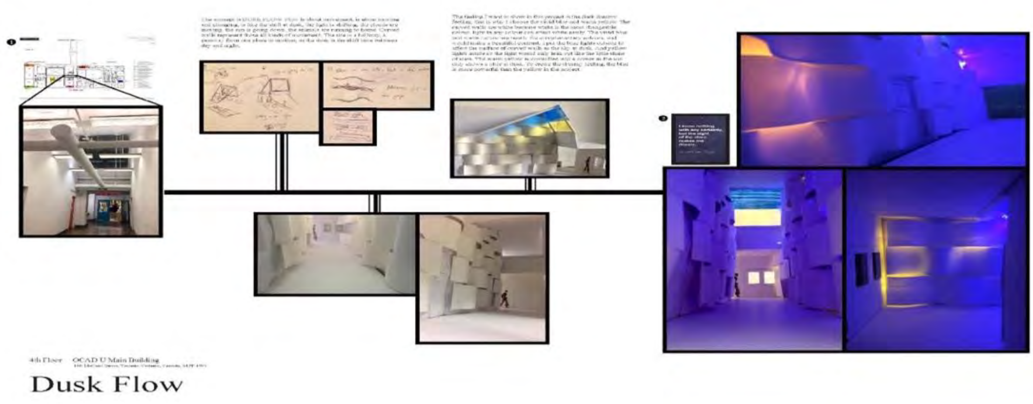

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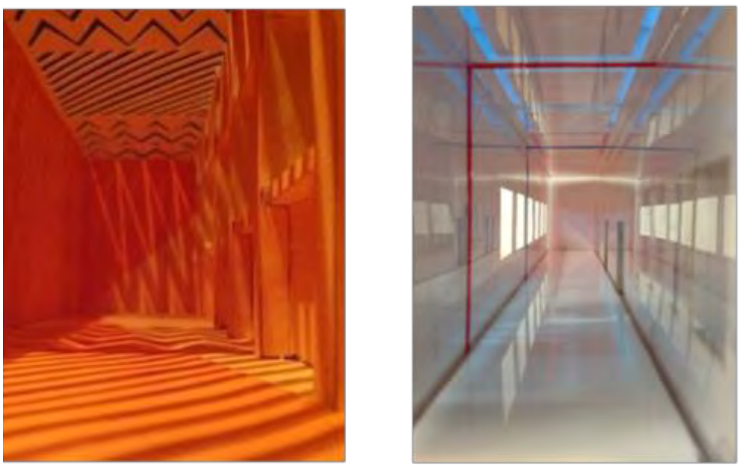

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Figure 5. Examples of Project 3 Campus Colour Installation project – transforming a space on campus (found by each student). Option to focus on using colour conceptually, practically, or phenomenologically.

Project 3 Our Place, Our Selves: Exploring Sense of Self as Space (alternative, new)

Due to the pandemic, Project 3 evolved into a personal space project (as we were not on campus). The brief asked students to create an environment reflecting their 'own sense of place', or their 'sense of self as place'. Student works were based on current or imagined or remembered spaces, and explored personal sensibilities in form and material, in light and colour and scale. The project's existential questioning was meaningful...the thoughtful responses to the brief seemed to have more 'heart' than pre-pandemic offerings.

Figure 6 Our Place, Our Selves: Autobiographical Space/Place project (2 examples).

Colour embedded in us as existential identity

Making a space imbued with colour that we feel is like us, feels like ourself, feels like our dream of being in a space, that expresses who we are...connects us to the poetics of space, in a time when technological, modular, similar, and achromatic approaches are prevalent. It connects us to where we came from, where we feel we belong, to our own emotionality and memory, it validates who we are.

Empathic approaches to colour consideration

By identifying sensibilities and needs ourselves as designers we explore our empathetic and personal resources to respond to human needs and issues in environmental design. Students value the opportunity to think deeply about what is important to them, to dig deeper into their own felt experience of light, colour, space/form/time. They will bring this humanistic approach to their future practices and lives.

Conclusion

There were many further learning experiences built into the course, ranging from walking tours to lighting demonstrations to colour/light science and colour/art/art history presentations. Diverse colour finding, sorting, selecting, mixing, collaging exercises are (or have been) part of the course. Students do research and create presentations on artists and designers exploring colour and light…all of these contribute to the richness of their own explorations, and the excitement students express as they come to see the world around them with new eyes. Fresh insight and inspiration are needed to continue to enliven teaching and learning about light/colour/environment as experiential, sensorially rich, and deeply meaningful, so that students are inspired to invest in further colour knowledge acquisition. Considering and building innovative colour education approaches will be an ongoing challenge and satisfying endeavour for all who engage in it. Former students have expressed how important this learning was for their life as practicing designers/builders. We hope that educators in architecture and design will find our work useful to future teaching and learning about colour.

References

Arnkil, H., and Pyykkö, S. 2017. Color–Light–Space: An interdisciplinary course for graduate and postgraduate students. *Color Research & Application*, 43(6): 857–864.

Gürel, M. Ö., and Potthoff, J. K. 2006. Interior design in architectural education. *International Journal of Art & Design Education (IJADE),* 25(2): 217–230.

Motamed, B., and Tucker, R. 2018. Colourful practice: Is design education informing architects' use of colour? *International Journal of Technology and Design Education*, 28 (4): 1001–1017.

Poldma, T. 2009. Learning the dynamic processes of color and light in interior design. *Journal of Interior Design*, 34(2): 19–33.

Robinson, S., and Pallasmaa, J. 2015. Mind in architecture: neuroscience, embodiment, and the future of design. Cambridge, MA: MIT Press.

Weber, R., and Kanthak, T. 2017. Teaching colour to architecture students. *Journal of the International Colour Association*, 17: 120-128.

Weaving the senses: Learning about color through sound and taste

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Abstract

Recent studies suggest that value and chroma, more so than hue, are what dictate the connection between color and the feelings they evoke and can be explained using Pleasure-Arousal-Dominance (PAD) Theory. As a practical matter, though, lecturing students on PAD Theory may be less efficient than offering them opportunities to discover the dynamic on their own through observation and activities that engage more than just their cognitive faculties. Studies on cross-modal correspondences (CMC), seemingly innate connections between the senses, may facilitate the learning process. The correspondences between color and sound, for example, may enable students to approach the study of color through music or everyday sounds. Although the CMC are less pronounced between taste and color, this sense may also be useful in understanding the process of design where the choice of color "ingredients" and their proportions can create very different types of experiences, just as they can with food. Letting students explore color though other senses, not just vision, opens endless opportunities for creative engagement in design projects that may deepen their understanding of how people feel about color.

Keywords: *Colour Education, Colour Psychology, Design*

Introduction

People are often surprised to learn that most design programs do not have a formal color curriculum, and if they do, it is inconsistent and so limited in scope that it fails to provide designers with the knowledge they need to work with color in a meaningful way (Calvo Ivanovic, 2022). While there are many books on the topic of color, most are either too general or too specific to be much help in the designer's particular field. A formal body of knowledge on the subject of colour as it pertains to design simply does not exist, although the strides already made by the AIC/ISCC Colour Literacy Project promise to change that in the future.

When it comes to color psychology, the topic of this article, there is even less solid information to guide designers in the use of color. In recent years there has been a shift away from traditional thinking about color where hues are the drivers of emotion to an understanding that it is value and chroma that elicit more consistent emotional responses from people. Valdez & Mehrabian (1994) research found this almost thirty years ago, but it has only been in the last decade that other researchers have begun to notice this dynamic, too (Gao et al, 2007; Dael et al, 2016; Bartram et al, 2017; Jonaskaite et al, 2019; Divers, 2020). Valdez and Mehrabian studied color using Pleasure-Arousal-Dominance (PAD) Theory and found that Dominance (high or low sense of personal control) correlated with the value dimensions of color, that is, low value (dark colors) are associated with low dominance. They also found that Arousal (high or low excitability) correlated with high and low chroma, respectively. Divers (2020) echoes this finding noting that subject descriptions of dark colors, pale colors and vivid color sets were qualitatively very different from each other, e.g., dark colors are serious/hard/mature/strong, pale colors are cheerful/soft/young/delicate, vivid colors are energetic/friendly/cheerful/intense. This approach to understanding the psychology of color is intuitive, yet explaining PAD Theory to undergraduates requires time that is already in short supply in an already packed design curriculum. This article explores ways to awaken this "color intuition" by recruiting other senses: sound and taste.

In his article on multisensory approaches to architectural education, Monshisade (2016) makes the observation that these programs have become "oculo-centric", that is, completely reliant on the sense of vision for the design process, and he argues in favor of engaging the other senses in the process. Although the psychology of color begins with the visual sense, once it reaches the brain, the experience of color evokes feelings in the body and associated thoughts which go beyond our sense of sight. Everyday expressions such as "loud colors" or "sharp flavors" make it apparent that people naturally experience the world through more than one sense at a time, which is not surprising considering that the environment *itself* is a multisensory experience. Establishing links between the senses is a very efficient way to process all the information the brain receives at one time. There exist some specific and well researched links known as cross-modal correspondences (CMC), and leveraging those connections, specifically between color and sound and color and taste, may help deepen (and hasten) learning about color psychology.

Associations, synesthesia and cross-modal correspondence

It seems that humans naturally pair things together and associations people have between colors and objects (or ideas) are well documented. They are often based upon the color of the actual object and one of its properties, are contextual (we like blue skies, but not blue meat) and they influence our preferences (Schloss & Palmer, 2017). That type of pairing is very common in the general population. Another type of pairing which affects about five percent of the population is known as synesthesia where a person automatically and involuntarily experiences two senses simultaneously, e.g., "blue smell". Although this fascinating phenomenon has garnered both research and media attention, its nature and low incidence makes it unsuited to the task of teaching a typical student about color. However, there is a third type of sensory combination known as cross-modal correspondence (CMC) which involves the pairing of attributes of two senses (as opposed to the senses themselves as happens in synesthesia). These are not involuntary as in synesthesia, and the meanings are shared by a large number of people (Cluskey et al, 2019). In his tutorial on CMCs, Spence (2011) explains that the integration of two senses is most likely to occur when they are presented at the same time, space and/or are semantically congruent, i.e., share a similar meaning, and that the presence of one or more of these strengthens the correspondence. Although most research has focused on auditory and visual stimuli, there is evidence of correspondences in taste-sound, color-texture, pitch-smell, pitch-visual elevation, taste-sound and others. The standard method of studying CMCs typically involves a speeded classification task, i.e., asking subjects to quickly complete a task involving one sense (e.g., light and dark colors) and then introducing a stimulus from the other sense (e.g., high or low pitch sound). If the stimulus is congruent with the color, response is faster and possibly more accurate; if incongruent, response time is slower and possibly less accurate. Spence goes on to say that these correspondences can be linguistically mediated, thus even just saying the words "high" and "low", as opposed to presenting the stimulus, is sufficient to elicit the response.

Sound-Color

One of the strongest and most well-researched correspondences is between pitch and brightness (bright vs dim); pitch and lightness (white vs black) have been studied as well (Zeljko et al, 2019). Examples of high pitch (high frequency) sounds include the chirp of a bird, or the sound of a piccolo; low pitch (low frequency) sound examples are a truck's rumble or the sound of a tuba. These correspondences are dimensional, they run on a low/high continuum just as do value and chroma, so they may be overlayed on a value-chroma chart (Figure 1). Simply put, the lighter the color, the higher the pitch associated with it, and the darker the color, the lower the pitch. There is also evidence that *loudness* of sound corresponds with both value and chroma (Marks, 1997; Caivano, 1994; Anikin & Johansson, 2019) which is not surprising since high pitches are sometimes perceived to be louder than lower pitches even if they are not. When we connect these sensory experiences (pitch with value and loudness with chroma), it is a short jump to connect the sound of a tuba, dark colors and words such as serious/strong/hard/ with low Dominance (personal control). Similarly, the sound of a pipe organ, vivid colors and words such as energetic/cheerful/intense are associated with high Arousal (excitability).

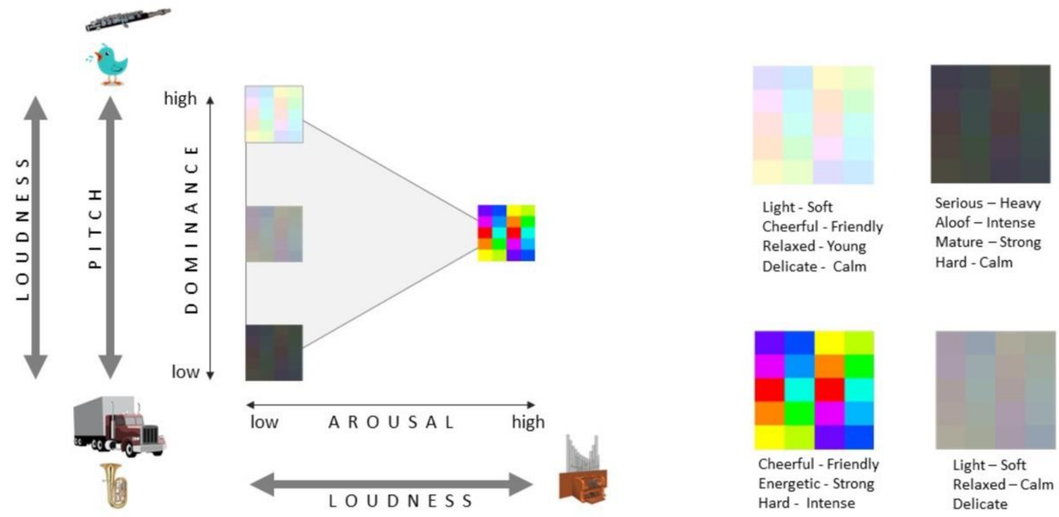

Figure 1. Correspondences between color, dominance/arousal, pitch, loudness, and language.

These findings open the door for students to explore color via their own auditory experiences, which makes learning both fun and relevant. The instructor can introduce pitch, for instance, by playing a sound and informally polling students about which color category (dark, pale, muted, vivid) best matches it. An exercise to reinforce these connections could be for students to collect sounds (instruments, animals, machines, etc.) and combine them with color categories and language to create a digital sound/color/feeling "collage". Or they can freeform a line that depicts the pitch and rhythmic elements from a passage from a favorite musical selection and then apply color in a way that is consistent with the research, e.g., higher pitches being lighter, lower pitches darker, and louder portions increasing in chroma. Hue choices are at the student's discretion. These exercises are springboards for applying color in their class design projects. Having articulated that dark colors and low sounds feel heavy (or that vivid colors are loud, or that light colors are soft), for example, they can experiment with altering the proportion of dark (or vivid, or pale) colors in a visual composition and observe the shifts in emotional tone. In a follow-up exercise they may then notice how the feeling of a composition changes when the proportions are kept constant, but the colors (e.g., dark/light, muted/vivid) are reversed. These exercises involve multiple iterations and retaining this process work will provide a record of their own progress in understanding these color nuances. Comparing projects with other students will demonstrate that these correspondences, these meanings, are shared by most people. Neither the teacher nor the student needs to understand PAD Theory in order to connect the feelings/sensations conveyed by color. And if they are curious to explore PAD Theory, they will understand it immediately having already "felt" the meanings that shifts in value and chroma impart.

Taste-color

Most of the research on the connection between taste and color not surprisingly comes from the fields of food science and product marketing and has mostly focused on hue (Spence, 2019). We pick up flavor/color associations very early in life. A number of studies have found that dark colors are associated with bitter tastes, green and yellows with sour, white and blue with salty, pinks and reds with sweet (Spence et al, 2015). It is easy to see how people might form these associations from experiences with food, yet this is not especially useful to the design process. The cross-modal correspondences are weaker between taste and color, in part because they don't necessarily go both ways, a requirement for a CMC. In other words, a color paired with a food may influence how it tastes, but the taste of a food may not necessarily affect how a color appears. Similarly, the color of an ingredient does not necessarily predict its flavor (bananas and lemons are both yellow, but taste very different). Complicating matters further, a single food item, such as a banana, may be green, yellow or brown, depending on ripeness. Unlike sound-color correspondences which are dimensional (e.g., high pitch is bright, low pitch is dim), flavors are basically distinct categories of taste (bitter, sweet, sour, fat, pungent, salty, bland) and it is precisely this aspect of taste that makes the process of designing a dish analogous to designing with color: like flavors, colors (dark, pale, muted and vivid) each have a unique character.

There are two lessons we can glean from the culinary world. The first is that food preparation and color design entail using more than one ingredient/color, and that ingredient/color proportions will vary in order to create different taste or color experiences. When preparing kale, for instance, which is often bitter, the chef will temper the dish with smaller amounts of the other flavors (sweet, sour, etc.). How much to use of each of these depends on the chef's understanding of flavor profiles. Similarly, in design it is a common practice to define dominant, subdominant and accent colors in a palette, but to do this successfully the designer needs to understand color "character" profiles. Fortunately, the sound-vision correspondences discussed earlier are one way to gain that understanding.

The second lesson in this taste-color analogy is the fact that each flavor category is represented by more than one ingredient. For example, if a sour flavor is needed and there is no vinegar, it is acceptable to substitute lime juice instead--that may alter the flavor some, but not so much that it changes the overall experience of the dish. In the same way, a designer can experiment with the hues within a color category without dramatically altering the fundamental character of the design. For instance, when designing a calm restful space, as long as chroma is low, this mood can be achieved using a pale orange, pale green, pale blue, etc. This is a critical distinction between the current view of color and emotion as compared to how it was viewed previously, through the lens of the hues.

Figure 2. Flavor categories represent a variety of ingredients with a similar taste. Color Categories include all the hues within a similar range of value and chroma. Chefs/designers can choose ingredients/colors which may modulate a dish/design without fundamentally changing it.

Although younger students may not yet have sufficient experience as "foodies", they can begin cultivating their sensitivity to flavor by testing recipes and watching cooking shows. They notice that flavors can be complex or simple, and they learn that they can make substitutions within a flavor profile without appreciably affecting the final result. Then they can apply a culinary mindset to a design project where the ingredients are the color categories; they begin by defining the most salient emotional quality drawing on language they have internalized from sound-color exercise or other activity, e.g., "strong" (dark colors). Then they choose complementary color categories for secondary and accent colors, e.g., "relaxed" (muted or pale) and "friendly" (vivid) that develop the nuances in the design. Taking this approach will raise their awareness of the fact that just as an enjoyable meal depends on the careful balancing of flavors in a dish, a successful design involves balancing dark, pale, muted and vivid colors rather than limiting the design to a single category, which runs the risk of being too intense or even boring.

Conclusion

Most humans have innate connections between the senses even if they may be unaware of them. Exposing inexperienced designers to the character of dark, pale, muted and vivid colors by exploring correspondences in sound and taste has the potential to help them access shared connections and strengthen their ability to manage color successfully.

References

Anikin, A. and Johansson, N. 2019. Implicit associations between individual properties of color and sound. *Attention, Perception, and Psychophysics*, 81(3), 764–777.

Bartram L., Patra A., Stone M. 2017. Affective color in visualization. Paper presented at: CHI '17: CHI Conference on Human Factors in Computing Systems; May 2017; Denver CO. doi:10.1145/3025453.3026041. Accessed date: May 19, 2019.

Caivano, J. 1994. Color and Sound: Physical and Psychophysical Relations. *Color Research and Application*. 19. 126-133. 10.1111/j.1520-6378.1994.tb00072.x.

Calvo Ivanovic, I. 2022. An analysis of the state of the art of colour training in design education during the last decade. In: Colour Design Training Itinerary, A framework for the teaching and learning of colour in the design discipline. [PhD in Design Research Thesis, Politecnico di Milano]. POLITesi - Digital archive of PhD and postgraduate theses. pp. 99-125

Cuskley, C., Dingemanse, M., Kirby, S. and van Leeuwen, T. M. 2019. Cross-modal associations and synesthesia: Categorical perception and structure in vowel–color mappings in a large online sample. *Behavior Research Methods*, 51(4), 1651–1675.

Dael, N., Perseguers, M.N., Marchand C., Antonietti J.P., Mohr C. 2016. Put on that colour, it fits your emotion: colour appropriateness as a function of expressed emotion. *Q J Exp Psychol*. 2016;69(8):1619–1630. doi:10.1080/17470218.2015.1090462

Divers, E. 2020. Hue: The affective response to value and chroma. In: *The International Scientific Conference of the Color Society of Russia. Smolensk*: Smolensk State University Press; 2020:154-159.

Gao X., Sin J., Sato T., Hansuebsai, A., Scalzo, M., et al. 2007. Analysis of cross-cultural color emotion. *Color Research and Appl*. 32(3): 223–229. doi:10.1002/col.20321

Jonauskaite, D., Althaus, B., Dael, N., Dan-Glauser, E., Mohr, C. 2019. What color do you feel? Color choices are driven by mood. *Color Research and Application*. 44(2):272–284. doi:10.1002/col.22327

Monshizade, A. 2016. Multisensory approach in architecture education: The basic courses of architecture in Iranian universities. In *Proceedings of 3rd International Congress on Ambiances*. Septembre 2016, Volos, Greece (pp. 355–360). Volos, Greece. Retrieved from https://hal.archives-ouvertes.fr/hal-01414239

Schloss, K. B., & Palmer, S. E. 2017. An ecological framework for temporal and individual differences in color preferences. *Vision Research*, 141, 95–108. https://doi.org/10.1016/j.visres.2017.01.010

Spence, C., Wan, X., Woods, A., Velasco, C., Deng, J., Youssef, J., & Deroy, O. 2015. On tasty colours and colourful tastes? Assessing, explaining, and utilizing crossmodal correspondences between colours and basic tastes. *Flavour*, 4(1), 23. https://doi.org/10.1186/s13411-015-0033-1

Spence, C. 2011. Crossmodal correspondences: A tutorial review. Attention, Perception, & *Psychophysics*, 73(4), 971–995. https://doi.org/10.3758/S13414-010-0073-7

Spence, C. 2019. On the Relationship(s) between Color and Taste/Flavor. *Experimental Psychology*, 66(2), 99–111. https://doi.org/10.1027/1618-3169/a000439

Valdez, P., Mehrabian, A. 1994. Effects of color on emotions. *Journal of Experimental Psychology*, 123(4), 394–409.

Session 8
Colour and Buildings

Powerful Red on Buildings of the Qinzheng Hall Complex at the Garden of Clear Ripples (Beijing)

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Abstract

The Emperor Qianlong (1711-1799) built the Garden of Clear Ripples known as the Summer Palace in the suburb of Beijing, China. Within this palace, the Qinzheng Hall complex known as the Hall of Diligent Government was where the symbolic Imperial Court was located. For this study, the only available image of the Qinzheng Hall complex during the Qianlong Reign (1735-1796) is the documentary handscroll *Longevity Blessing*. According to this handscroll, there were four conspicuous and meaningful colours on the buildings of this complex, red, qing (grey with a blue-green tinge), green, and white. Among those, red was the only one that was markedly associated with the ruling power. Based on a close reading of the red architectural elements recorded in the handscroll and related recompiled archives, this paper suggests that on buildings of the Qinzheng Hall complex, red was used in a strict systematic way to distinguish the hierarchy for the people of the ruling class, furthermore, in using the red colour to manifest the Emperor-centred power structure, the colour variances in the chromaticity and blackness between all red architectural elements were omitted by the people.

Keywords: *Architectural Colour, Pigment, Summer Palace, Hierarchy, Power*

Introduction

During the Qianlong Reign (1735-1796) the population of the Qing Dynasty reached a historical high, more than three hundred million people lived in the Empire (Woodside 2002: 230). By the end of seventeen seventies, the Ministry of Revenue reserved 80 million taels silver in total (Woodside 2002: 270). It was in this most flourishing period of the Qing Dynasty, that the Garden of Clear Ripples also known as the Summer Palace was constructed under the order of the Emperor Qianlong between 1750 and 1764 (Zhou 2006: 50-60). This palace was the result of the greatly accumulated national strength and the highly centralised imperial power.

At the Garden of Clear Ripples, the Qinzheng Hall complex was where the symbolic Imperial Court was located. The architectural historian Guo (2018: 182) mentions that this complex was constructed to ritually symbolise the Imperial Court at the Forbidden City, where was the real physical location of the power centre of the Qing regime. During the Qianlong Reign, one pivotal national ritual related to the Qinzheng Hall complex was the Emperor Mother's 60th birthday celebration. This birthday ceremony was recorded in four handscrolls known by the collective title *Birthday Celebration of the Empress Dowager Chongqing*. Of those, the key buildings of the Garden of Clear Ripples including the Qinzheng Hall complex were painted in the first handscroll *Longevity Blessing* (Liu 2019: 12-22). Currently, this is the only available image of the Qinzheng Hall complex in the Qianlong Reign. Instead of an artistic artwork, this painting was a documentary one, which was seriously made for the Emperor and his mother. According to the *Longevity Blessing*, there were four conspicuous and meaningful colours on the buildings of this complex, red, qing (grey with a blue-green tinge), green, and white (Wu et al. 1761, Figure 1). In the absence of the yellow glazed tiles on roofs, which symbolised the emperorship (Leng 2021), for this complex, red was the only colour that distinctly expressed the ruling power. The red colour had a long and profound history of being involved with power in China. Linguistically, the characters such as the red door, red building, and red wall were all closely related to the ruling class whose powers were endowed by the Emperor. Take, for example, these verses excerpted from Du Fu's (712-770AD) poem *Inner Feelings for the Journey to Fengxian County from the Capital in Five Hundred* Characters:

> Behind red doors, the wine and meats become foul;
> Out on the road, the bones of the frozen dead spread.
> In one inch, the prosperity and impoverishment are disparate;
> Extremely distressed, the feelings are hard to narrate.
> (Du 1348-1312: 18)

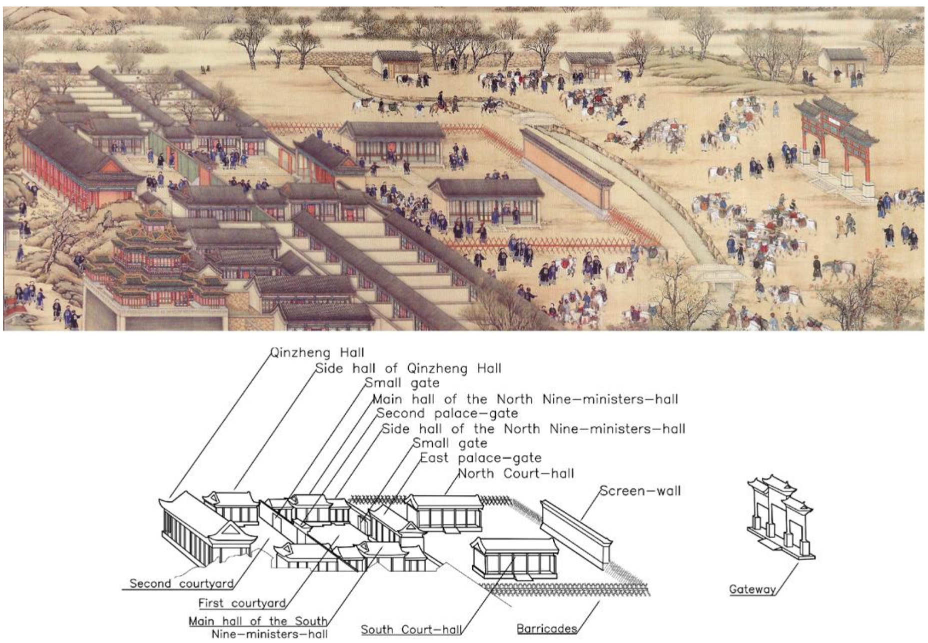

Figure 1. Qinzheng Hall complex [detail view of *Longevity Blessing*],1761, Palace Museum, China.

Red as A Tool of Hierarchy Differentiation

During the Qianlong Reign, on buildings of the Qinzheng Hall complex, red was used in a strict systematic way to distinguish the hierarchy for the people of the ruling class such as the Emperor, the aristocrats, and the officials. This was mainly done in successive spaces along the central axis, as shown in the handscroll *Longevity Blessing* (see Figure 1).

On the central axis of the Qinzheng hall complex, red first appeared on the lofty gateway, which served as a landmark at the east side of the Garden of Clear Ripples. On this gateway, the two timber columns, the vertical studs and the horizontal girts were all painted red. The gateway stood on an open space, it was taller than the buildings in the distance and the trees on both sides. Compared with the grey, white, and other detailed colourful patterns, red was the most conspicuous colour on the gateway. Both the redness and the height made red a penetrating colour that could invite people's sight from a far distance. Here, red functioned as an official visual notification, which was the sign for the location of the imperial power. Moreover, it was also a psychological warning as the towering red generated awe and fear in the viewers.

Behind the gateway, the screen-wall was the second building that was coated in red. This screen-wall was not constructed for all viewers, it was only built for those who had the right to enter the Qinzheng Hall complex. Unlike the gateway which attracted people's attention, the wall blocked the gaze of the lower-rank government staff who were standing in the gateway square from trespassing beyond the east palace-gate. Behind the red screen-wall was the realm of exclusive power thoroughly controlled by the Emperor. As a visual barrier, the red protected this exclusive power from being shared by any outsider.

This screen-wall, however, could never separate people physically, the segregation work was finally done by the red barricades. For these barricades, red was painted on the X forms, which were both aggressive and defensive shapes psychologically. The red colour on them manifested the formidable force and power that were legally exercised by the Emperor, aristocrats and officials behind the barricades and the screen-wall. Therefore, here, red mainly functioned as a physical barrier between the people in the Imperial Court and the lower-rank government officials. Although these red barricades were not tall enough, they were the insurmountable obstacles that were set between the people of the imperial court and the outsiders, since they were held up by the authority of the Monarch and for the authority of the Monarch.

On the west side of the barricades, the square behind the screen-wall, the first courtyard and the second courtyard were respectively connected by six red gates. The Emperor was the only one who could walk through the broader east palace-gate and the second palace-gate, which stood on the central axis. Evidence for this can be seen in the *Longevity Blessing*, in the absence of the Emperor those two doors were closed. In terms of the officials and aristocrats who were wearing badge-robes, they could merely walk through the four small gates on the left and right sides of the two main gates. These red entrances were the materialised forms of power. The larger areas and better locations of red on the two palace-gates demonstrated that the power was absolutely dominated by the Emperor in the Imperial Court. While those four small red entrances spoke for relevant pedestrians' subordinate and assistant statuses to the Monarch.

In addition to those gates, red also existed on the narrow curtains hanging on the doors of the North-south Court-halls and the North-south Nine-ministers-halls, which were the duty offices for the officials in the Imperial Court. The same as the small red entrances, here, red re-emphasised the limitations of those officials' powers.

At the end of the central axis, red also widely appeared on the main hall known as Qinzheng Hall, which was for the Emperor to handle governmental and military affairs. The red area of Qinzheng Hall was much larger than any other buildings in the complex, except the building's roof, base and eaves; the red colour existed on all elements, such as the columns, windows, gables, walls and doors, etc. Though the front facade and the left facade were not painted in the documentary painting, it could still be speculated that all of them were as red as the back facade and right facade. The extensiveness and purity of red on Qinzheng Hall symbolised the insuperable imperial power. This huge volume of red generated an immersive experience for the officials standing in front of it, for them to realise that here was the headstream of their personal powers, and more importantly, for them to understand how negligible and powerless they were when facing the Emperor. Generally, in using red to manifest the Emperor-centred power structure, there was no difference in the visual appearance of each red architectural element. The colour variances in the chromaticity and blackness between all red elements were omitted by the people in their minds. Here, these red elements functioned like one language. Although it was spoken in different accents, the contents were never changed.

Varieties of Red

As a matter of fact, there were mainly two kinds of reds on buildings of the Qingzhen Hall complex, the one coated on the woodwork, and the one applied on walls.

As recorded in the book chapter *Collected Archives for Oiling-works of the Imperial Court, Longevity Hill and Old Summer Palace* that was recompiled by the antiquarian Wang (2009: 329-343), for the Garden of Clear Ripples, the red coating on woodwork contains two kinds of pigments, mercury-red and pian red-soil. According to the science historian Pan's (1989: 468-478) annotation to the encyclopaedia *Exploitation the Works of Nature*: the composition of the mercury-red is man-made mercury sulphide; while the composition of the pian red-soil is natural iron(III) oxide. As red pigments, the mercury-red and pian red-soil can enhance the thickness and strength of the paint and effectively block the erosion caused by the sunlight. The choice of these two pigments was, however, motivated by the expression of political power, instead of being driven by their physical function. The reason is that they were not the only pigments that have anti-corrosion function, moreover, the key protection for the woodwork was provided by the base-works—layers below the coating of these pigments. The function of the base-works is acknowledged by the master craftsman Zhao (1999: 1) who had led the renovations of the Summer Palace.

As documented in the collected archives, for these red coatings on different timber architectural elements, such as the columns and frames around the windows and doors, the frameworks of the windows, and the gables, the ratios between the mercury-red and pian red-soil, as well as other ingredients were different (Wang 2009: 329-338). Although these archives documented the compositions of red coatings for various architectural elements, none of them directly mentioned which kind of coating was coated on which building in the Garden of Clear Ripples, in addition, many architectural elements that were also coated in red were omitted, such as the gates, doors, and barricades, etc. It can be reasoned that the red paint on the woodwork of the buildings in the Qinzheng Hall complex also strictly followed the same rule as with the one in the archives. Hence, in this complex, the columns of the gateway, the columns and frames around the windows, and the doors of the main hall, the frameworks of the windows, the doors of the main hall, the gables of the main hall, the two palace gates, and the barricades, etc would have been coated with different reds, although no clear distinctions can be seen on the *Longevity Blessing*. For the redness of these red coatings, regardless of other compositions, it was mainly determined by the ratio between the mercury-red and red-soil, as the chromaticity of the mercury-red is higher than the red-soil and its blackness is lower than the latter, so more mercury-red and less red-soil will make the red paint appear more saturated and brighter, and vice versa. These differences in the redness of different architectural elements mainly resulted from economic, visual and psychological reasons: the mercury-red was much more expensive than the red-soil in the Qing Dynasty. Therefore, more saturated and bright mercury-red was added to the paint of these elements—such as the columns and frames around the windows and doors, and the frameworks of the windows—that were publicly visible, thereby reminding the general populace of the power structure dominated by the Emperor; while, for less visible elements—such as the gables near the roofs—that could seldom attract people's attention, less mercury-red and more red-soil were added in their paint.

In addition to these red coatings lacquered on woodwork, the red colour can also be found on the side-walls under the gables of the Qinzheng Hall and the screen-wall. Those two kinds of walls were all coated with red plaster. According to

Wang's (2009: 267) another book chapter *Collected Archives for Pottery-works of the Imperial Court, Longevity Hill and Old Summer Palace*, in the Garden of Clear Ripples, the pigments for the red plater are the first-ranked red-soil and the second-ranked red-soil. These two kinds of soil are all natural iron(III) oxide, their difference is that the purity of the first one is higher than the second one. Unlike the red coatings on woodwork, there is no evidence in Wang's collected archives that shows the red plaster was made differently for different walls. Hence, there should be no difference between the red plaster on the sidewalls of the Qinzheng Hall and the one on the screen-wall. As the main ingredient of the red plaster, this red-soil can shield bricks from being weathered by natural forces, nevertheless, they were neither necessary nor the irreplaceable anti-corrosion materials. The choice of these two kinds of red-soil was also mainly determined by economic, visual and psychosocial reasons. According to the collected archives, the costs for every 596.8 grams of the first-ranked red-soil were 0.373 grams of silvers, for the same weight of the second-ranked red-soil were 0.1865 grams of silvers (Wang 2009: 947). As one of the two pigments for the red coatings on woodwork, every 596.8 grams of plain red-soil was worth 0.2984 grams of silvers (Wang 2009: 609), which are close to the prices of the first-ranked red-soil and second-ranked red-soil. The price of mercury-red was, however, much higher than the above three kinds of soil, every 596.8 grams of it was worth 17.158 grams of silvers (Wang 2009: 609). Compared with the limited amount of mercury-red and pian red-soil required for the woodwork, a large amount of red soil was needed by the brick walls in the same area. Hence, it is reasonable for the Emperor to choose these first-ranked and second-ranked red-soil because of their low costs. Furthermore, though the red plaster on brick walls did not have the same vivid appearance as the red coatings on woodwork, it could still generate the same psychological reaction for people in the Qinzheng hall complex, because the dull-iron red colour was also directly associated with the power centred on the Sovereign.

Conclusion

For the Emperor Qianlong, choosing red for specific architectural elements was a measure of governance. The colour variances of red could not affect the effect of this political measure. The red colour on the Qinzheng Hall complex clearly clarified the hierarchical order within the ruling class, meanwhile, it also classified the ruling class as a well-organised powerful whole as distinct from the powerless ruled. The ultimate purpose for the use of red on this complex was to ensure the supremacy of the Emperor and the maintenance of the Emperor-dominated power structure.

Acknowledgement

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References

Du, F. 1348-1312. *Ji qian jia zhu fen lei du gong bu shi* [Collection of thousands of annotations to the poetry of Minister Du]. 25 vols. Vol. 2. Unknown: Unknown.

Guo, D. 2018. *Yuan shi de hui huang yuan ming yuan jian zhu yuan lin yan jiu yu bao hu* [Disappeared glory: the research and preservation for the architecture and landscape architecture of the Old Summer Palace]. 2 ed. Shanghai: Shanghai ke xue ji shu chu ban she.

Leng, X. 2021. The meaning of blue-green tiles on roofs of the Qinzheng Hall complex at the Summer Palace. In: *Proceedings of the International Colour Association (AIC) Conference 2021*. Milan, Italy. AIC, 927-932.

Liu, L. 2019. *Shi ba shi ji jing hua sheng jing tu* [Magnificent view of the capital in the 18th Century]. 2 vols. Vol. 1. Beijing: Gu gong chu ban she.

Pan, J. 1989. *Tian gong kai wu jiao zhu ji yan jiu* [Annotation and study on the Exploitation the Works of Nature]. Chengdu: Bashu shu she.

Wang, S. 2009. *Qing dai jiang zuo ze li* [Rules and cases for the craftsmanship of the Qing Dynasty]. 6 vols. Vol. 2. Zhengzhou: Da xiang chu ban she.

Woodside, A. 2002. "The Ch'ien-lung Reign." In *The Cambridge History of China*, edited by Willard J. Peterson, 230-309. Cambridge: Cambridge University Press.

Wu, W., D. Xu, F. Gu, H. Gu, W. He, and D. Zhao. 1761. *Longevity blessing*. Beijing: Palace Museum.

Zhao, L., and M. Zhao. 1999. *Qing dai gu jian zhu you qi zuo gong yi* [Oiling and painting craftsmanship for the traditional buildings of the Qing Dynasty]. Beijing: Zhong guo jian zhu gong ye chu ban she.

Zhou, W. 2006. *Yuan lin feng jing jian zhu* [Garden, landscape, and architecture]. Tianjin: Bai hua wen yi chu ban she.

Colin McCahon's House and its Colours: A Glimpse of New Zealand Beyond its Colonial Past

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Abstract

Colin McCahon's Titirangi Kauri-forest nestled house was not only a tiny and humble house for his wife and 4 children for the years of 1953-60, but it was the birthplace of some beautiful paintings and (what has turned out to be) culturally important images for New Zealand emerging from its colonial past. This period of Colin's work was totally focussed on producing warm colourful images, as opposed to the Black paintings with White lettering of his later years. The Northland panels, 1958, is an important painting of that period, made up of eight vertical unframed canvas panels. They evoke a spirit of place that seemingly many Kiwis can easily relate to. The colours of these panels seem to also adorn the surfaces of the house. This paper unpacks the colours of his house, which still stands today. The colour palette collection, surveyed and analysed through a field study, has been compared with colour theories and relevant palettes available at that time. The final aim of the paper is to extend our knowledge on this important artefact for New Zealand's culture and help with its future conservation.

Keywords: *New Zealand, Art, Architecture, Colour palette, Colour conservation*

Introduction

One hypothesis of this piece of research came from a casual conversation: that the paint used in the iconic *Northland panels*, 1958, was house paint. An idea that has stuck for many years stemmed from a personal conversation with Landscape Architect Rod Barnett: about where might Designers' find clues and cues for their Designs? Rod replied, 'the answers are often close at hand,' (Rennie, 2000). It seemed possible given that the McCahon family was very poor, making a living off art alone in New Zealand was (and still is) very risky, especially if the artist had to support a family. Julian should know, his artist father: Bruce Rennie, (Thomas, 2018), had to support his wife and three children with income gained solely from teaching Art at the local Secondary School, (often gifting his drawings and pen & ink works away to friends).

Colin McCahon and his family lived at the 67 Otitori Bay Road, French Bay house between 1953 and 1960. The family's poverty is clearly expressed by the small bedrooms given over to the children whilst the parents slept in bunks under the house in a cave-like space exposed directly to the damp Kauri bush and wet weather. Yet the joyous *Northland Panels*, 1958, were "painted on the sun deck at Titirangi all on one Sunday afternoon and corrected for weeks afterwards" (Brown, p.58, 2010). The same deck is used for parties with friends and students. This setting of house in the bush: ying to yang, colour of nature/material poverty, family nest/image-making, making do/timeless nuances brought forth a unique and primal expression of local colours that have become primal road makers for visually portraying this unique milieu. The *Northland Panels* painted colours and even the titles of the eight panels evoke a spirit of place, (viz. reading the artwork from left to right): *Black and White*; *Red Clay Landscape; Manuka and Red Clay Landscape; Rain; A Landscape with too few lovers; Tui; Landscape with White Road; It can be dark here*." (*Te Papa Tongarewa:* "McCahon's Northland Panels"). The colours of those paintings are reflected in the surfaces of his humble house which, at the same time, seem to embrace the colours of the surrounding environment. Refer for example, to the third panel (from the left-hand side*): Manuka and Red* Clay Landscape.

The house interior with its pull-out drawers and cupboard doors that open to reveal McCahon histories (designed by Architect Rick Pearson), to expose glimpses of joyous colour, and other 'built-in' colour creates (during a Covid-19 ravaged world) a haptically child-like magical atmosphere and a time-warp back to the 1950's. The goal is to understand how the Artist transferred his colour palette (and the colours of local nature) into the design of the house, and test whether he used those same house paints in his painted canvases, blending his daily life with the vividness of his art.

Research Methodology

The research was carried out in two directions following a methodology based on literature review and a field study using a NCS Colourpin SE tool. The literature review, based on resources available in Wellington where the *Northland Panels*, 1958, are held at *Te Papa Tongarewa*, (Museum of New Zealand). Along with various texts and online resources helped galvanize the research in its two-pronged approach: namely to establish what the colour palette of the house was. And to try and find out whether those same paints were used in the production of the *Northland Panels* themselves. Relevant colour theories, schemes and artist paint usage of that time were also considered in comparison.

It is important to specify that we based our research on the current surface colours of the house, as it is not possible to capture the original colours due to the intervening modifications that have occurred over the years. However, some information was helpful from Burgess and Mace's Heritage report (2003) which was developed for the recent house conservation project.

To establish the colour palette of the house a field study was carried out. Using the “Natural Colour System (NCS)” which is the colour model most used by professionals in this field. Surface colours were detected by pressing the NCS Colourpin SE tool directly against each surface and reading the possible matches on the Colourpin software on an adjacent smartphone. The colours have been tabulated via the NCS 1950 chart and the relative RGB values, (refer below).

To carry out a comparison with Le Corbusier’s colour palette we considered the NCS codes already identified by Juan Serra and others (2016). In relation to Frank Lloyd Wright’s palette, we converted the colours printed in Wright’s Complete Works 1943-1959 (Brooks Pfeiffer and G. ssel, 2009) using the same NCS Colourpin SE tool.

Given that *Te Papa* would not allow the physical touching of any artwork within its collection, (by such a Coloupin device), we had to research various texts and videos to back up our house paint for artwork hypothesis.

Results

The colour palettes of McCahon house are represented in Figures 1 and 2 below. Figure 1 shows the surveyed exterior colours superimposed upon Colin’s very own 1955 drawings for an application for a Building Consent. Figure 2 covers the colours of the indoor spaces.

Elevations

Three elevations of the house are painted in ‘ferric oxide’ red (5040-Y80R) and only the south-west elevation is a darker grey (8005-G50Y). The cladding of the basement is painted in black (9000-N). Window frames are white (0804-Y10R), and windowsills are black (9000-N). Gutters are of galvanized metal and the metal roofing is a light grey, as well as the upper part of the chimney. The colour that stands out with great clarity is the red cladding.

Floors

Timber floors are generally dark brown (e.g., living rooms 7010-Y70R) while the entry, kitchen and dining room are covered with a sand-coloured linoleum. The outdoor deck is covered with a dark grey tar-type membrane.

Indoor spaces: ground floor

Walls and ceilings are generally whitish (0502-Y) with a greyish skirting (3005-Y50R). The part that stands out the most are the kitchen walls, storage, and shelves which are all painted in yellowish green (3030-G40Y). The ceiling battens and cornice are closer to a natural green (5020-G10Y).

Indoor spaces: basement

Ceiling, structure, beds, and shelves of the open bedroom are characterized by a colour similar to the ‘ferric oxide’ red cladding, but less vivid (e.g., 4020-Y70R). The room that stands out is the bathroom which was built by McCahon. Walls and ceilings are organized in a Mondrian-like scheme with black cover battens (between sheet linings) frame, and panels of different colours: 5010-B30G grey, 5030-R red, 6020-G90Y brown, 7010-B70G blue-green, etc.

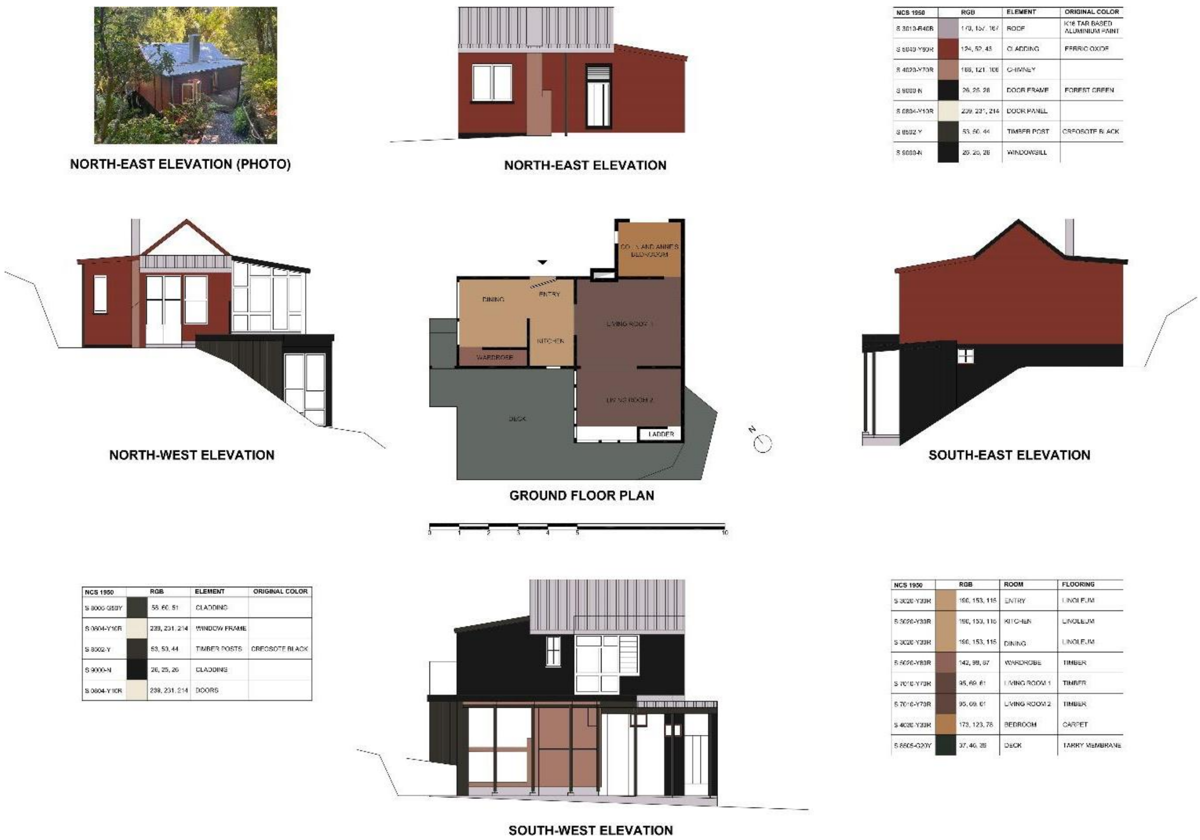

Figure 1. Colour palette of the exteriors and ground floorings (A. Premier).

GROUND FLOOR

ROOM	NCS 1950	RGB	ELEMENT
ENTRY	S 0505-Y20R	247, 237, 212	CEILING
	S 5020-G10Y	87, 119, 96	CEILING BATTENS/CORNICE
	S 3030-G40Y	140, 159, 108	WALL/STORAGE/SHELVES
	S 2010-Y	203, 192, 162	DOOR FRAME
	S 0804-Y10R	239, 231, 214	DOOR PANEL
KITCHEN	S 0502-Y	246, 240, 228	WALL
	S 0505-Y	247, 240, 218	WINDOW FRAME
	S 2030-Y10R	213, 179, 115	BENCHTOP

ROOM	NCS 1950	RGB	ELEMENT
DINING/WARDROBE	S 2020-Y20R	213, 179, 115	CEILING
	S 6030-Y10R	113, 84, 37	WALL (MURAL)
	S 0502-Y	246, 240, 228	WALL (WHITE)
	S 0603-Y20R	241, 234, 218	WALL (WARDROBE)
LIVING ROOM 1	S 0505-Y10R	246, 237, 215	CEILING
	S 0502-Y	246, 240, 228	WALL
	S 3005-Y50R	181, 165, 153	SKIRTING
	S 4030-Y30R	173, 123, 78	FIREPLACE CORNICE

ROOM	NCS 1950	RGB	ELEMENT
LIVING ROOM 2	S 5020-Y40R	147, 107, 79	BENCH
	S 3060-Y20R	188, 125, 31	DOOR (LADDER)
	S 0505-Y20R	247, 237, 212	FURNITURE/WINDOW FRAME
	S 5020-Y50R	147, 107, 86	WINDOWSILL
BEDROOM	S 3030-Y20R	187, 147, 93	CEILING
	S 2020-Y10R	207, 184, 138	WALL
	S 3030-Y20R	187, 147, 93	WINDOW FRAME (OPENABLE)
	S 0804-Y10R	239, 231, 214	WINDOW FRAME

BASEMENT

ROOM	NCS 1950	RGB	ELEMENT
OPEN BEDROOM	S 5030-Y80R	136, 78, 67	CEILING/STRUCTURE
	S 2002-Y	199, 195, 187	WALL
	S 4020-Y70R	166, 121, 106	BED/SHELVES
	S 0804-Y30R	238, 228, 211	WINDOW FRAME
	S 3010-Y30R	187, 164, 139	FLOOR
BATHROOM	S 5020-Y30R	145, 109, 75	SINK
	S 5030-Y90R	133, 75, 71	FLOOR
	S 9000-N	26, 25, 26	WALL FRAME

ROOM	NCS 1950	RGB	ELEMENT
BATHROOM	S 5010-B30G	107, 125, 127	CEILING (GREY)
	S 0603-Y20R	241, 234, 218	CEILING (WHITE)
	S 2020-Y20R	214, 182, 137	CEILING (BROWN)
	S 5030-R	126, 67, 71	WALL (RED)
	S 0505-Y10R	246, 237, 215	WALL (WHITE)
	S 5010-B10G	107, 125, 131	WALL (GREY)
	S 6020-G90Y	111, 98, 63	WALL (BROWN)
	S 7010-B70G	59, 82, 80	WALL (GREEN)

ROOM	NCS 1950	RGB	ELEMENT
BATHROOM	S 5020-Y40R	147, 107, 79	WINDOW FRAME (BATHROOM)
	S 5040-R80B	21, 65, 117	CEILING (SHOWER)
	S 0603-Y20R	241, 234, 218	WALL (SHOWER)
	S 3030-G40Y	140, 159, 108	WINDOW FRAME (SHOWER)
LADDER	S 5010-Y10R	145, 129, 105	WALL (BASEMENT)
	S 8005-Y80R	69, 53, 49	STEPS
	S 1510-Y20R	224, 204, 172	WALL (GROUND FLOOR)

Figure 2. Colour palette of the interiors (A. Premier).

McCahon painted the *Northland panels* after a 1958 United States trip "viewing the work of Jackson Pollock, Mark Rothko, and Willem de Kooning. Their work inspired him to paint at larger scale and in a more expressionist style." (*Te Papa Tongarewa*: "Northland Panels"). This included larger scale paint brushes to apply the paint to canvases.

Researching the possible use of at-hand materials to complete the artistic *Northland panel* canvases: Melanie Carlisle says on a *Te Papa* video: "…people often think conservators only work on old paintings, 100 years or more…Colin McCahon used a particular paint to complete this painting, it was a commercial house paint…" (Te Papa Tongarewa: "Tales from Te Papa Episode 64: Painter's Nightmare").

Comparison with relevant architectural colour palettes (1931-1959)

At that time a few architectural colour palettes were available. Two of the most relevant ones were Le Corbusier and Frank Lloyd Wright.

Le Corbusier developed the Colour Keyboards in 1931 for the company Salubra, with 43 shades, and the Salubra collection in 1959 with 20, for a total of 63 shades. The comparison between the NCS codes of the Colin McCahon house palette and the NCS codes of Salubra 1931 has shown that earthy colours – in particular Sienna 6020-Y80R and 4040-Y70R – are somewhat similar to the colour of the external cladding (5040-Y80R) and of the chimney (4020-Y70R). Similarities have been found in the yellowish landscape-green (1030-G40Y) and the colour of the kitchen (3030-G40Y), with slightly different values of blackness and chromaticity. The ultramarine blue (3050-R80B) is also close (but lighter) to the one used by McCahon for the ceiling of the shower (5040-R80B). However, if we observe the work of Le Corbusier, like the Maison La Roche-Jeanneret in Paris (1923-25) or the Unité d'Habitation in Berlin (1959), we can easily infer that colour-combinations are very different from McCahon's approach.

Wright's colour palette was created for Martin-Senour Paints in 1955. The collection included the original Frank Lloyd Wright colours used in two of his most acclaimed projects, Fallingwater (1936-39) and Taliesin West (1937). The palette included 36 original colours and it was called 'Taliesin Palette'. As per Le Corbusier's palette, there are some similarities in the earthy colours and in the greens. In particular, Wright's 'deep rust' (no. 370) is close to McCahon's 'ferric oxide' cladding. Wright's 'spring green' (no. 396) is also close to the green of the kitchen and the white colour of the walls may be close to Wright's 'pearl white' (no. 994). In general Wright's palette seems to be less saturated than Le Corbusier and McCahon ones.

Comparison with relevant colour theories (1921-1933)

At that time, the colour theories that were more popular amongst artists were those developed under The Bauhaus School (1919-33). Those theories were brought to the USA by Joseph Albers in 1933. It is possible that McCahon came into contact with them on his trip to the USA or through literature. Those theories were based on the interaction between different colours (Albers, 1963). According to Johannes Itten's theory of contrasts the ferric oxide red of the external cladding of the house is diametrically opposite (in his colour wheel) to the green of the surrounding forest and the colour of the kitchen. This is a typical red-green contrast. They are opposite and they incite each other to maximum vividness when adjacent (Itten, 1961). In this way, the house is part of the environment with its ferric-oxide-red but it is also clearly distinguishable from it (Figure 3)

Figure 3. Colours of the house very close to McCahon's Northland Panels (1958).

Albers' lessons on colour may help us understand the effect of McCahon's colour combinations. In particular, the mix of so-called warm and cold colours. In the complex organization of the bathroom, blue and red are combined with achromatic colours, like white, black, and grey and their blend with green (of neutral temperature). With such organization, the interpretation of warm and cold colours becomes totally arbitrary, and this tells us that McCahon was probably aware of this fact.

Conclusions

The research has proved our hunch about 'needs must,' was correct. That the inner artistic urges find ways and means to express that which needs to see the light of day. Colin McCahon's use of what was close-at-hand everyday house paint was a practical vehicle to express his poetic memories of New Zealand's North land and skyscapes.

The survey carried out on the colours of Colin McCahon house has revealed the colour palettes of the outdoor and indoor spaces. Palettes have been described through the NCS notation in order to be able to reproduce the colours in the future. This will help stakeholders in the conservation of this important artefact of New Zealand heritage. The study also highlighted that McCahon was aware of current theories on colour interaction, and he applied them also in his house. Comparison with architectural colour palettes of that time has revealed some similarities with earthy colours and greens used by Le Corbusier and Frank Lloyd Wright. However, McCahon's approach to colour design has been revealed to be quite different.

Acknowledgements

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References

Albers, J. 1963. *Interaction of color*. New Haven, CT: Yale University Press.
Brooks Pfeiffer, B. and G. ssel, P. 2009. *Frank Lloyd Wright, 1943-1959: the complete works*. K. In: Taschen.
Brown, G.H. 2010. *Towards a Promised Land.* Auckland: Auckland University Press.
Burgess, G. and Mace, T. 2003. Conservation Plan McCahon House 67 Otitori Bay Road Titirangi. Auckland: Waitakere City Council and McCahon House Trust. Retrieved from: https://mccahonhouse.org.nz/about/conservation
Hackshaw, B. 2021. The Architect and the Artists: Hackshaw, McCahon, Dibble. Auckland: Massey University Press.
Itten, J. 1961. The Art of Color: The Subjective Experience and Objective Rationale of Color, revised ed. New York: John Wiley & Sons, 1973.
Morris, P. 2019. The dank and magical house where Colin McCahon lived. *The Spinoff.* Retrieved from: https://thespinoff.co.nz/art/31-08-2019/colin-mccahon-the-bus-tour
Rennie, J.J. 2000. Personal conversation with Landscape Architect Rod Barnett.

Rüegg, A. 1997. *Polychromie architecturale: Le Corbusier's color keyboards from 1931 and 1959*. Basel: Birkh user.

Serra, J., Llopis, J., Torres, A. and Giménez, M. 2016. Color Combination Criteria in Le Corbusier's Purist Architecture Based on Salubra claviers from 1931. *COLOR research and application*, 41(1), 85-100. https://doi.org/10.1002/col.21940

Simpson, P. 2007. *Colin McCahon: the Titirangi years, 1953-59*. Auckland: Auckland University Press.

Te Papa Tongarewa: "McCahon's Northland Panels." Te Papa Tongarewa, 2022, Retrieved from: https://collections.tepapa.govt.nz/topic/946.

Te Papa Tongarewa: "Northland Panels." Te Papa Tongarewa, 2022, Retrieved from: https://collections.tepapa.govt.nz/object/38664.

Te Papa Tongarewa: "Tales from Te Papa Episode 64: Painter's Nightmare." Retrieved from: https://collections.tepapa.govt.nz/topic/2923.

Thomas, C. 2018. *Verve: 60 Years of the Art of Bruce Rennie.* Marton, New Zealand: Julian Rennie.

Research on the influence of the natural environment of residence on city color preference: A case study of Busan, South Korea

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Abstract

The city color guidelines were established under the leadership of the government recently in Korea. However, the color regulations in urban planning lead to the question of how to deal with residents' preferences for city color. In the context of color preference as a cultural phenomenon and the geography of color, it is believed that different natural environments in various regions will shape the different color preferences of local residents. Therefore, this study used data obtained from a questionnaire survey in Busan City. Through the chi-square test, the correlations between the natural environment and city color preferences were analyzed, along with the color preferences of people with different residential locations, including hue preferences, value preferences, and chroma preferences. It was found that the natural environments affected residents' urban color preference, and residents of different living natural environments have different urban color preferences. including hue preference, value preference, and chroma preference.

Keywords: *Color preference, City color, Natural environment*

Introduction

In the research on color preference, many scholars believe that there are cross-cultural differences in color preferences (Miho S. 1994). Color preference is considered a cultural phenomenon, and the perception of color is affected by geographical and cultural factors (Ou L-C 2004, Gi-Yeon J. 2011, Jac T. M. D. 2021). City color, as an important part of the urban landscape, is composed of artificial colors including those of buildings, external facilities, roads, and billboards, and natural colors such as mountains, rivers, rock, vegetation, and other natural elements (J.B. Wang2020). Therefore, the formation of city colors is influenced by both natural colors and by the personal attributes of the urban citizens; simultaneously, the natural elements also shape the personal characteristics to a certain extent.

It is generally believed that the modern systematic study of urban colors started with the study of Turin's urban colors by Giovanni Beino in the 1950s. In the 1970s, combined with the spread of Jean-Philippe Lenclos's thoughts on “the geography of color," color scholars, planners, and policymakers realized that the creation of urban colors must consider the city's natural geographic environment, national characteristics, and citizen customs. At the beginning of the 21st century, Korea also recognized the importance of urban color, and to enhance urban landscapes and city images, many cities successively launched city color guidelines (J.H. Kim 2017). Busan Metropolitan City established city color guidelines in 2009 with reference to local and overseas cases.

Busan Metropolitan City (35◦05'N, 129◦04'E), is located on the southeastern tip of the Korean peninsula. The natural environment of Busan is a harmonious relationship of mountains, rivers, and sea. Therefore, the Busan City Color Guidelines divide the color planning area into ocean areas, river areas, mountain areas, etc. according to the unique natural environment of Busan.

Based on the above, in the context of a cultural phenomenon in color preferences, and to examine the influences of the natural environment on city color preferences, this study used data obtained from a questionnaire survey in Busan Metropolitan City, South Korea. Through the chi-square test, the correlations between the natural environment and choices of city color were analyzed, along with the color preferences of people with residential locations with different natural environments, including hue preferences, value preferences, and chroma preferences.

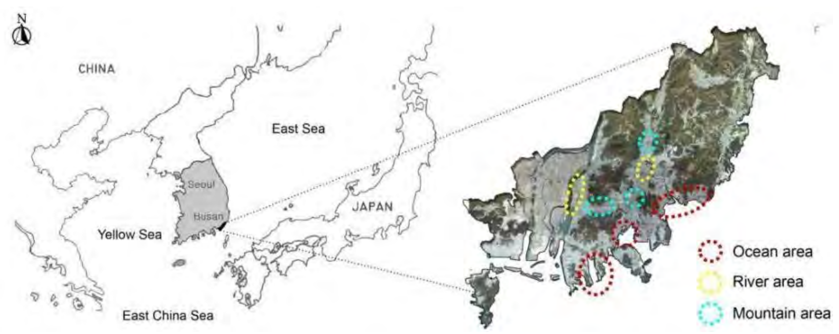

Figure 1. The location of Busan Metropolitan City and color areas of city color guideline.

Methods

Questionnaire survey

Before the formal survey, a preliminary survey (N=55) was conducted in May, 2021 and the contents of the questionnaire and the research color chart were revised based on the results of the pre-survey. The questionnaire consists of two parts: basic personal information and color questions. Among them, the basic personal information was the natural environment near the place of residence (ocean, river, mountain, or none). Considering that architectural colors take the biggest proportion of city colors, this study replaced the city colors with the exterior colors of a building. Therefore, the color question was, if constructing a new building near your home, what color would you prefer for the main color (more than 70% of the total color area) of the exterior of this building?

The stimulus comprised a "color chart" with 233 colored chips, including 227 chromatic colors and six achromatic colors. Among them, the hue of chromatic colors included R (2.5R, 5R, 7.5R), YR (2.5YR, 5YR, 7.5YR), Y (2.5Y, 5Y, 7.5Y), GY (2.5GY, 5GY, 7.5GY, 10GY), G (2.5G, 5G, 7.5G), BG (2.5BG, 5BG, 7.5BG, 10BG), B (2.5B, 5B, 7.5B), PB (2.5PB, 5PB, 7.5PB, 10PB), P (2.5P, 7.5P), and RP (2.5RP, 5RP, 10RP). The Munsell notations of achromatic colors were 10N, 9N, 7N, 5N, 4N,and 3N, respectively. The value range was 3 to 10, and the chroma range was 0 to 14.

The formal questionnaire survey was mainly conducted in the main representative areas of the sea, rivers, and mountains in Busan from June to August 2021. The surveys were generally conducted between 10 am and 12 am and between 2 pm and 5 pm, when the weather was clear.

The subjects of the survey were residents in Busan, excluding tourists and foreigners. A total of 319 questionnaires were returned in the formal survey. Among them, there were 310 valid questionnaires, with an effective rate of 97%. Regarding the residential location, 79 (25%) samples were near the ocean, 52 (16%) samples were near the river, and 162 (51%) were near the mountain.

Statistical method

First, descriptive statistical analysis was performed on the questionnaire results, and then the chi-square test was used to verify whether different residential locations were related to color preference, including hue preference, value preference, and chroma preference. Finally, combined with descriptive statistical analysis charts and test results to find out the different color preferences of residents in different natural environments, and get the conclusion.

The chi-square test for association determines whether there is a correlation between two nominal variables (Arnholt, A. T. 2007). It does this by comparing the frequencies observed in the cells to the frequencies that would be expected if there was no correlation between the two nominal variables (Dulan S. 2020). Since the expected frequencies are based on the absence of an association, the greater the association between the two nominal variables, the greater the difference between the expected observed and expected frequencies. If the p-value is small enough (usually $p < 0.05$ or $p < 0.1$), it can conclude that there is significant evidence against the null hypothesis of independence and that there is an association between the two variables in the population. In this study, the natural environment of residence and hue are nominal variables, and value and chroma are ordinal variables. Therefore, in order to examine whether there is a correlation between natural environment and hue, value, and chroma, the Chin-square test was used. And it was performed using IBM SPSS Statistics version 26.

Results and analysis

The results of hue

Table 1 is the crosstabulation of the natural environment and hue. Because the natural environment has 3 variables and the hue has 11 variables, it is a 3 x 11 crosstabulation. It can be seen from Table 1 that the most preferred hue for residents living near the ocean was Y (27.8%), followed by YR (13.9). Residents who live near rivers preferred Neutral colors. Whereas people living near the mountain were more willing to choose Y, PB, and GY.

Table 2 is the Chi-Square Tests with the test value is 30.052. Compare this value with a chi-square distribution with 20 degrees of freedom (i.e., the "df" column) to test for statistical significance, i.e., asymptotic Significance (2-sided). In the test, $p<0.1$, which means there was a significant association between the natural environment and hue preference.

		HUE											Total
		RP	**R**	**YR**	**Y**	**GY**	**G**	**BG**	**B**	**PB**	**P**	**N**	
Ocean	Count	3	5	11	22	8	1	2	8	9	1	9	79
	% with location	3.8	6.3	13.9	27.8	10.1	1.3	2.5	10.1	11.4	1.3	11.4	100
	Adjusted Residual	0.4	0.4	1.1	2.0	-0.6	-1.1	-1.2	0.2	-0.7	-0.9	-1.0	
River	Count	1	2	2	9	4	2	3	4	5	4	16	52
	% with location	1.9	3.8	3.8	17.3	7.7	3.8	5.8	7.7	9.6	7.7	30.8	100
	Adjusted Residual	-0.5	-0.6	-1.7	-0.6	-1.0	0.4	0.2	-0.5	-0.9	2.4	3.6	
Mountain	Count	5	9	18	28	23	6	10	16	26	3	18	162
	% with location	3.1	5.6	11.1	17.3	14.2	3.7	6.2	9.9	16.0	1.9	11.1	100
	Adjusted Residual	0.0	0.1	0.3	-1.4	1.3	0.7	0.9	0.2	1.3	-1.0	-1.9	
Total	Count	9	16	31	66	37	9	15	29	43	8	47	310
	% with location	2.9	5.2	10.0	21.3	11.9	2.9	4.8	9.4	13.9	2.6	15.2	100

Table 1. Location * Hue Cross Tabulation.

Cramer's V is a measure that provides the strength of the association between natural environment and hue preference (Dulan S. 2020). It can be seen from Table 3, Cramer's V is 0.226, which means there is a moderately strong correlation between natural environment and hue preference (Cohen, J. 1988). In addition, residual analysis can represent statistically significant results and is a method of comparison between cells. A residual is the difference between the expected frequency and the observed frequency. The larger the residual, the further the observed frequency is from its expected frequency. The adjusted residuals are shown in Table 2. From the adjusted residuals, it can be found that residents living near the ocean preferred warmer colors such as Y and YR more than people in other natural environments. Residents who live near rivers preferred neutral colors more than people in other environments. Residents who live near mountains prefer cool colors such as PB and GY to those who live near the sea or rivers.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	30.052	20	0.069
Likelihood Ratio	27.738	20	0.116
Linear-by-Linear Association	0.463	1	0.496
N of Valid Cases	293		

Table 2. Chi-Square Tests.

		Value	Approximate Significance
Nominal by Nominal	Phi	0.320	0.069
	Cramer's V	0.226	0.069
N of Valid Cases		293	

Table 3. Symmetric Measures.

The results of value and chroma

Table 4 is the 3 x 8 cross tabulation of natural environment and value. From Table 5 it can be found that in general, residents of Busan living in different natural environments preferred high-value urban colors. However, the specifics were different. For example, people living near the ocean were more willing to choose colors with values 8 and 9, whereas people living near rivers liked colors with values 8, 9, and 10. Differently, people living near mountains preferred colors with values 7, 8, and 9.

		Value								Total
		3	4	5	6	7	8	9	10	
Ocean	Count	6	2	5	7	6	21	28	4	79
	% with location	7.6	2.5	6.3	8.9	7.6	26.6	35.4	5.4	100
	Adjusted Residual	2.4	-0.7	-0.8	0.1	-1.8	1.2	0.6	-1.0	
River	Count	0	5	1	5	5	12	15	9	52
	% with location	0.0	9.6	1.9	9.6	9.6	23.1	28.8	17.3	100
	Adjusted Residual	-1.5	2.5	-1.9	0.3	-0.9	0.2	-0.7	3.0	
Mountain	Count	4	4	19	13	29	31	53	9	162
	% with location	2.5	2.5	11.7	8.0	17.9	19.1	32.7	5.6	100
	Adjusted Residual	-1.0	-1.3	2.2	-0.3	2.4	-1.2	0.0	-1.4	
Total	Count	10	11	27	26	44	64	104	24	310
	% with location	3.2	3.6	8.7	8.4	14.2	20.7	33.6	7.7	100

Table 4. Location * Value Crosstabulation.

From the Chi-Square test results in Table 5 and Symmetric Measures in Table 6, it can be seen that there is a significant medium-strength correlation between natural environment and value preferences of city color. Specifically, from the adjusted residuals in Table 6, it can be found that residents who live near the sea were more likely to choose a high value of 8 than those who live in other natural environments. Residents with rivers near their residences preferred white color with a value of 10 than those with sea and mountains near their residences. However, people living near mountains preferred a lower value of 7 than those near water.

	Value		df		Asymptotic Significance (2-sided)	
	Value	Chroma	Value	Chroma	Value	Chroma
Pearson Chi-Square	32.010	28.724	14	16	0.004	0.026
Likelihood Ratio	31.154	28.503	14	16	0.005	0.028
Linear-by-Linear	0.057	2.118	1	1	0.811	0.146
N of Valid Cases	293	293				

Table 5. Chi-Square Tests of value and chroma.

		Value		Approximate Significance	
		Value	Chroma	Value	Chroma
Nominal by Nominal	Phi	0.331	0.313	0.004	0.026
	Cramer's V	0.234	0.221	0.004	0.026
N of Valid Cases		293	293		

Table 6. Symmetric Measures of value and chroma.

		HUE									Total
		0	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	
Ocean	Count	9	9	7	15	14	8	6	8	3	79
	% with location	11.4	11.4	8.9	19.0	17.7	10.1	7.6	10.1	3.8	100
	Adjusted Residual	-1.0	1.9	-0.4	1.9	0.9	-1.2	-1.4	0.5	-1.0	
River	Count	16	3	4	2	3	7	8	5	4	52
	% with location	30.8	5.8	7.7	3.8	5.8	13.5	15.4	9.6	7.7	100
	Adjusted Residual	3.6	-0.3	-0.6	-2.2	-2.0	-0.1	0.8	0.2	0.5	
Mountain	Count	18	8	18	21	26	26	21	13	11	162
	% with location	11.1	4.9	11.1	13.0	16.0	16.0	13.0	8.0	6.8	100
	Adjusted Residual	-1.9	-1.4	0.8	0.0	0.7	1.1	0.6	-0.6	0.5	
Total	Count	47	21	30	40	43	44	37	28	20	310
	% with location	15.2	6.8	9.7	12.9	13.9	14.2	11.9	9.0	6.5	100

Table 7. Location * Chroma Cross Tabulation.

Table 7 is the 3 x 9 crosstabulation of the natural environment and chroma. From Table 7 it can be found that residents who live near the sea preferred chroma 4 and 6 the most, residents who live near the rivers preferred neutral colors with chroma 0, followed by chroma 10 and 8. On the other hand, the chroma preference trend of people living near the mountain was chroma 8 and 6. In addition, it can be seen from Table 5 and Table 6 that there is a significant medium-strength association between the natural environment and chroma preferences. Moreover, it is clear from the adjusted residuals in Table 7 that residents living near the sea preferred low chroma 4 more than residents living in other locations, whereas residents living near the mountain preferred medium-high chroma 8. Differently, people living near the river were more willing to choose achromatic colors with a chroma of 0 than those near the ocean or mountain.

Conclusion

In summary, in this study, the Chi-Square test was used to investigate the correlation between city color preferences and the natural environment in Busan Metropolitan City. In the end, the following meaningful findings were discovered.

First, there was a correlation between natural environment and color preference, including hue preference, value preference, and chroma preference. That is to say, the natural environment of the place of residence affected the residents' city color preference.

Second, residents of Busan living in different natural environments had different color preferences, including hue preference, value preference, and chroma preference. Specifically, residents of Busan who live near the ocean preferred warm colors, such as Y and YR with high value and low chroma. In contrast, people who live near the mountain preferred cool colors, such as PB and GY with medium value and medium-high chroma. Differently, Residents living near the river were more willing to choose neutral colors, especially white.

Acknowledgements

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References

Saito, M. 1994. A cross-cultural study on color preference in three Asian cities: Comparison between Tokyo, Taipei, and Tianjin. *Japanese Psychological Research*. (36): 219-232.

Ou L.-C., Luo M.R., Woodcock A. and Wright A. 2004. A study of colour emotion and colour preference. *Color Res Appl*. ;29:292–298.

Gi-Yeon Je and Kyoung-Hee Lee. 2011. Color Preference and Color Meaning of University Students. *J. Kor. Soc. Cloth. Ind.* (13): 346-352.

Jac T. M. Davis, Ellen Robertson, and Sheina Lew-Levy, et al. 2021. Cultural Components of Sex Differences in Color Preference. *Child Development.* 1-16.

Wang, Jiangbo, Lingyun Zhang, and Aiping Gou. 2020. Study on the preference of city color image selection based on the logistic model: A case study of Shanghai. *Color Res Appl.* (1): 1-16.

Juhee Kim, Seokhyun Kim. 2017. An Analysis Current and Improvement Methods of Landscape Color Guideline in Korea. *AIC 2017 Jeju*, 375-378.

Arnholt, A. T. 2007. "Statistics : The Art and Science of Learning From Data", *The American Statistician*, Vol. 61, No. 2, 181-182.

Dulan S., Namjae Cho. 2020. The analysis of association between learning styles and a model of IoT-based education: Chi-Square test for association. *J. Inf. Technol. Appl. Manag*. 27(3): 19-36.

Cohen, J., 1988. *Statistical power analysis for the behavioral sciences* (revised ed.) Academic Press, New York.

An Investigation of Color-Realm Visual Perception: The Effectiveness of Multi-Color Appliance of Design Hotel (DH) Interior Design in Taiwan

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Abstract

Design Hotel (DH) is a hotel type that emphasizes the role of design throughout the visual display inside its environment (Chen, 2018). To create such a unique sensory experience for the travelers, designers usually use various color strategies creating an image for improving the customers' experience (O'Connor, 2018). Since color is a significant interior element with the power to influence emotions and behaviors in a particular environment (Cho & Suh, 2020). In this content, multi research methods including Color Image Scale related questionnaires (Kobayashi, 1981) & eye-tracking, aims on investigate the preferred and highly connotative total appearance consist of numerous color combinations among the largest domestic travel group: Taiwanese aging from 20 to 30 years old, and also creating the atmosphere that the DH owners can express the theme, resulting in suitable color planning as a reference for DH interior design related color planning industry.

Keywords: *Design Hotel, Total Appearance, Color Image Scale, Eye-Tracking, Color Realm Perception*

Introduction

Previous researches investigate the emotional effectiveness of applying mono color in interior design. In fact, instead of perceiving mono-color, colors are normally experienced in the environment simultaneously. However, relative studies based on collective emotional, cognitive, and behavioral effects created by combinations of colors applied to a space have not been thoroughly investigated (Cho & Suh, 2020). The notable theory that investigates individuals' reaction toward colors can date back to John Hutchings' research (Hutchings, 1995a) elaborate that individuals' image to a specific appearance, not only related to mono-color, but colors and their interaction between shapes, textures, and even the play of light. Therefore, due to its complexity, conducting any kind of related analysis seems to be extremely difficult. To begin with, this research settled its setting at the guest room of Design Hotel (DH). Since DH, as the name implies to this category of hotel, notably for its design, such hotel types focus more on satisfying customers' spiritual or aesthetical requirements than on traditional star-rating criteria, such as the availability of facilities, transportation, and location(Chen, 2018). To fulfill such a requirement, visualization of the atmosphere, especially via the changes of colors, serves as the common design method throughout all the interior design of DH. To step into this discipline, the research group referred to the three-color combinations provided by Kobayashi's Color Image Scale (CIS), then multi research methods, multi-steps questionnaires and eye-tracking try to understand the perception and preference of our targets by evaluating the spatial total appearance that contains different color combinations.

Theoretical Background

To achieve the goal mentioned in introductory section, the literature review of Total Appearance Psychology, Color Image Scale (CIS), and Color Realm Eye-Tracking Research Methodology will be mentioned as follow.

Total Appearance

Hutchings (1995a) contended that appearance imaging of an object plays an important role in directing and controlling human behavior. Such appearance imaging including color, size, shape, and all sorts of visual elements based on ones' sensory, emotional, and intellectual experience will affect the anticipation of an object results in determining whether to participate in the occasion or not. Such philosophy was so-called "Total Appearance" philosophy, firstly proposed in the food industry. Hutchings (1995a) mentioned that such total appearance can be applied on the connotative judgments of color imaging. Also Hutchings (1995b) contended that such color- related total appearance philosophy has been used in 3D architectural design for "communication" purposes since ancient times. However, calculation of the value and quality of images that consist of multi-colors is a complicated process, also usually colors interact with shapes textures, and sometimes the changing appearances due to the play of light also affects one's evaluation of color. Such reality makes any kind of analysis extremely difficult. Therefore, total appearance evaluation studies are still developing discipline. In this study we adapted one multi color evaluating method, Color Image Scale, by focusing on its Image Scale 3 color combinations (1987 to present) (Figure 1), as a stepping stone into this discipline.

Color Image Scale

Color Image Scale (CIS), invented by Shigenobu Kobayashi at Nippon Color & Design Research Institute, investigates how the appliance of multi colors initiates human's emotion (Yoon & Wise, 2014). In general, Kobayashi concluded over 174 semantic keywords on the emotion perceived from 1000 color combinations. In addition, Kobayashi proposed a two-dimensional emotion space, the color image scale, which consists of two axes that correspond to cool-warm and soft-hard

(Kang, Shim, & Yoon, 2015). Nevertheless, Kobayashi contends CIS is psychological, not physical, we can pattern many cases through the system (Kobayashi, 1981). It is natural to judge the meaning of colors and words differently. Due to the flexibility of this system, CIS has been commonly used in many different industries for nearly 40 years (Horiguchi & Iwamatsu, 2018), in this study, into our questionnaire, for roughly understanding the perception of our target customers.

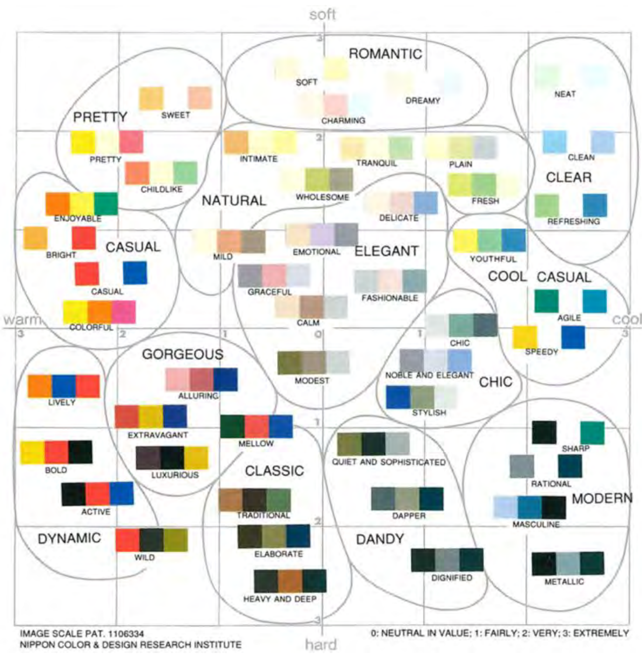

Figure 1. Image Scale 3 color combinations (1987 to present) (Horiguchi & Iwamatsu, 2018).

Color Realm Eye-Tracking Research

In the late 18th century (Jacob & Karn, 2003), scholars discovered individuals' eye movement is not a smooth sweep of the eye as assumed, it involves a series of eye movement patterns when interacting with the environment. For better understanding these eye movement patterns, scholars develop a series of eye trackers to diagnose them. Usually when conducting eye tracking studies, researchers will mark the part they want to analyze as Area of Interest (AOI) and collect this eye movement data in it(Huddleston, Behe, Minahan, & Fernandez, 2015). Among these data, fixation duration (the time required to fully understand the AOI) and visit times (the counts that participants eyesight move back and forth in AOI before the next behavior) were mainly used to measure the psychological involvement processes of participants. In color realm eye-tracking study, another indicator: Pupillometry is commonly used. Pupillometry, changes of pupil diameter, not only highly correlate with one's emotion, but explain the phenomenon that pupil size changes when visible light spectrums enter our eyes at a fixed distance (Granholm & Steinhauer, 2004). To sum up, this study will try to investigate the relationship between participants' choices and the mentioned eye movement indicators: fixation duration, visit times, pupillometry.

Methodology

To investigate the holistic process that related to simultaneous change of colors in 3-dimensional visual display, three stages of multi research methodologies were conducted as follows.

In the first stage, based on all the 13 groups of adjectives that are provided in Figure 1, randomly compiled 30 images each from hundreds of actual DH bedroom images available on a variety of media, in a total of 390(13*30) images were chosen. Then six color theoretical trained interior, industrial and graphic design related professionals were invited to rate the 6 most corresponding images toward the mentioned 13 color-combinations-groups in Figure 1, resulting in a total of 13 collective images as Figure 2. Then 58 men and women, totally 116 participants, were invited to reply 2 specific questions in an online questionnaire based on the 13 collective images (Figure 2): a 7-point scale measuring the degree of warm and cold (- 3~3) associated with hue, hard and soft (-3~3) associated with tone, perceived from these 13 collective images, and a preference ranking selection of these 13 collective images.

In the second stage, after analyzing the statistical results of the first stage. Another 37 men and 41 women, totalling 78 people were invited to reply to the most correspondent lexicon toward the picture that contained a hypothetical DH guest applying the selected color-combinations inside as Figure 3 via the other online questionnaire.

Figure 2. 13 Collective Color Combination Groups Consisted Selected DH Photos.

Figure 3. Hypothetical DH Bedroom with selected color-combinations

In the third stage, the other 5 men and 5 women, totally 10 people were invited to do eye movement study via a screen-based eye tracker: Tobii-Pro Nano. Participants were asked to look at each selected literal representative color combination containing a hypothetical DH bedroom image by its categorized group displayed on a computer screen for 20 s per image. This process serves as the "Baseline" Stage inside the analysis progress.

Then the images from the former step were displayed together onscreen for free viewing (FV) with no task specified for 20 s. This process serves as the "Experimental" Stage of the analysis progress. Finally, a combination with the photo from the previous step and a printed instruction showed up asking the participants to choose what they believed to be the most correspondent image toward the grouping adjective and provide a verbal response within 20 seconds. This process serves as the "Fitness" Stage inside analyzing progress. Figure 4 is a sample diagram of the experiment process.

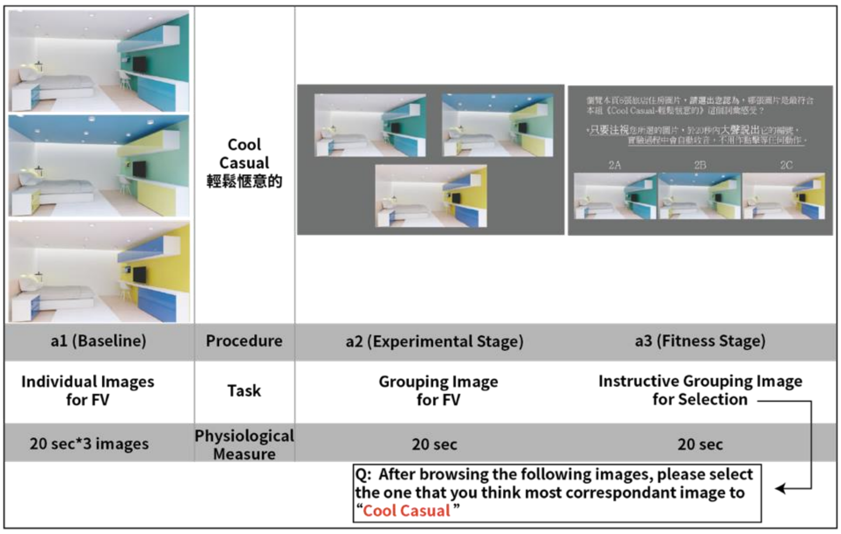

Figure 4: A Sample Diagram of Experiment Procedure in Color Combinations Group Cool Casual

Results And Discussion

From the first stage, after receiving the degree perception of the hue (warm and cold) and tone (hard and soft) among these 13 groups, Table 1 shows that the image that contains the color combination Cool Casual, the perception of hue has the largest standard deviation (M = -1.288, SD = 1.953).

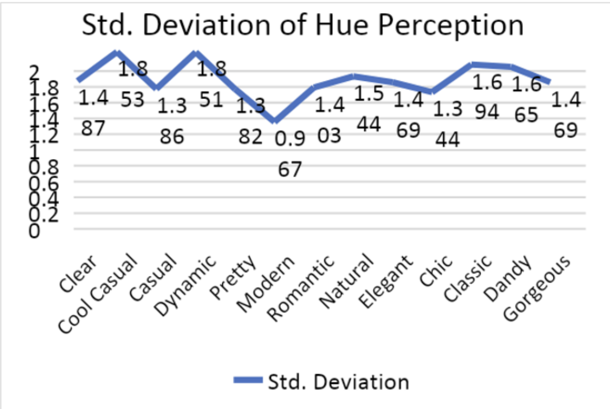

Table 1. The Hue Perception Standard Deviation Chart of all Color Combinations Group in Figure 1

Secondly, according to preference ranking, a weighted sum measurement was conducted, Color Combination Cool Casual also ranked at the 3rd place as indicated in Table 2. A following Pair T-Test of the preference among the DH images that contains color combinations from Cool Casual indicates that no significant differences between men and women when evaluating their preference of Cool Casual.

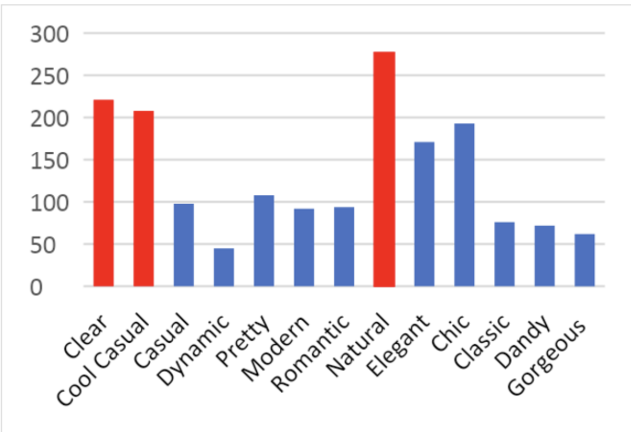

Table 2. The Weighted Sum of Preference Ranking

During the second stage, the correspondence measurement between representative lexicons and color combinations of Cool Causal: Agile (RGB code: 7,129,112; 255,255,255; 17,138,170), Youthful (RGB code: 245,239,109; 140,200,155; 60,136,184), and Speedy (RGB code: 238,209,45; 255,255,255; 4,84,165) was conducted. Among the three-color combinations and the lexiconic selection, the result of the Binomial Test indicates that the word Youthful is statistically significantly greater than (61.5%, p=.027) the other two lexicons to the image that contains the color combination Youthful.

During the third stage, the DH hypothetical bed room contains the representative color combinations from group Cool Casual. To ensure the participants eye sights do fix on color appliance area, a rough study throughout the heat map, as shown in the second row of Figure 5, the big distributions of red spots are located on the color appliance area indicating that the participants' eyesight do fix on our testing color combinations. After ensured the fixation of participants, for the analyzing convenience of pupil size average (mm), visit counts (count), fixation duration (sec) among each stimulus, as shown in the third row of Figure 5, all DH hypothetical bedroom images were drawn as Area of Interest in the stimuli of Experimental and Fitness Stage.

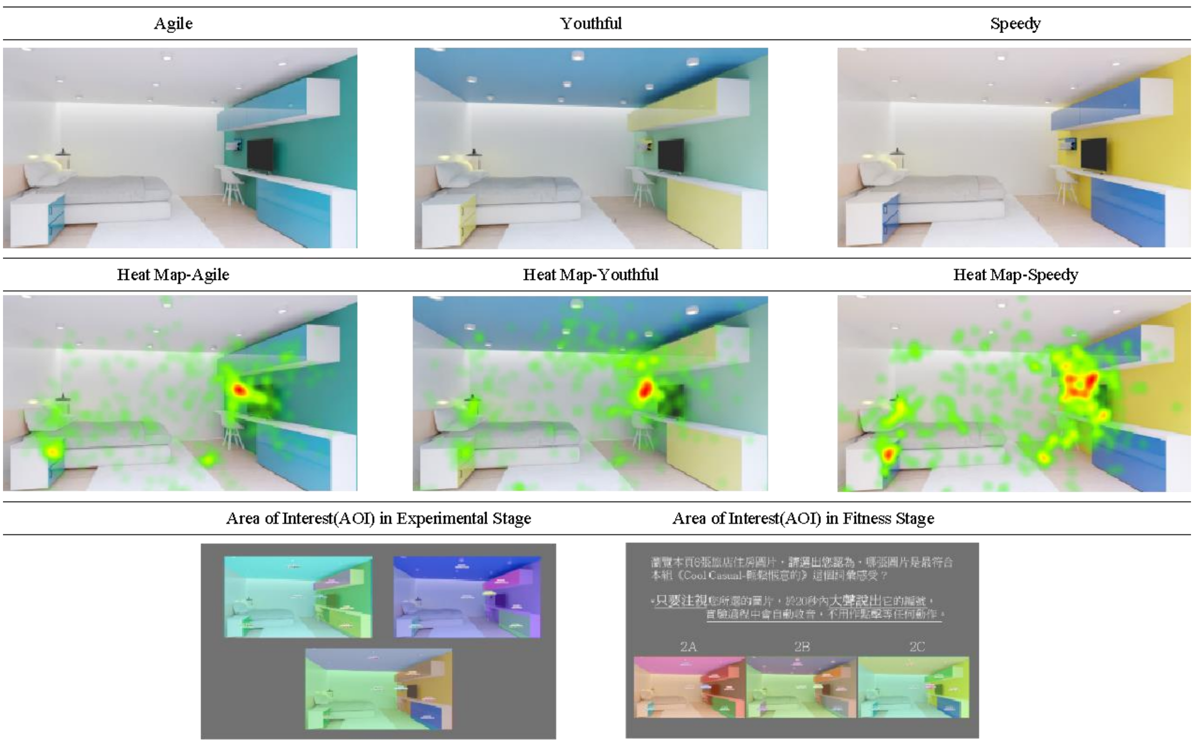

Figure 5. A Sample Diagram of Experiment Procedure in Color Combinations Group *Cool Casual*

To investigate the psychological reaction that was initiated by DH hypothetical bedroom that contains color combination in Group Cool Casual, Series of Pair T-tests were conducted.
Firstly, the results of pair samples correlation among all color combinations in Cool Casual has significant results (p<0.001).

Secondly, for the Pair T-test results among all color combinations in Cool Casual, statistically significant differences between the pupil average when perceiving the info from the DH hypothetical guest room that contains representative color combination Speedy (M = 2.619, SD = .356) to Youthful (M = 2.758, SD = .356); $t(9)$ = 3.544, p = .006), and also Speedy (M = 2.619, SD = .356) to Agile (M = 2.717, SD= .352); $t(9)$ = -4.984, p = .001) in Baseline Stage.

Lastly, the results of Pair T-Test among all the stages in each color combination indicates that the statistically significant difference exist in color combination Speedy between the pupil size between Baseline Stage (M = 2.619, SD = .346) and Experimental Stage (M = 2.720, SD = .321); $t(9)$ = -3.582, p = .006, Experimental Stage (M = 2.720, SD = .321) and Fitness Stage (M = 2.933, SD = .379); $t(9)$ = -5.438, p < .001, Baseline Stage (M = 2.619, SD = .346) and Fitness Stage (M = 2.933, SD = .379); t(9) = -7.738, p < .001. Statistically significant differences also exist in color combination Youthful between Baseline Stage (M = 2.759, SD = .356) and Fitness Stage (M = 2.885, SD = .400); $t(9)$ = -3.463, p = .007.

Such results indicate that without considering any instructions, the pair sample correlations indicate that emotional arousal of color combination appliances in DH hypothetical bedrooms is not significant.

However, the pair t-test results among the color combinations and proceeding process show that some color combinations can be more visual effectively than the others, for example: Speedy (RGB code: 238,209,45; 255,255,255; 4,84,165) in Cool Casual. However, the visual effectively color combination is not the one that perceptional connotated with the other, for example it is easier for participants to choose the lexicon “Youthful” to the DH hypothetical bedroom that contains color combination Youthful (RGB code: 245,239,109; 140,200,155; 60,136,184), while such significant do not exist between color combination and lexicon Speedy.

Conclusion

In terms of the results and discussion, when individuals evaluate the total appearance of a spatial design, colors usage is not that emotionally aroused, but some combinations of colors are still effective to individuals’ visual perception. \
Based on such instinct, to stimulate one's preference of an environment, the usage of colors is still vital. Therefore, it is possible to find the visual effective total appearance that contains multi colors.

In the future, by understanding what kind of attributes from the effective color combinations that are demonstrated in the environment, hopefully, the results can not only contribute to the total appearance theory but also provide color planning principles for related industries.

References

Chen, T.-H. 2018. Play Design Hotel: Transforming Hotel Rooms into Experiential Destinations.

Cho, J. Y., & Suh, J. 2020. Spatial Color Efficacy in Perceived Luxury and Preference to Stay: An Eye-Tracking Study of Retail Interior Environment. *Frontiers in Psychology, 11*, 296-296. doi:10.3389/fpsyg.2020.00296

Granholm, E. E., & Steinhauer, S. R. 2004. Pupillometric measures of cognitive and emotional processes. *International Journal of Psychophysiology*.

Horiguchi, S., & Iwamatsu, K. 2018. From Munsell color system to a new color psychology system. *Color Research & Application, 43*(6), 827-839.

Huddleston, P., Behe, B. K., Minahan, S., & Fernandez, R. T. 2015. Seeking attention: an eye tracking study of in-store merchandise displays. *International Journal of Retail & Distribution Management*.

Hutchings, J. 1995a. The continuity of colour, design, art, and science. I. The philosophy of the total appearance concept and image measurement. *Color Research & Application, 20*(5), 296-306.

Hutchings, J. 1995b. The continuity of colour, design, art, and science. II. Application of the total appearance concept to image creation. *Color Research & Application, 20*(5), 307-312.

Jacob, R. J., & Karn, K. S. 2003. Eye tracking in human-computer interaction and usability research: Ready to deliver the promises. In *The mind's eye* (pp. 573-605): Elsevier.

Kobayashi, S. 1981. The aim and method of the color image scale. *Color Research & Application, 6*(2), 93-107.

O'Connor, Z. 2018. *Environmental visual literacy: Examining the roles of color and contrast.* Paper presented at the Proceedings of the AIC2018, Interim meeting of the international color association, Margarida Gamito and Maria João Durão (Editors), AIC: Lisbon.

Yoon, S.-Y., & Wise, K. 2014. Reading emotion of color environments: computer simulations with self-reports and physiological signals. In *Industrial applications of affective engineering* (pp. 219-232): Springer.

Session 9

Colour and Cultural Preferences

Everyday Objects' Color Preferences Among Japanese University Students

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Abstract

The purpose of this study is to investigate and identify the association between color preferences and everyday objects. For this reason, an experiment was conducted among 122 Japanese university students. Red and blue hues were among the most favorite colors of the participants. Blue hues were mainly considered masculine, while red hues were considered feminine. Turquoise and lavender were considered the most beautiful. Lavender, dark mauve, and violet were the most elegant colors, while light blue and pastel blue were considered the most refreshing. Moreover, colors considered formal and masculine were used for the men's suits, while colors considered elegant, beautiful, and refreshing were used for the night gown. Participants mainly chose black for the frying pan. They chose warm sepia for chopsticks as it is the color wood, and they chose gray hues for cutlery because they like silverware. In sum, it was observed that rather than using their preferred color for every item, the participants used colors which they thought were most suitable for the product.

Keywords: *Everyday products, Characteristics, Preferences, Color Pencils*

Introduction

Numerous studies (e.g., Palmer et al., 2010 & Schloss et al., 2013) have examined human preferences for simple patches of color but it is not yet clear how these abstract color preferences generalize to different object contexts. The purpose of this study is to investigate and identify the association between color preferences and everyday objects. The aim is to identify whether personal color preferences extend to everyday products when there are numerous color choices, or to what degree might an individual want personal color preference to feature in their everyday objects.

Methodology

Participants

122 Japanese university students (67 female and 55 male) between the ages of 19 to 24 (M=20.7) participated in this study.

Procedure

Before the experiment, each participant was provided with a set of 48 color pencils. The name of the color pencils was written on them, and participants were to use those names. The names were as follows: white, lemon, light yellow, yellow, sand, peach, light orange, orange, scarlet, red, carmine, light carmine, magenta, pink, Bordeaux, Tuscan red, lavender, dark mauve, violet, cobalt blue, blue, delft blue, cyan, light blue, pastel blue, hooker's green, turquoise, sea green, lime green, willow green, sap green, green, green earth, light olive, olive green, dark ochre, golden ochre, fawn, burnt sienna, dark sand, VanDyke brown, warm sepia, cool gray, dove gray, light gray, warm gray, gray and black.

The experiment consisted of the following steps which were done randomly among the participants.

- Participants were asked to choose most/least favorite, happiest/saddest, most beautiful/ugliest, most masculine/feminine, warmest/coolest, brightest/darkest, most powerful/weakest, most peaceful/chaotic, most modern/old-fashioned, most formal/casual, most unique/ordinary, softest/hardest, most refreshing/boring, most elegant/unsophisticated color among color pencils. They were advised to write the name of the color pencil as well as use the chosen color pencil to write the answer.

- Participants were given detailed realistic drawings of bedroom, car (SUV and sports car), clothes (women's nightgown, men's suits, polo shirt), kitchen utensils and dinnerware and were asked to consider these items as their own and color them accordingly.

Results

Colors and Characteristics

This section focuses on the step where participants had to choose a color for a specific character/adjective. Due to space, only some of these will be discussed in this paper. Moreover, as there are 48 colors in total, only colors selected by the participants are shown in the Figures.

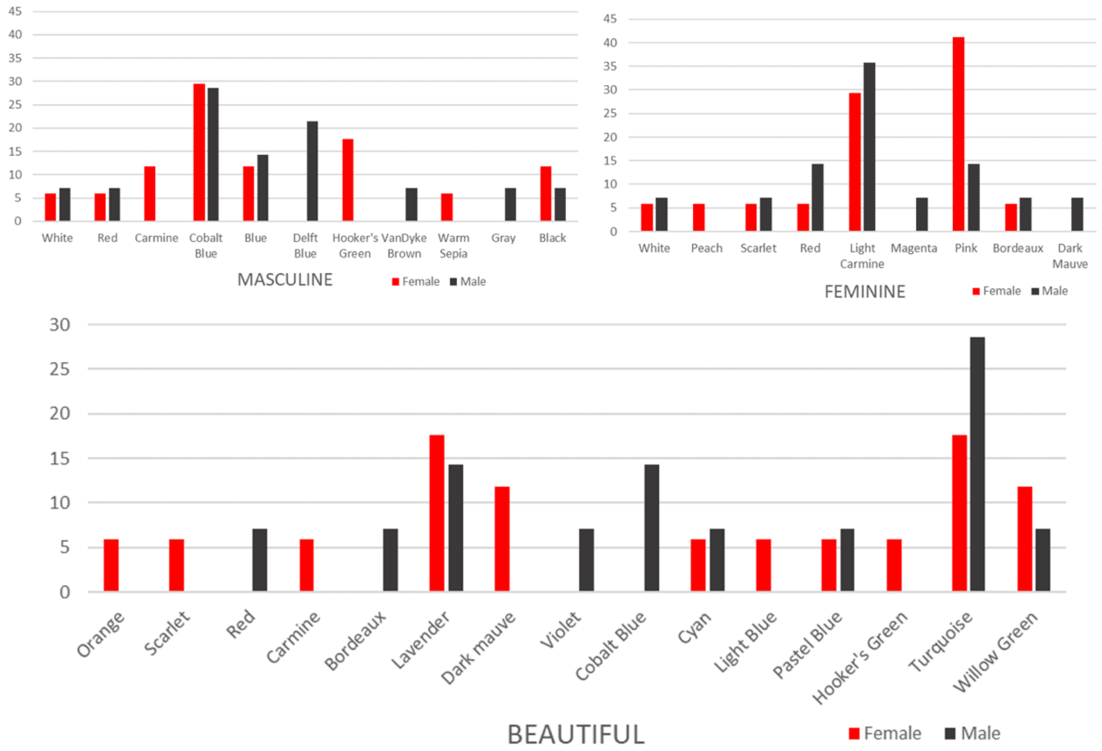

Figure 1A. Colors and characteristics: Masculine, Feminine, Beautiful.

As can be observed from Figure 1A, cobalt blue, blue, and black are considered masculine colors by all the participants. Delft blue is also considered a masculine color by male participants, while hooker's green and carmine are considered masculine by female participants. Pink and light carmine are considered feminine colors by female participants, while light carmine, red, and pink are considered feminine colors by male participants. Moreover, male participants also considered magenta and dark mauve as feminine colors. Lavender and turquoise are considered most beautiful by the participants. Female participants rated dark mauve as beautiful as well, while male participants rated violet and cobalt blue as beautiful.

Peach is considered the most peaceful by female participants followed by lime green (Figure 1B). Lime green, peach and pastel blue are considered peaceful colors among male participants. White, black, blue, and the gray hues are considered as formal colors. Violet is considered formal as well among female participants. Lavender is considered the most elegant followed by dark mauve. Light blue and pastel blue are considered as refreshing colors followed by turquoise and cyan.

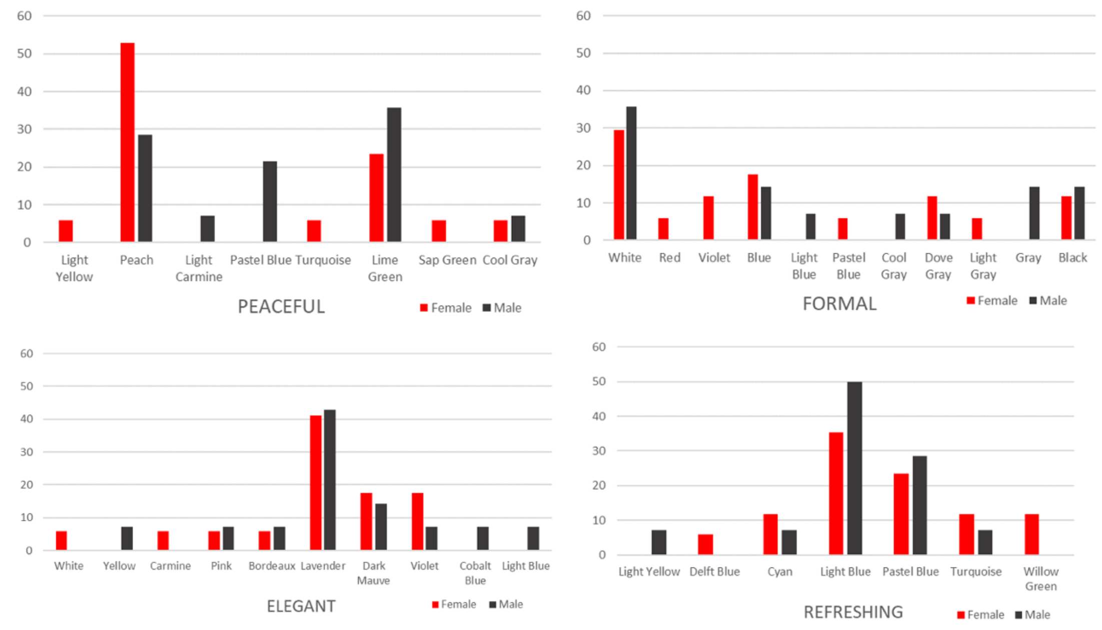

Figure 1B. Colors and characteristics: Peaceful, Formal, Elegant, Refreshing.

Color Preferences

Participants had to choose their favorite color among the color pencils. Results can be seen in Figure 2.

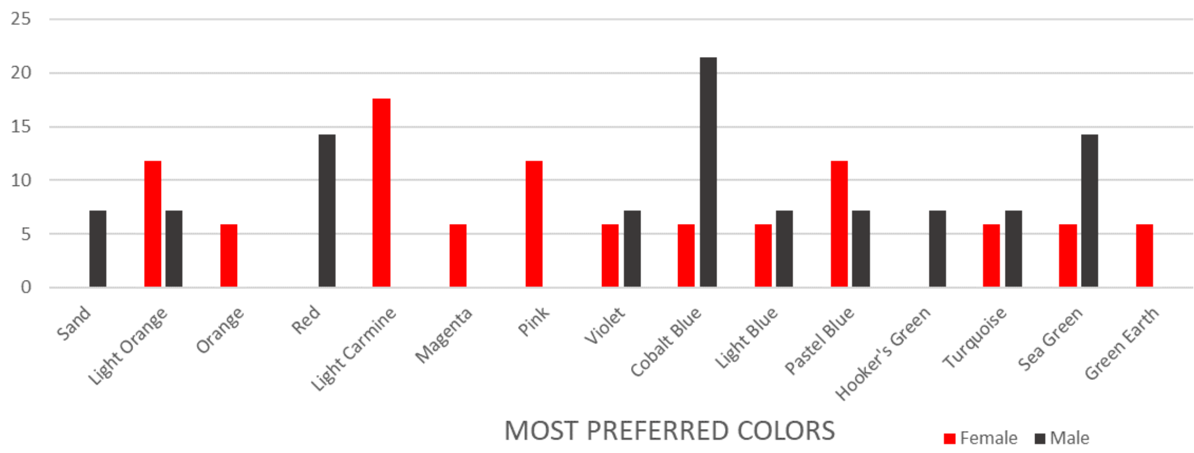

Figure 2. Color preferences of the participants.

As can be observed, blue hues are among the most favorite colors. Light carmine, magenta, and pink were only chosen by female participants as their favorite color. Although not included in this research paper, these are the least favorite colors of male participants. Red and sand are only chosen by male participants as their favorite color. In sum, similar to other studies, blue and red hues were among the most favorite colors of the participants.

Color Preferences for products

Participants were given realistic drawings of everyday products and were asked to consider them as their own and color them accordingly. The colors chosen for suits, night gown, frying pan, cutlery, chopsticks, and plate will be discussed in this paper. The results can be seen in Figure 3.

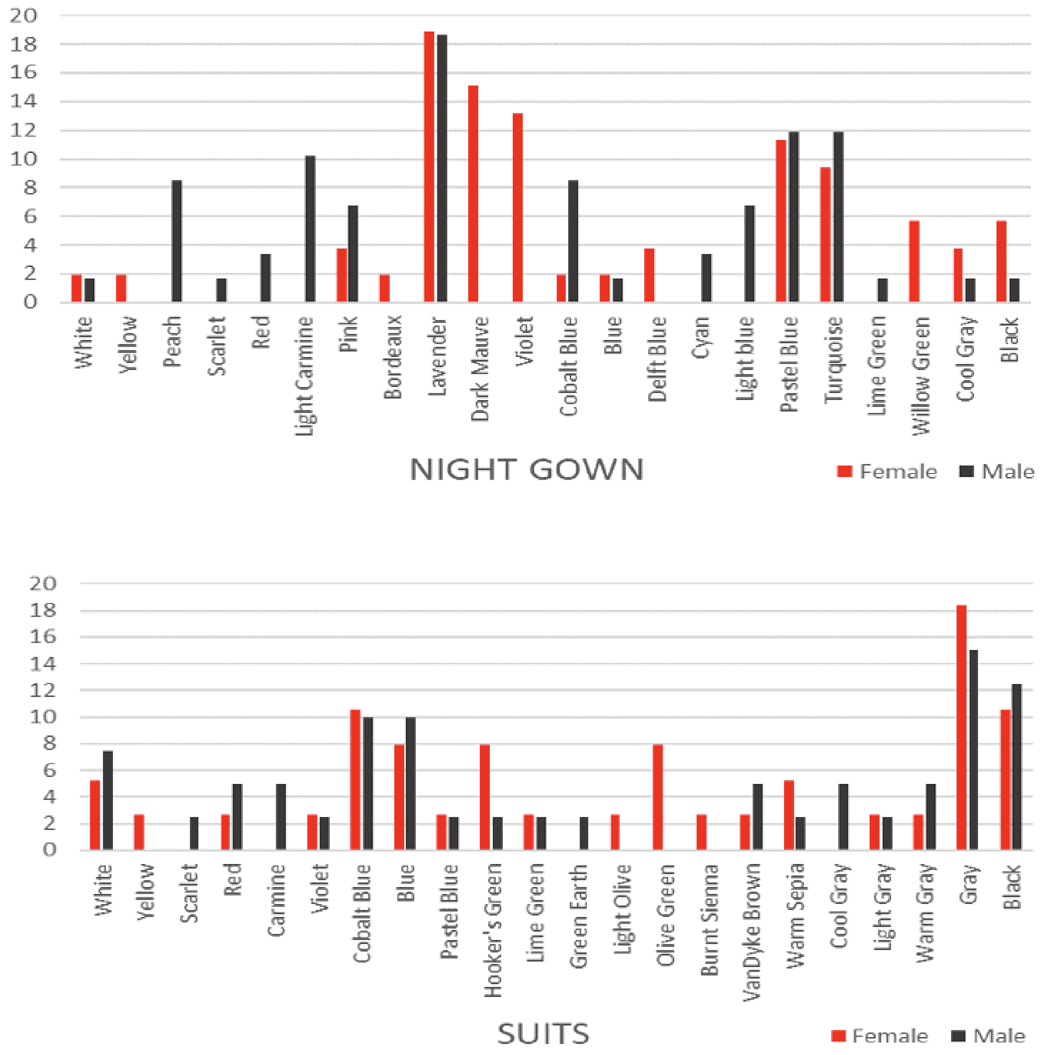

Figure 3A. Color preferences for women's nightgown and men's suits.

Lavender was the color most selected for the night gown by both male and female participants ($P<0.05$). This is a color which is considered both elegant and beautiful. Followed by lavender, dark mauve, violet, pastel blue, and turquoise were most selected by female participants. These colors are also considered beautiful, elegant, or refreshing. Participants chose colors they consider formal or masculine such as blue hues, black, and gray for men's suits.

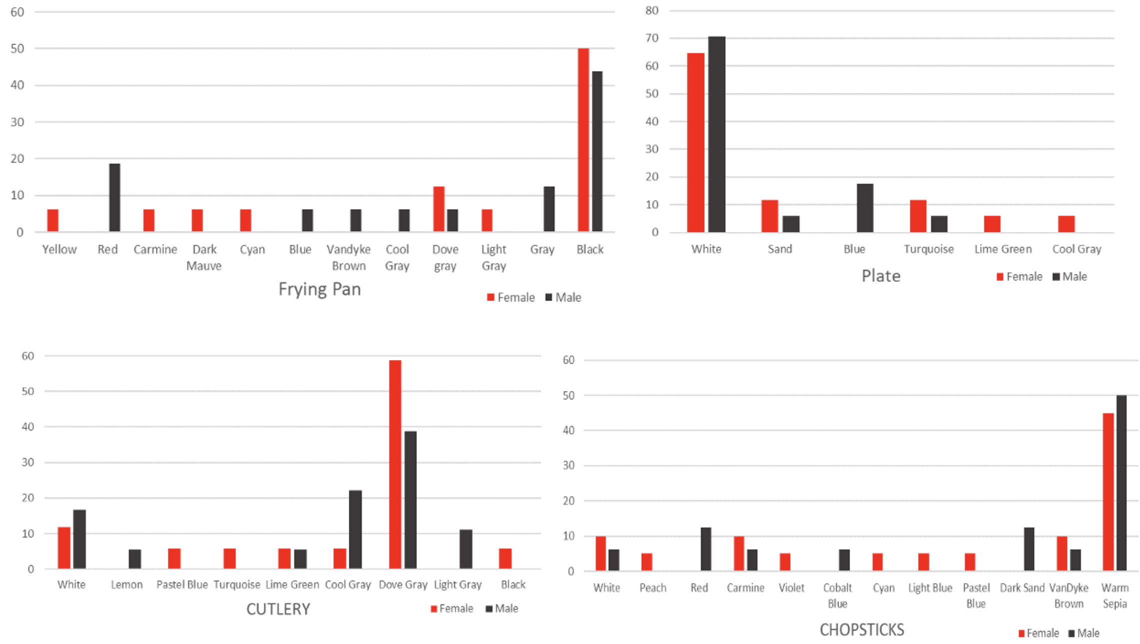

Figure 3B. Colors preferences for kitchen.

Furthermore, although a few participants chose their favorite color for the kitchen utensils, they mainly chose colors that they thought were functional for these items. For example, black was mainly chosen for frying pan. The participants stated that this is the best color for heat. They mainly selected white for the plate and their reason was that white makes food look more delicious.

Additionally, gray hues –in particular, dove gray – were selected for the cutlery. They said that they really like silverware and that is why they chose gray hues. Main color chosen for chopsticks was warm sepia. Participants chose this color as it is the color of wood.

Discussions and Conclusions

The aim of this study was to identify whether personal color preferences extend to everyday products, or to what extent might an individual want personal color preferences to feature in their everyday objects. For this reason, an experiment was conducted among Japanese university students.

It was observed that male participants preferred blue hues the most, while female participants preferred red hues. Similarly, blue hues were mainly considered as masculine colors, while red hues were considered as feminine colors. Turquoise and lavender were considered the most beautiful, while lavender, dark mauve, and violet were considered the most elegant. White, black, gray, and blue hues were considered formal. Light blue, pastel blue, and turquoise were considered refreshing.

Moreover, colors considered formal and masculine were used for the men's suits, while colors considered elegant, beautiful, and refreshing were used for the night gown. Participants mainly chose black for the frying pan because of heat. They chose warm sepia for chopsticks as it is the color wood and wooden chopsticks are very popular in Japan. They chose white for the plate saying that it makes food look delicious, and they chose gray hues for cutlery because they like silverware.

In sum, it was observed that rather than using their preferred color for every item, the participants used colors which they thought were most suitable for the product.

References

Palmer S.E., and K.B. Schloss. 2010. An ecological valence theory of human color preference. *Proceedings of the National Academy of Sciences of The United States of America* 107(19): 8877- 8882.

Schloss K.B., E.D. Strauss, and S.E. Palmer. 2013. Object Color Preferences. *Color Research and Application* 38(6): 393-411.

Color Meanings of Lucky Charms in Taiwan

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Abstract

This study aims to investigate whether the color of Taiwanese lucky charms has an impact on the viewer's expectation about the lucky charm's meaning and, if yes, whether such an impact can be affected by the viewer's religious faith. To achieve this aim, a psychophysical experiment was carried out using images of Taiwanese lucky charms. Each lucky charm was colored based on the 11 basic color names proposed by Berlin and Kay, including red, orange, yellow, green, blue, purple, pink, brown, white, gray, and black. Six most common meanings for lucky charms in Taiwan, including safety, health, love, fortune, business, and learning, were used in rating the lucky charm colors via a 4-step scaling method, ranging from "strongly agree", "agree", "disagree" to "strongly disagree."

Experimental results show that in general, warm colors were mostly regarded as having a strong link with a good luck for all of the 6 common meanings of Taiwanese lucky charms as described above, while cold and achromatic colors tended to have a weaker link. Religious faith was found to have little impact on color meanings of the lucky charms in Taiwan.

Keywords: *lucky charms; color meaning; religious study; color psychology*

Introduction

In Taiwan, seeking good luck and avoiding evil have been a tradition. People like to make Spring Festival couplets, place mythical beasts, or wear lucky charms. The person who wears a charm hopes to bring good luck and avoid bad luck. The lucky charms have a special sacredness, which is believed to confer protection upon their owner.

Lucky charms in Taiwan had one style over the past decades: red color with the issued name of the temple or shrine. In recent years, the lucky charms in Taiwan were influenced by the Japanese Omamori and started to have various colors and designs and have various meanings accordingly.

The present study aims to investigate the relationship between colors of Taiwanese lucky charms and the associated meanings, and whether such a relationship is influenced by the religious faith of the observer. Research questions include: would a lucky charm be linked with a good luck for fortune when it is colored in red rather than in yellow? Would such a link be stronger for viewers with a religious faith than those without a faith?

Methods

A psychophysical experiment was carried out to clarify the relationship between color meanings of lucky charms in Taiwan. Through an online questionnaire, observers were shown images of lucky charms displayed individually against a medium grey background. Each image did not show any words or patterns on the lucky charm in order to avoid the implication of which type of lucky charm they might appear. Each lucky charm was colored based on the 11 basic color names (Collier, Berlin, and Kay 1973), including red, orange, yellow, green, blue, purple, pink, brown, white, gray and black, CIELAB values of the 11 colors as summarized in Table 1. Six common meanings of lucky charms in Taiwan were used in this study in rating these images: safety, health, love, fortune, business, and learning, to investigate the relationship between lucky charm color and its associated meanings.

Color	L*	a*	b*	Color	L*	a*	b*
Red	50	70	65	Pink	65	50	0
Orange	65	55	75	Brown	25	15	35
Yellow	90	-10	90	White	100	0	0
Green	50	-25	40	Gray	50	0	0
Blue	30	15	-60	Black	0	0	0
Purple	30	50	-50				

Table 1. CIELAB values of the 11 lucky charm colors.

The lucky charm colors were rated via a 4-step scaling method, ranging from “strongly agree”, “agree”, “disagree” to “strongly disagree”. Each response was transformed into a point scale, ranging from 2 (i.e. strongly agree) to -2 (i.e. strongly disagree). During the experiment each observer was asked the following question: “Do you agree that the color of this lucky charm has the following meaning - safety?” The questions also covered the other 5 types of meanings, including health, love, fortune, business, and learning. Each observer answered the questions for each lucky charm color.

A total of 172 observers took part in this online survey, after excluding those with color deficiency. Among these observers were 11 Christians, 19 Buddhists, 70 folk believers and 25 Taoists; the rest of them had no religious faith.

Results and Discussion

Observer accuracy

Out of the 11 colors, 5 were repeated, and the validity of each questionnaire is tested in this way. Questionnaire options "strongly agree", "agree", "disagree" to "strongly disagree" correspond to scores of 2, 1, -1, -2 respectively. We subtract the values corresponding to the options answered twice by the observer and take the absolute value as the deviation value. If the observer answers the same option twice, the deviation value is 0. The higher the deviation value, the weaker the accuracy was. We sum and average the deviation values of each observer to obtain the mean deviation of each person. The mean deviation ≥ 1 point, which means that the repeatability spans more than the difference of one option, so the observer's data is judged to be inaccurate.

Meanings of lucky charm colors

The experimental data were expressed as the average score. The higher the score of the lucky charm color, the stronger the link was. As summarized in Table 2, red, orange, and yellow show strong links with safety, while brown, gray and black have weak links. For health, only green, red, orange, and yellow have positive scores. Brown, black and gray have weak links. For love, pink and red show strong links, while green, black, and gray were found to have very weak links. For the fortune meaning, yellow, red, and orange show positive scores, while achromatic colors have negative values for fortune. For business, red was found to have a strong link, followed by orange and yellow. However, brown, pink, and achromatic colors have weak links with business. For learning, red, orange, and blue show high scores, while brown, pink, and achromatic colors have weak links

	Safety	Health	Love	Fortune	Business	Learning
Red	1.19	0.75	1.05	1.24	1.04	0.69
Orange	0.77	0.46	-0.06	0.82	0.57	0.52
Yellow	0.33	0.04	-0.97	1.31	0.55	0.15
Green	0.21	0.77	-1.23	-0.7	0.23	0.16
Blue	-0.28	-0.29	-0.99	-0.69	0.34	0.36
Purple	-0.13	-0.37	-0.13	-0.08	0.19	0.13
Pink	0.13	-0.28	1.63	-0.42	-0.56	-0.58
Brown	-0.56	-0.84	-1.2	-0.67	-0.59	-0.59
White	-0.23	-0.34	-1.08	-1.19	-0.7	-0.47
Gray	-1.11	-0.3	-1.42	-1.3	-0.67	-0.89
Black	-1.2	-1.28	-1.38	-1.2	-0.88	-1

Table 2. Average scores of the 6 meanings for each lucky charm color.

Impact of religious faith

Safety

The correlation coefficients between the average scores of “safety” for the Christians in this study and those for the other 4 religious backgrounds are all below 0.6, indicating unique perception for safety of lucky charm color. Christians tended to see bright colors, such as white and yellow, as having a strong link with safety, while observers of the other 4 religious backgrounds tended to regard red and orange as having strong links with safety. For all religions, blue, gray, and black have weak links with safety.

Health

The results show that the Christians saw the health of lucky charm color differently from believers of the Folk religion and Taoism. Christians tended to expect yellow, green, and pink to have strong links with health, while believers of folk religion and Taoism tended to regard red, green, and orange as bringing health. Purple, brown, gray, and black were found to have weak links with health for all religions.

Love

High correlation between the 5 religious backgrounds for the meaning of love in lucky charm colors indicates that all observers, regardless of religious faith, have the same color association for love. They tended to see pink and red as having strong links with love. Achromatic colors and green have the weaker links.

Fortune

Again, there was little difference between the 5 religious backgrounds in observers’ association of lucky charm color and “fortune”. Yellow and red both have high scores for all religions. Buddhists and Taoists regarded purple as good fortune. Orange was found to be strongly linked with good fortune for folk religion believers and those with no religious faith. Green, blue, brown, and achromatic colors all have weak links with fortune for all religions.

Business

Christians in this study tended to give high scores for red in association with good luck in business. Believers of other religions tended to regard red, yellow, orange, and blue as having strong links with good luck in business, while achromatic colors and pink were found to have weak links.

Learning

Christians tended to link white and blue strongly with good luck in learning, but for the other 4 religions, white had a weaker link with learning. Folk believers tended to see red as representing good luck for learning. Believers of Taoism and those with no religious faith tended to link orange with learning. Pink, gray, and black had weak links with leaning for all religions.

Conclusion

In general, warm colors were mostly regarded as having strong links with good luck in all of the 6 meanings, a finding in line with a recent study (Zhou and Zhang, 2011). Among the 11 lucky charm colors, red was found to have the strongest link for all types of good luck, especially for safety and business. Orange can be regarded as a substitute for red, with high correlation with all of the 6 meanings and was second only to red. Yellow was found to be strongly linked with good luck for fortune. Green had a strong link for health but was a weaker link for love. Blue was found to have a good link for both business and learning, but it was a weak link for the other types of good luck. Purple did not have a strong link with any of the 6 types of good luck. Pink had a very strong link with good luck for love. Brown and the three achromatic colors, i.e. white, gray and black, were found to have very weak links with all of the 6 types of good luck.

This study also clarifies the relationship between religious faith and color meanings. Correlation analysis shows that religious faith can affect the color meaning of the Lucky charms. Christian has a unique color association for the lucky charms. As indicated above, bright colors like white and yellow have more positive meanings for Christians. In many temples in Taiwan, Gods of Buddhism and Taoism can be worshiped together. This may be why those believers have similar perceptions of color meanings in this study.

This study reveals the relationship between Taiwanese lucky charm color and associated meanings. Religious faith was found to affect such color meanings. The results are useful for applications in temples and shrines in Taiwan.

Acknowledgment

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References

Zhou, Yuexi, and Ximiao Zhang. 2011. "Exploring the Methods of Using the Chinese Traditional Folk-Custom Color Cultural Representations on the Industrial Design." In *Proceedings of 2011 International Conference on Electronic & Mechanical Engineering and Information Technology*, 4489–92. IEEE. https://doi.org/10.1109/EMEIT.2011.6024026.

The Effect of Facial Mask Colour Tones on the Image of Retail Services

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Abstract

Since the COVID-19 pandemic, mask wearing has become routine for retail staff in Taiwan. This new appearance for staff may have an influence on whether customers approach staff or not. According to previous research, hue played an important role in the masks that should be worn. However, other research has found that lightness and chroma were more important than hue in terms of colour emotion. Thus, this study intends on supplementing previous work with incorporating other mask samples with various lightness, chroma, and hues to investigate the influence of colour theory on retail staff image. Based on previous methodology (Meng et al. 2021), the ranking for these four attributes for staff images are finalized and the popular colours of masks are identified through these criteria. With the results from this study and previous literature, the angles of hue for these popular masks are located in the first and fourth quadrant. It indicates hues play an important role in the masks of retail staff service image. Besides, the tones of these popular masks are low chroma with high lightness. These results can be provided to retail staff management for retail practice.

Keywords: *Colour Emotion, Coloured Facial Masks, COVID-19*

Introduction

The COVID-19 pandemic has led to mask wearing being routine, especially for retail staff. Since masks cover two-thirds of facial expressions, the appearance and degree of approachability that retail staff have on customers has been affected. According to previous research, colour hues play an important role on one's image when wearing a mask. However, other research has found that lightness and chroma have greater importance than that of hue on colour emotions. Therefore, the objective of this study is to expand previous literature by incorporating mask samples with a variety of lightness, chroma, and hue to further investigate the influence of mask colour on retail staff appearance and approachability.

Literature Review

The effect of mask wearing in retail has been the subject of research in many countries. Kong et al. (2021) showed that mask-wearing in hotel industries in

Hong Kong is associated with hygiene and safety. Cobanoglu et al. (2021) found mask wearing does not affect the attractiveness of hotels and restaurants in the United States. Hies and Lewis (2022) found that in the United Kingdom, medical masks increased facial attractiveness more than other face covers. In particular, colour theory and the impact of colour on emotions has been highly studied. Xin et al. (2004) showed that out of lightness, chroma, and hue, lightness and chroma were found to be much more important than hue in colour emotions. Yu et al. (2018) found in customer purchasing decisions, hue was very important. In particular, Meng et al. (2021) found that the hue of a coloured mask plays an important role in the appearance of someone wearing a face mask. Cobanoglu et al (2021) found that white masks have the best social rating, followed by coloured masks, black masks, blue masks, and clear masks for hospitality in the United States.

Based on the existing literature and the previous study done by the authors, additional masks with a wider range of lightness, chroma, and hue will be collected and investigated. The appearance and approachability of retail staff will be investigated against these coloured masks.

Method

Twelve single-coloured masks available in the market were collected as the samples for this study. There were black(Bk), dark blue(dkgB), dark green(dG), dark red(dR), dark purple(dP), strong red(sR), soft purple(sfP), milk tea(sfYR), soft green(sfG), soft plum red(sfR), soft orange(sYR) and bright green(bGY), shown in Figure 1.

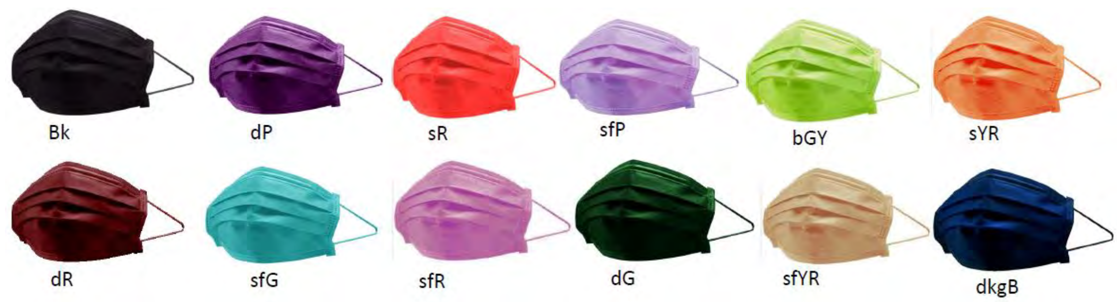


Figure 1. Twelve Single Coloured Sample Masks and their abbreviations.

Followed by previous research methodology (Meng et al. 2021), the NCS ColourPIN instrument was used to measure these 12 masks and obtain CIELAB coordinates. Each sample mask was measured at three different points (left, center, and right), then the average value was calculated.

Sixty university staff members and students participated in this questionnaire survey. Firstly, participants ranked top first in 4 attributes (Aesthetics, Friendliness, Expertise and Self-confidence) for the salesperson's image which they mainly concerned when approaching a salesperson in department stores. Secondly, they ranked top first coloured masks for each question of questionnaire relevant to the colour image adjective. Chi-square test with 0.05 significance level was used to determine whether there were significant differences in 4 attributes and among colour masks for each question. The main concerned attribute would be identified for the image of retail staff and the most popular coloured masks were then identified based on the highest frequency of ranked top first in each question.

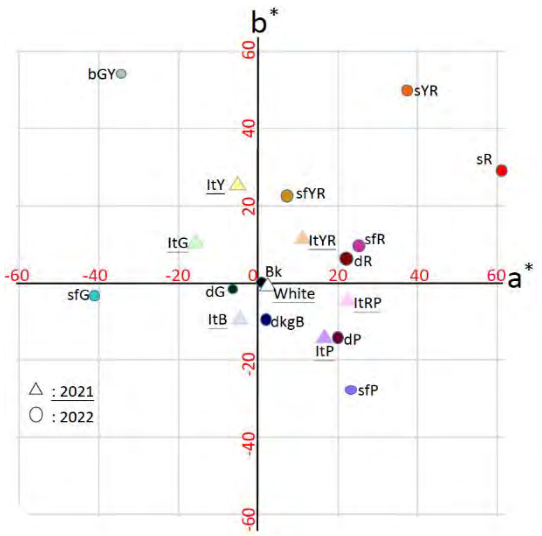
Results

The colour measurement results for twelve single coloured sample masks of CIELAB (D65, 2°) coordinates and corresponding lightness L^*, chroma C^*ab, and hue angle values h_{ab} were shown in Table 1.

	Bk	dkgB	dG	dR	dP	sR	sfP	sfYR	sfG	sfR	sYR	bGY
L^*	22.42	28.32	30.37	30.66	33.47	50.86	67.01	69.17	70.11	70.40	71.22	81.19
C^*_{ab}	0.50	9.51	6.79	22.3	24.16	67.42	36.32	23.77	41.2	26.74	62.43	64.28
h_{ab}	14	280	193	17	325	26	310	73	184	21	54	148

Table 1. Colour Measurement of Twelve Sample Masks.

According to Table 1 and combined with previous study's result of colour measurement for seven masks, all these nineteen sample masks were various in lightness, chroma and hue angle. Their distributions in the CIE a*-b* diagram was shown in Figure 2, and the CIE L^*-C^*_{ab} diagram was shown in Figure 3.



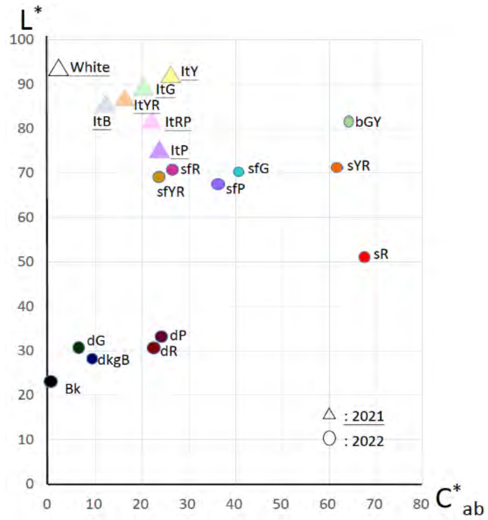


Figure 2 (left). CIE a*-b* Diagram of 19 Sample Masks.
Figure 3 (right). CIE L^*-C^*_{ab} Diagram of 19 Sample Masks.

Sixty university staff members and students (43 females, 17 males) with department store shopping experiences were invited to participate in the survey. For age, 46 persons were below 41 years old. For education, 40 persons were graduates and 20 persons were undergraduate. The detailed information of participants is shown in Table 2.

Parameter	Level	Frequency [n(%)]
Gender	Male	17(28.3%)
	Female	43(71.7%)
Age(years)	21-30	31(51.6%)
	31-40	15(25.0%)
	41-50	7(11.7%)
	above 50	7(11.7%)
Education	Undergraduate-Associate	3(5.0%)
	Undergraduate-Bachelor	17(28.3%)
	Graduate-Master	30(50.0%)
	Graduate-PhD	10(16.7%)

Table 2. Respondent Characteristics.

For four attributes ranking results, combining the data from the previous investigation of forty respondents with the data from the current survey of sixty participants, the results of the frequency of ranking top first for four attributes by one hundred participants were shown in Table 3. By Chi-square test, there were significant differences in frequency among attributes ($p<0.05$). The result of main-concerned attributes for staffs' image which is judged by customers is Friendliness, then followed by Expertise, Aesthetics and Self-confidence.

Attributes	Aesthetics	Friendliness	Expertise	Self-Confidence	p Value
Frequency(n=100)	11	64	20	5	< 0.0001

Table 3. Frequency of Ranking Top First for Four Attributes

The results for the frequency of ranked top first from the questionnaire were shown in Table 4. As same as by Chi-square test, there were significant differences in frequency among sample masks for all twelve questions ($p<0.05$).

Attributes/adjectives	Item	Bk	dkgB	dG	dR	dP	sR	sfP	sfYR	sfG	sfR	sYR	bGY	p Value
Aesthetics														
Elegant	A1.	4	4	0	10	6	0	10	22	2	2	0	0	< 0.0001
Styling	A2.	19	7	3	3	3	8	3	5	3	1	1	4	< 0.0001
Chic	A3.	14	7	6	4	3	4	3	5	10	1	1	2	0.0006
Friendliness														
Friendly	F1.	4	3	0	0	1	2	12	23	1	7	7	0	< 0.0001
Tender	F2.	1	0	0	0	3	2	13	28	1	8	4	0	< 0.0001
Amiable	F3.	1	0	1	2	2	1	11	29	0	6	5	2	< 0.0001
Expertise														
Intellectual	E1.	17	21	3	4	6	2	2	2	2	1	0	0	< 0.0001
Distinguished	E2.	12	8	3	5	9	4	2	1	10	2	3	1	0.0008
Cultivated	E3.	9	12	4	6	3	3	6	13	1	3	0	0	< 0.0001
Self-Confidence														
Mature	S1.	16	7	5	21	6	0	2	1	1	0	0	1	< 0.0001
Steady	S2.	25	15	8	5	1	0	2	1	0	2	1	0	< 0.0001
Tasteful	S3.	8	14	5	5	8	3	1	11	3	1	0	1	< 0.0001

Table 4. Frequency of Ranked Top First for Twelve Sample Masks from Questionnaire.

In Table 4, the frequency of the top first mask was highlighted with a yellow background for each questionnaire item.

The most popular mask colours for each of the four attributes were identified.

Soft milk tea colour (sfYR) was close to Friendliness. Black colour (Bk), dark blue colour (dkgB) and milk tea colour (sfYR) were close to Expertise. Black colour (Bk), and milk tea colour (sfYR) were close to Aesthetics. Black colour (Bk), dark blue colour (dkgB) and dark red colour (dR) were close to Self-confidence. The four most popular single-coloured masks (sfYR, Bk, dkgB and dR) were located in the first and fourth quadrant in CIE a*-b*coordinate in Figure 2.

Conclusion

Combining previous and current studies there were seven popular single-coloured masks. The colour measurement results of these seven popular masks were shown in Table 5. The angles of hue (h_{ab}) of these seven popular masks extended from the fourth quadrant, in the previous study, to the first quadrant, in this study. In an article of Ahmad (2017), which described colour could produce different reactions depending on which industry it appears in. In the retail industry, hue plays an important role in mask wearing for retail staff's service image.

In Figure 3, these seven popular masks were with low chroma (values below 30) and were distributed separately into two areas, with high lightness and with low lightness. This study showed that Friendliness was the main attribute by customers for retail staffs' image. In the questionnaire survey for the three adjectives of Friendliness, the milk tea colour (sfYR) was all ranked top first. Therefore, milk tea colour (sfYR) was the most popular colour to attract customer's attention for retail service image. Similar to the result for pink colour (ltPR) in previous study, both milk tea colour (sfYR) and pink colour (ltPR) were low chroma with high lightness and definitely close to Friendliness.

For neutral colour, white was close to Aesthetics and Expertise, black was close to Self Confidence and Expertise. Above results could be provided to managers and retail staff for retail practice and management.

	Current Study (AIC 2022)				Meng et al. 2021 (ACA 2021)		
Sample Masks	black	dkgB	dR	sfYR	ltP	ltRP	white
L^*	22.42	28.32	30.66	69.17	74.18	81.14	92.89
C^*_{ab}	0.50	9.51	22.3	23.77	24.16	22.50	1.28
h^*_{ab}	14	280	17	73	311	346	322

Table 5. Colour Measurement of Popular Sample Masks.

References

Ahmad, I. 2017. Color Psychology In Branding: Industry Colors Explained [Infographic], *SocialMediaToday*, Online: https://reurl.cc/GxV76D.

Cobanoglu, C., F. Ali, L. Nanu, K. Shahtakhtinskaya and I. Rahman. 2021. Do Masks Make A Difference In Customer Perception Of Service Quality In Hotels And Restaurants? *Hospitalitynet.* www.hospitalitynet.org/opinion/4102177.html.

Hies, O., and M. B. Lewis. 2022. Beyond the beauty of occlusion: medical masks increase facial attractiveness more than other face coverings. *Cognitive Research: principles and implications*, 7(1): 1-6. https://doi.org/10.1186/s41235-021-00351-9

Kong, A., J.E. Oh, and T. Lam. 2021. Face mask effects during COVID-19: Perspectives of managers, practitioners, and customers in the hotel industry. *International Hospitality Review*, 35(2): 195-207.

Meng, H.H., R.C. Wu, and L.C. Chen. 2021. A study on the Colour of Masks for Frontline Retail Staffs. In: *Proceeding of the Asian Colour Association (ACA) Conference 2021*. Yogyakarta: Universitas Gadjah Mada, 1-6.

Xin, J.H., K.M. Cheng, G. Taylor, T. Sato, and A. Hansuebsai. 2004. Cross-regional comparison of colour emotions Part I: Quantitative analysis. *Color Res. Appl*., 29: 451-457.

Yu L., S. Westland, Z. Li, Q. Pan, M.J. Shin and S. Won. 2018. The role of individual colour preferences in consumer purchase decisions. *Color Res. Appl*., 43: 258–267.

Modelling Facial Attractiveness from Various Colour Characteristics

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Abstract

Colour is a perceptual stimulus which is essential in daily life and is often considered in terms of aesthetics. Various colour characteristics have shown their influence on facial attractiveness. Previous studies have assessed the impact of each single colour characteristic on facial attractiveness, yet very few of them established the quantitative relationship between various factors and facial attractiveness. The present study was designed to model facial attractiveness from various colour characteristics using multivariate statistical techniques. Sixty-eight colour characteristics including average/local skin colour, feature colour, skin colour variation, and facial colour contrast were measured and employed to model the facial attractiveness of both Caucasian and Chinese faces. The results revealed the significant facial colour cues utilized by Caucasian and Chinese people for attractive judgements. In the Caucasian model, five selected predictors obtained by MLR were used for the prediction of attractiveness with a predictive success (adj. R^2) of 43.8%. Seven colour variables were selected from Chinese datasets for predicting Chinese facial attractiveness and the predictive success (adj. R^2) was found as 55.6%. The methodology used in this study could serve as an important analytical tool for future facial attractiveness prediction.

Keywords: *Facial Attractiveness, Skin Colour, Colour Variation, Facial Contrast*

Introduction

Colour is a perceptual stimulus which is essential in daily life and is often considered in terms of aesthetics. Various colour characteristics have shown their influence on facial attractiveness. These colour characteristics include the average facial skin colour, local skin colour, facial colour contrast, and skin colour variation and texture, etc. The average skin colour has been studied most widely, and facial redness and yellowness have been claimed to enhance facial attractiveness (Appleton et al., 2018; Foo et al., 2017; Pazda et al., 2016; Thorstenson et al., 2017). Feature colours such as the lip colour has also been found to affect perceived attractiveness of human faces (Stephen & McKeeganh, 2010). Facial colour contrast was found a cross-cultural cue of perceiving facial beauty (Jones et al., 2015; Stephen & McKeeganh, 2010). Moreover, the visible skin colour variation has been revealed to play a role in the perception of attractiveness in both male and female faces (B. Fink et al., 2011; Bernhard Fink et al., 2006, 2012).

Previous studies have assessed the impact of each single colour characteristic on facial attractiveness, yet, very few of them established the quantitative relationship between different factors and facial attractiveness. Preference judgement process is much more complex in our daily life when various colour characteristics are considered together. The importance of the role of skin colour to facial attractiveness, however, is unknown when taken all the colour characteristics together. Moreover, these colour characteristics can be highly correlated, which increases the complexity of the facial attractiveness predictions. Therefore, the present study was designed to consider the relationship between facial attractiveness and various colour characteristics .

It's worth noting that majority previous attractiveness researchers have used manipulated facial stimuli and changed a single colour variable in controlled experiments and then had observers choose the more attractive face or rate the attractiveness scores of different faces. However, the manipulated experiment may overstate the importance of the single colour variable that is being changed in the experiments and meanwhile could not reflect the role of various colour cues in the real situation of attractiveness evaluation in daily life. More recently, there is a growing body of work using realistic skin models in experiments for attractiveness evaluation without any skin colour manipulation (Appleton et al., 2018; Jones, 2018; Lu et al., 2021; Tan et al., 2018). The difference and the necessity of using real facial images has been discussed in our previous work (Lu et al., 2021). In the current study, the realistic skin model was used, and the important challenge is to develop an analytical tool that could be used to select valid predictors from the large amount of colour characteristics and to predict facial attractiveness.

Multivariate statistical techniques are useful for modelling the relationship between a large dataset of facial colour characteristics and the response of facial attractiveness judgement. In this study, the relevant variables from various colour characteristics were first selected, and then facial attractiveness modelling was done by multiple linear regression (MLR) method to predict facial attractiveness from relevant colour variables. The objective was to model facial attractiveness from various facial colour characteristics using multivariate statistical techniques. The effectiveness of using colour variables to predict facial attractiveness was evaluated and the performance of developed MLR models for Chinese dataset and for Caucasian dataset were compared. The methodology used in this study could serve as an important analytical tool for facial attractiveness prediction.

Experiment and Analytic Strategy

In the present study, 68 colour characteristics including average/local skin colour, skin colour variation, and facial colour contrast were measured using eighty non-manipulated images of both real Caucasian and real Chinese faces. A rating study was conducted, using both Caucasian and Chinese observers, to obtain facial attractiveness evaluations (Lu et al., 2020). The cultural difference was found in previous studies, thus the collected data were treated separately to obtain prediction models for Caucasian groups and Chinese groups. For the data analysis, the associations between attractiveness ratings and all the facial colour characteristics were first identified so that the irrelevant colour characteristics could be removed from each dataset and will not be used as predictors in the next step of mathematical modelling. The relevant colour variables were then employed to predict facial attractiveness using stepwise multiple linear regression methods. The performance of the Chinese model and the Caucasian model (adj. R2, RMSE, MSE, MAE) were compared. All the analyses were carried in R.

Results and Discussion

Analysis of facial colour characteristics

Based on the exhaustive literature review, we included a total of 68 explanatory colour variables classified into 5 categories in this study. They were the average skin colour (the mean L*, a*, b*, C* and h_{ab} of facial skin areas), the local skin colour (the mean L*, a*, b*, C* and h_{ab} of each area of forehead, cheek, nose, chin, and periorbital), the feature colour (the mean L*, a*, b*, C* and h_{ab} of lip, brows, and eyes), the skin colour variation (MCDM of the forehead, cheek, nose, chin, and overall facial skin area) and the facial colour contrast (the adapted version of Michelson contrast and CIELAB colour differences between three facial features, eyes, eyebrows, and mouth, and their surrounding skin). All these facial colour characteristics were accurately calculated from each of the eighty facial images in CIELAB colour space.

Correlations between attractiveness and various facial colour characteristics

Before the multiple regression modelling, a pre-processing step of correlation analysis was done to screen all the colour variables and remove the irrelevant ones. The correlation matrix between each of the facial colour characteristics and facial attractiveness ratings were calculated for Caucasian dataset and Chinese dataset, respectively. The colour variables with statistically significant correlation ($p<0.05$) in relation to attractiveness for Caucasian and Chinese dataset were listed in Table 1. In general, more correlated colour characteristics in relation to facial attractiveness were found for Chinese observers compared to Caucasian observers, which showed Chinese tend to utilize more facial colour cues when rating facial attractiveness. With regard to the specific colour cues, Caucasian observers relied more on colour cues related to skin yellowness (b*), chroma (C*) or skin colour variation, while Chinese observers relied more on colour cues related to skin lightness (L*), redness (a*) or hue angle (hab). Caucasian observers linked increased skin yellowness (b*) and chroma (C*) with enhanced facial attractiveness, while Chinese observers tended to relate higher skin lightness (L*)/ hue angle (h_{ab}), lower redness (a*), and less colour variation with more attractive-looking faces.

Category	Caucasian	Chinese
Average skin colour	b*, C*	**L***, a*(-), hab
Local skin colour	Cheek-b*, C* Periorbital-b*	Forehead-L*, a*(-), **hab** Cheek-L* Nose-L*, a*(-), hab **Chin-L***, a*(-), hab
Feature colour	Eyes-L*(-)	Brows-L*
Skin colour variation		MCDM-Cheek(-) MCDM-Nose(-) MCDM-overall(-)
Facial colour contrast	Brows-C-hab Mouth-C-L*(-), b*, C*(-)	Brows-C-a***(-)**, hab Mouth-C-a*, hab, △E

Table 1. Summary of the variables with statistically significant correlation (P<0.05) in relation to attractiveness for Caucasian and Chinese dataset

All the variables show very significant correlation (P≤0.01) with attractiveness are highlighted in bold. Variables ending with (-) have negative correlations with attractiveness while the rest show the positive correlations.

Modelling facial attractiveness from facial colour characteristics

Aiming to find the statistically valid regression parameters, all the colour characteristics with statistically significant correlations were used as independent variables in the stepwise multiple linear regression analysis for facial attractiveness. The developed multiple regression models were summarized in table 2. Finally, the actual values of facial attractiveness (ratings) recorded during the experiments and the predicted values of facial attractiveness calculated from the regression models were compared, as shown in Figure 1.

In the Caucasian model, only five selected predictors obtained by MLR were used for the prediction of attractiveness and the predictive success (R^2) of the model was found as 43.8%. The model performance indicated that our model predicted attractiveness to within 0.646 points on a 7-point scale and all the colour predators together explained 43.8% of the variance in facial attractiveness. The facial colour contrasts (Brows-C-h, Mouth-C-L*) were the most important colour predictors for facial attractiveness of Caucasian faces. On the other hand, seven colour characteristics were selected from Chinese datasets for predicting facial attractiveness and the predictive success (R^2) was found as 55.6%. All the colour predators together explained 55.6% of the variance in Chinese facial attractiveness and the RMSE of 0.555 showed that our model predicted Chinese facial attractiveness to within 0.555 points on a 7-point scale. The most important colour predictors for attractiveness of Chinese faces were the brows contrast (Brows-C-a*) and facial lightness (L*, Nose-L*).

MLR model summary					
(a) Caucasian			(b) Chinese		
model term	β	Sig.	model term	β	Sig.
(Intercept)	8.395	0.004	(Intercept)	0.771	0.821
C*	-0.375	0.044	L*	-0.416	0.006
Cheek-C*	0.364	0.023	Cheek-L*	0.280	0.011
Eyes-L*	-0.086	0.027	Nose-L*	0.195	0.007
Brows-C-h	22.873	0.001	MCDM	-0.935	0.055
Mouth-C-L*	-18.744	0.003	Brows-C-a*	-6.530	0.000
			Brows-C-h	-16.193	0.064
			Mouth-C-a*	4.548	0.020
DF	5		DF	7	
F	6.914		F	7.986	
Sig.	0.000		Sig.	0.000	
R-Squared	0.512		R-Squared	0.636	
Adj. R-Squared	0.438		Adj. R-Squared	0.556	
Range of VIF	1.092-6.978		Range of VIF	1.747-11.1136	
RMSE	0.646		RMSE	0.555	
MSE	0.417		MSE	0.495	
MAE	0.461		MAE	0.410	

Table 2. Summary of developed models of facial attractiveness for both Caucasians (a) and Chinese (b)

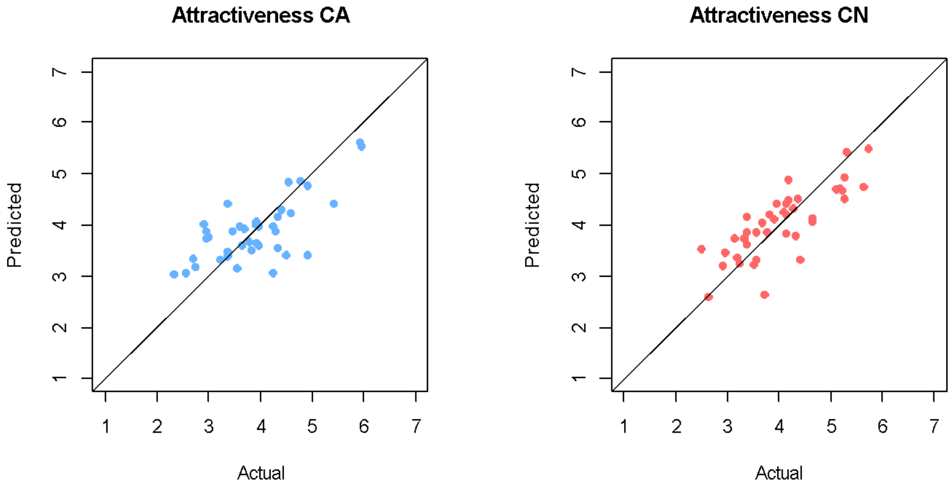

Figure 1. Model performance of the MLR models in predicting facial attractiveness for the Caucasian dataset (left) and the Chinese dataset (right)

Conclusion

The present study provided a useful method of modelling facial attractiveness from various colour characteristics. Generally, our results have shown that the MLR modelling approach can be used to build facial attractiveness prediction models for both Caucasian and Chinese populations. Considering the different methods of variable selection could lead to different MLR models due to the correlations between independent variables, the future work will focus on optimizing variable selection and removing possible collinearities, so that a more precise and completed regression model for facial attractiveness predicting could be achieved.

References

Appleton, K. M., McGrath, A. J., McKinley, M. C., Draffin, C. R., Hamill, L. L., Young, I. S., & Woodside, J. V. (2018). The value of facial attractiveness for encouraging fruit and vegetable consumption: analyses from a randomized controlled trial. *BMC Public Health*, 18(1), 298. https://doi.org/10.1186/s12889-018-5202-6

Fink, B., Matts, P. J., D'Emiliano, D., Bunse, L., Weege, B., & Röder, S. (2011). Colour homogeneity and visual perception of age, health and attractiveness of male facial skin. *Journal of the European Academy of Dermatology and Venereology*, 26(12), no-no. https://doi.org/10.1111/j.1468-3083.2011.04316.x

Fink, B., Bunse, L., Matts, P. J., & D'Emiliano, D. (2012). Visible skin colouration predicts perception of male facial age, health and attractiveness. *International Journal of Cosmetic Science,* 34(4), 307–310. https://doi.org/10.1111/j.1468-2494.2012.00724.x

Fink, B., Grammer, K., & Matts, P. J. (2006). Visible skin color distribution plays a role in the perception of age, attractiveness, and health in female faces. *Evolution and Human Behavior*, 27(6), 433–442.

Foo, Y. Z., Rhodes, G., & Simmons, L. W. (2017). The carotenoid beta-carotene enhances facial color, attractiveness and perceived health, but not actual health, in humans. *Behavioral Ecology*, 28(2), 570–578. https://doi.org/10.1093/beheco/arw188

Jones, A. L. (2018). The influence of shape and colour cue classes on facial health perception. *Evolution and Human Behavior*, 39(1), 19–29. https://doi.org/10.1016/j.evolhumbehav.2017.09.005

Jones, A. L., Russell, R., & Ward, R. (2015). Cosmetics alter biologically-based factors of beauty: evidence from facial contrast. *Evolutionary Psychology*, 13(1), 147470491501300. https://doi.org/10.1177/147470491501300113

Lu, Y., Yang, J., Xiao, K., Pointer, M., Li, C., & Wuerger, S. (2020). Investigation of effect of skin tone to facial attractiveness. *Color and Imaging Conference*, 2020(28), 25–29. https://doi.org/10.2352/issn.2169-2629.2020.28.5

Lu, Y., Yang, J., Xiao, K., Pointer, M., Li, C., & Wuerger, S. (2021). Skin coloration is a culturally-specific cue for attractiveness, healthiness, and youthfulness in observers of Chinese and western European descent. *PLOS ONE*, 16(10), e0259276. https://doi.org/10.1371/journal.pone.0259276

Pazda, A. D., Thorstenson, C. A., Elliot, A. J., & Perrett, D. I. (2016). Women's facial redness increases their perceived attractiveness: mediation through perceived healthiness. *Perception*, 45(7), 739–754. https://doi.org/10.1177/0301006616633386

Stephen, I. D., & McKeeganh, A. M. (2010). Lip colour affects perceived sex typicality and attractiveness of human faces. *Perception*, 39(8), 1104–1110. https://doi.org/10.1068/p6730

Tan, K. W., Tiddeman, B., & Stephen, I. D. (2018). Skin texture and colour predict perceived health in Asian faces. *Evolution and Human Behavior*, 39(3), 320–335. https://doi.org/10.1016/j.evolhumbehav.2018.02.003

Thorstenson, C. A., Pazda, A. D., Elliot, A. J., & Perrett, D. I. (2017). Facial redness increases men's perceived healthiness and attractiveness. *Perception*, 46(6), 650–664. https://doi.org/10.1177/0301006616680124

Session 10

Colour and Art: Inspiration & Materials

Yellow is the Sound of a Trumpet: An International Survey on the Association between Color and Sound and a Comparison with Color Theory

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Abstract

This study is an international survey of the tendency to associate color with sound from the perspective of color theory. However, the purpose of this study is to identify a color-sound link that many individuals can relate to, rather than to investigate synesthesia's perceptual qualia. Since ancient times, there has been an idea that there is a link between color and sound. According to Sir Isaac Newton's "Opticks" (1704), the rainbow's spectrum is divided by a musical scale. Previous research has revealed that the colors and sounds that people identify with colors are quite consistent. Respondents were asked to fill out a questionnaire about the sounds they associate with different colors in either English or Japanese, and statistics were produced. According to Hashimoto et al., color and sound stimuli are linked through hue, saturation, and lightness. The scales and hues in the standard color theory outlined in Collopy's paper (2009) were compared to the results of our survey. In terms of color connections, Newton's E and G colors tended to be similar, whereas Field's C and G colors tended to be similar. We can obtain more consistent data by categorizing the cohorts by gender, age, and favorite activities.

Keywords: *Color Theory, Color to Sound Association, Warm and Cool Colors, Music Scale, Newton*

Introduction

It has been said since ancient times that there is a certain correlation between color and sound. This study is an international survey of color-sound associations from the viewpoint of color theory. Synesthesia research has received a lot of attention in recent years. The objective of this survey, however, is not to investigate the perceptual qualia of synesthesia, but to identify a color-sound relationship with which many individuals can identify and empathize. Questionnaires were given in both Japanese and English regarding what sounds people associate with certain colors, and statistics of the responses were collected.

The research data from this study can be applied to the development of educational toys and apps that use colors and sounds. There are toys such as “*Specdrums*”, which produce sound when the user touches various object colors and the sensor detects the color. These toys can provide music in response to changes in the sound assigned to each color. Furthermore, "*mupic*", developed by DOZAN11 et al. (2019) is an app that automatically generates music from the colors in a photo to which the sound is assigned.

Newtonian Color Theory

The spectrum of the rainbow is divided by a musical scale, according to Sir Isaac Newton's "Opticks" (1704). This had a significant impact on color theory in the Western world. He also connected the number seven to the seven notes of music scale and arranged them in a circular form. Taking a length equal to the length of the visible spectrum on the outer extension of the red color and finding the ratio of the lengths from the end to the dividing line of each spectral color, these are approximately proportional to the length of a stringed instrument, thus he made the dividing line of the colors of the rainbow correspond to do-re-mi-fa-so-la-ti of the scale. The entire development of Newtonian color theory is tied to the worldview from Pythagoras of scales and celestial music. The octave scale has been the foundation of Western music. The music of the spheres is the idea that each of the six planets (Mercury, Venus, Earth, Mars, Jupiter, and Saturn), beginning with the Sun, plays a scale of one octave, as detailed by the German astronomer Kepler in his "Harmonices Mundi" (The Harmony of the World, 1619)

Furthermore, Newton also appears to have been inspired by the Jesuit monk, music theorist, and mathematician Kircher. Kircher advocated the theory that sound had an objective correspondence with certain colors. In support of these predecessors' theories, it is justifiable that Newton would have asserted that the octave scale and the colors of the rainbow are correlated.

Previous Studies

Previous studies have looked at music from both directions, such as what kind of music is created depending on color or what colors come to mind based on the type of sound. The results of these studies have also been applied to algorithms for the automatic generation of music and images by computers (Matanski. 2015). Sound stimuli and color are associated by hue, saturation, and lightness, according to Hashimoto et al. (2002), and people see colors with high lightness for high and bright sounds, red, orange, yellow, and achromatic colors for populated noises, and green and blue colors for natural sounds.

Collopy (2009) has listed and compared the following 13 scholars, musician, art teacher, and physiologist etc. who have applied music scale to hue: such as Newton, Bertrand-Castel, Field, Jameson, Helmholtz, Seemann, Rimington, Bishop, Scriabin, Klein, Aeppli, Belmont, and Zieverink.

Method

In this study, two online surveys, one in Japanese and the other in English, were prepared to ask respondents to identify the sounds and instruments that they connected with the 12 colors. The surveys were conducted over a two-week period from 22 May to 6 June 2020. 79 Japanese speakers and 45 English speakers were compared. The respondents were from six countries: the United States, Taiwan, Brazil, the Netherlands, India, and Japan. In the English survey, many of the respondents had a high level of knowledge of music. These surveys were conducted to determine what sounds and musical instruments people associate with the 12 colors shown in Figure 1. To avoid the possibility of associations that might occur if the color names were presented at the same time, the color names were all omitted from the survey. Respondents were asked to answer the question "What instrument sounds do you associate with the colors (1) through (12)?" and to list the sounds they linked with the colors, such as instruments, types of sounds, and mood. The colors were displayed independently and randomly. As a result, the impact of color comparisons was lessened.

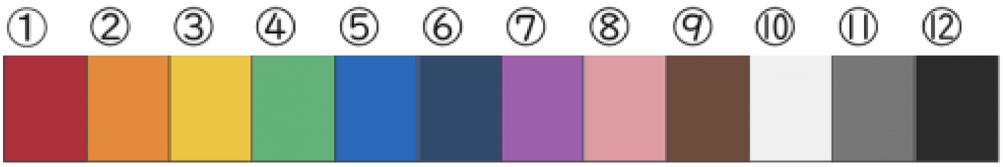

Figure 1. List of colors shown in the questionnaire

The following was the survey's hypothesis: Warm and bright tones were chosen for fast tempo music, while dark tones were chosen for slow tempo music, purple and red purple tended to be chosen for minor melodies, and achromatic colors such as black and gray were chosen for minor and slow tempo music, according to earlier studies.

Results

The survey on the musical instruments associated with the 12 colors yielded results that were common to Japanese and English speakers, i.e., common across nationalities, languages, and cultures. The warm colors (red, orange, yellow), or warmth, were associated with the trumpet, while the achromatic colors (black, white, gray) were associated with the piano. There was no common image for cold colors (blue).

Figure 2 summarizes the colors with the most common associations with color and sound. Contrary to this, Figure 3 is the colors that did not show a common association for color and sound.

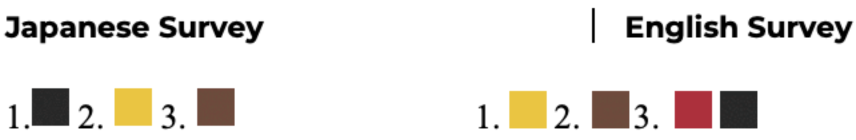

Figure 2. Colors that showed common association for color and sound.

Figure 3. Representative colors that did not show a common association for color and sound

Through the responses to this survey, the following findings were obtained. Warm colors were linked with trumpets and other high-pitched instruments including trumpet, while achromatic colors related to pianos, garnering votes from both Japanese and English speakers, indicating that there was no language difference. There were no specific instruments that were substantially related with either of the cold colors. The piano was the most frequently associated sound with the color by Japanese respondents, with 44 votes for the piano among males and 22 votes for the violin in second place, a wide gap from the second place, indicating that the piano is more familiar to males. The electric guitar was the fourth most frequently associated with color by males, while it was 27th for females, a considerably lower number, indicating that the electric guitar is a more familiar instrument to males.

The most frequently associated sounds with the color by English respondents were violin, flute, cello, piano, trumpet, and clarinet, showing a wider range of sounds than those by Japanese respondents. Unlike the Japanese respondents, there was no significant difference between male and female respondents, but here, too, the percentage of male associations with guitar was high, while that of female associations was low. The colors of ⑤, ⑥, and ⑪ were found to be similar regardless of language. The findings also demonstrate that the color of music is determined by characteristics such as preference, emotion, and impression.

Discussion

How do the color associations in this survey's results differ from past color theory scholars' and musicians' assignments of color and sound? The results were compared to the scales and colors in Fred Collopy's PLAY(WITH)COLOR (2009) which provides color theorists associations. Sir Isaac Newton (1642-1727) and George Field (1777?-1854) were two individuals whose inclinations were similar to those of this survey. The scales C, D, E, F, and G were all associated in this study, however the scales A, B, and # (semitone higher) were not. (Semitone higher) were not linked in any way. In terms of scale and color, the colors of E and G in Newton tended to be comparable, while the colors of C and G in Field tended to be similar.

①: D
②: E, F
③: G
④: G
⑤: G
⑥: C

Figure 4. Each associated color and sound.

Conclusion

Although no color's associations were perfectly consistent, there were still some international commonalities. Even though the associations were significantly skewed, it was important that some people associated the colors with opposite meanings (for example, some people identified low tones with colors that were typically associated with high tones). Minor tones and slow tempos were frequently connected with black, gray, and dark dull purple and reddish-purple tones, whereas major tones and slow tempos were generally associated with pale tones. These findings imply that the combination of music and color is determined by three factors: first, the preference for each music and color, second, the similarity of emotions evoked, and third, the similarity of impression evaluation.

As a result, there is a correlation between color and music. In the future, I hope that the specific relationship between color and sound will become more concrete.

Acknowledgements

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References

Collopy, F. 2009. PLAYING (WITH) COLOR. *Glimpse* Vol 2.3:62-67.

Hashimoto et al. 2002. On synesthetic associations of sound and color. Journal of *Sugiyama Jogakuen University* 33: 57-67.

Hidaka, K. 2021. *Color Categorization*. Kyoto: Kyoto University Press.

Johansson et al. 2020. Color sound symbolism in natural languages. *Language and Cognition* 12(1), 56-83.

Matanski, V. 2015. Generative visualization based on sound. Doctoral Conference in Mathematics and Informatics.

Matsuyama et al. 2020. A Survey of Color and Sound Associations Using the App "mupic". *Journal of the Color Science Association of Japan* 44(3+): 74.

Simner, J., Ward, J. Lanz, M, Jansari, A. Noonan, K., Glover , L, and Oakley, D.A. 2005. Non-random associations of graphemes to colours in synaesthetic and non-synaesthetic populations, *Cognitive Neuropsychology* Volume 22 Issue 8:1069-1085.

Wells, A. 1980. Music and Visual Color: A Proposed Correlation. *Leonardo* 13(2):101–107.

Multimodal and Pseudo-Synaesthetic Systems in Visual Music Composition: Applying Color Harmony to the Musical Process

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Abstract

The application of ideas based on color and visual theory into the musical domain has gained more and more interest in the last century. With the advent of animation, coupled with the advancements of technology, there have been several techniques and concepts invented and used in the creation of audiovisual art. While many such theories exist in these disciplines, there has also been a lack of concepts that consolidate the mathematical correspondences of color and sound with the cognitive audiovisual experience. Through research on the experiences of musicians with synaesthesia, as well as how non-synaesthetic people react to synaesthetic and pseudo-synaesthetic constructs, several cross-modal constants have been derived in both the creation and experience of audiovisual aesthetic information. This enables the creation of systems which can apply color and visual harmony into the emergent properties of music - not only singular notes, chords, and rhythms, but also the relationships between these musical parameters.

Keywords: *Color, Music Theory, Aesthetics*

Introduction

The use of color as a basis for an audiovisual vocabulary is not a new idea. The concept of equating colors (or systems of colors) into musical practice has been present in history as early as Pythagoras. The ideas of Newton, as well as the color music instruments created by Louis Bertrand Castel and Alexander Wallace Rimington have taken these concepts further by solidifying them into a theory.[1] The 'Ocular Harpsichord' of Castel and the 'Color Organ' of Rimington were intended as color-based visual instruments where the musical performance would translate into a specific collection and movements of color, representative of the notes present in the music. The use of a color system as an analogue to music is especially apparent in the works of Rimington, in which he presents a new 'Mobile Colour Art' as a new art form that would use color in an abstract manner that is similar to the intrinsically abstract nature of music.[2]

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[1] Jewanski, Synesthesia in the Nineteenth Century, 2013.
[2] Rimington, *Colour-Music*, 43-48, 2005.

However, the experimental performances and the instruments of Rimington, which he has used to perform music along with his 'Mobile Color Art', have not been entirely successful. A review from *The Times* has noted that the choices of color and their movements were "[...] unsatisfying, and did not convey the same impression to the mind as the music."[3] Indeed, it seems that the search for an audiovisual mapping between colors and musical notes that reflects a universal aesthetic truth is not possible. The phenomenon of chromesthesia, in which people experience sensations or associations to color as a response to musical sensory input, seems to support this idea. Chromesthesia and synaesthesia (of which chromesthesia is a subset) has idiosyncrasy as one of the defining features – every person with synaesthesia will have a unique set of associations.[4] For instance, a D Major chord might be scarlet to one person, whereas it is green with speckles of gold to someone else.

The question then remains on the possibility of deriving a color harmony (or a certain collection and usage of colors) as a sufficient metaphor for the harmonic qualities of music (as a certain collection and usage of musical pitches.) The investigation on how the previous color-music theorists derived their associations and how humans cognitively and culturally derive their associations may then reveal certain mapping systems that are cognitively and aesthetically effective.

Classical Color-music Systems

In the theories of Rimington, as well as Castel and Newton, the color associations are mostly derived from one-to-one relationships between ordered pitches. The chromatic or diatonic scale is taken as a basis for a spectrum, which is then juxtaposed to a spectrum of colors.[5] The justification of the color choices are usually based on a scientific foundation: Matching the lowest element of the visual spectrum to the lowest note and the highest element of the visual spectrum to the highest note. This seems to be the general strategy in the matching of visual and aural components of the senses. A similar example is the composer Alexander Scriabin's approach of using the circle of fifths (a way of ordering pitches by spreading them over the interval of a perfect fifth) as the basis for his own color associations.[6] These approaches result in certain hard mappings where a note is equated to a specific color. Such color-notes are then used to depict the pitch content of music, or to create new music where the color associations are used as a building block of the creative process. In Figure 1 we can see how Rimington creates color-chord progressions by 'mixing' colors in chords and changing colors on each progression.

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[3] Rimington's Mobile Color Music, The Times, 1895.
4 Curwen, Music-Colour Synaesthesia: A Sensorimotor Account, 2020.
5 Rimington, Colour-Music, 127-128, 2005.
6 Whipple, Two Cases of Synaesthesia, 1900.

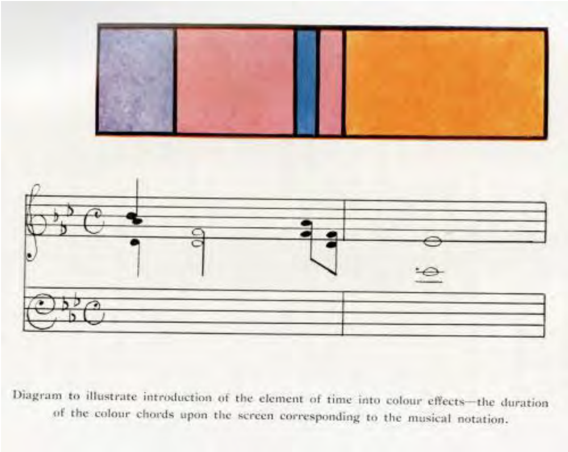

Figure 1. Rimington's application of his color mappings on a musical excerpt.

A general critique of such a system is based on its inadequacy in addressing the contextual needs of a piece of music. The experience of music is not based on the agency of singular elements, but their relations to each other and the emergent property that results when all the parameters that create the musical experience interact with each other (the pitches, timbres, dynamic, rhythm...).

Direct Audiovisual Mapping versus Cognitive and Synaesthetic Perspectives

To highlight this problem, we can consider the concept of 'function' in western classical functional music theory: A musical note does not exist in a vacuum, but in the context of a scale, pitch collection, and harmonic possibilities. The note C can be thought of as the Tonic in a C-Major scale, but as a leading tone in a Db-Major scale. In the first case the note would have the function of 'home', facilitating a feeling of resolution from tension created by other notes and chords, whereas a leading tone would create an opposite feeling: tension that 'wants' to resolve into the tonic of the scale. It is important to note here that in both cases the note is the exact same: It has the same frequency and timbral properties. However, it is its application within a musical context that changes how it is perceived by the listener within a given framework of pitch organization.

In composers with chromesthesia (also called sound-color synaesthesia), this property of 'functions' seems to work in reverse. As synaesthesia has a core component with fixed, one-way associations (e.g., C is red) the experience of the synaesthete does not directly reflect the functional component of the musical experience. This is to be expected as the associations are based on the semantic level, where ordered concepts are dominant. (Note names, scale names, chord types...) Despite this, it is possible to see the application of the functional elements of music in the synaesthetic expression. Synaesthetic composers such as Olivier Messiaen and Michael Torke, as well as pseudo-synesthetes like Scriabin are drawn towards certain musical parameters and intensities when certain color associations are in play: Even though the association of the color red is different for each composer, they all display the application of musical parameters reflect both the cultural meaning and the 'intensity' associated with that color.[7] For all of these composers the expression of the synaesthetic red comes with faster rhythms, more dissonant chords, and more dense timbral choices. Even though these choices do not correspond to their synaesthetic experience directly, the application of this experience brings cross-modal associations that are reflective of the cultural and cognitive associations non-synaesthetic people tend to possess.

We see therefore that the problems with the classical models of color-music associations are twofold: First, they assume that each note has a fixed association regardless of the musical context. This is a consequence of prioritising mathematical correspondences instead of cognitive and music theoretical perspectives. Secondly, the other musical parameters which constitute the emergent property of the final musical 'product' are not considered. The references to timbre, chord progressions, harmonic context, rhythm, and other parameters are seldom mentioned and only used as an extension of the fixed color-note associations. An ideal color-note system has to then consider these two lacking perspectives. For the creation of my own audiovisual works that deal with this subject I have derived two main axioms:

- The mapping of visual components to the aural components for an audiovisual vocabulary cannot be fixed and have to be considered for the needs of the specific musical work.
- The colors need to be mapped to the functions of pitches instead of their pitch classes, which is then treated as the building block of the sound-color harmony.

Crafting a Harmonic Sound-Color Vocabulary

My audiovisual works have a strong color component, where a certain sound-color vocabulary is created and used either in response to the musical harmonic material or driving this material through audiovisual instruments. The components that create the sound-color vocabulary and the resulting audiovisual mappings are unique to each work, as the structure and the important perceptual elements for each work greatly differ. Given that the subject of musical harmony is extremely wide (especially considering contemporary and non-Western approaches,) I will limit myself to the color mapping of the western classical harmonic system and other adjacent systems. As an example, my work *Shallow Steps* makes use of an audiovisual instrument, where the touchpad used to control and play a synthesizer also paints on the screen.[8] Figure 2 shows an image from the work.

[7] Eldem, Junction between the Senses: Synaesthesia and Cross-Modality in Music, 2019.
[8] Eldem, Shallow Steps, 2021.

Figure 2. Excerpt from the visuals of *Shallow Steps*. The watercolor-like textures on the screen move and disappear over time, leading to new musical Figures and colors.

In this work, the parameters that control the synthesizer, such as pitch, duration, reverb, timbral density, are mapped onto a digital watercolor painting Max/MSP patch created by me. The choice of these parameters directly influence how and when the visual elements will appear on the screen. As multiple or successive notes are played, the combination of the colors create a color harmony that is reflective of the harmonic content.

To justify my sound-color mappings, and to keep them relevant on the cognitive level, I have made use of the concept of a musical lattice. Musical lattice is a conceptual model that orders notes in the way of their rational relationships.[9] This model is used for tuning instruments as well as clarifying the harmonic relationships between different notes as derived from a central note. Such a model is very useful as it reveals the amount of harmonic tension that is created when different notes are played together. This makes it possible to go beyond the consonant/dissonant dichotomy and ascertain the different feelings and levels of consonance created by different intervals. It is important to realize here that the central note is insignificant: The harmonic relationships are indeed created from the *relationship* between the one note and the other. If we use the note A instead of C as the central note, all of the other notes will change, but relationships between the notes will remain.

My approach to color then had to reflect this quality of musical harmony and the musical lattices: There are no fixed relationships in the way of unique parameters in the audiovisual space (unless you are a synaesthete) but the relationships between the parameters can be used as the main element that gets mapped. This means that instead of giving a fixed color to a note, assigning color *relationships* to the musical note *relationships* may create audiovisual spaces that reflect the cognitive experience of musical harmony more strongly in the visual realm. To create such a 'Sound-color Lattice', I have used hue and

[9] Mathieu, Harmonic Experience, 1997.

brightness as the elements of color from which to measure different ratios. As the distance from the central note in the musical lattice changes horizontally (thus in the intervals of a fifth,) the hue and brightness from the central color will also differ by a set amount. Similarly, a horizontal difference (in the intervals of a major third) will be reflected inof the colors changing by a slightly lesser amount. Figure 3 is an example where the central note C is associated with a specific shade of green, which results in the other colors which are to be mapped with the rest of the musical lattice. The color combinations therefore reflect the harmony derived from this lattice: Playing a certain chord will result in color associations that are very strongly tied to the intervallic ratios of the component notes. For musical pieces where harmony plays an effective role, this approach can translate the pitch content without falling into the mistakes of the previous sound-color models.

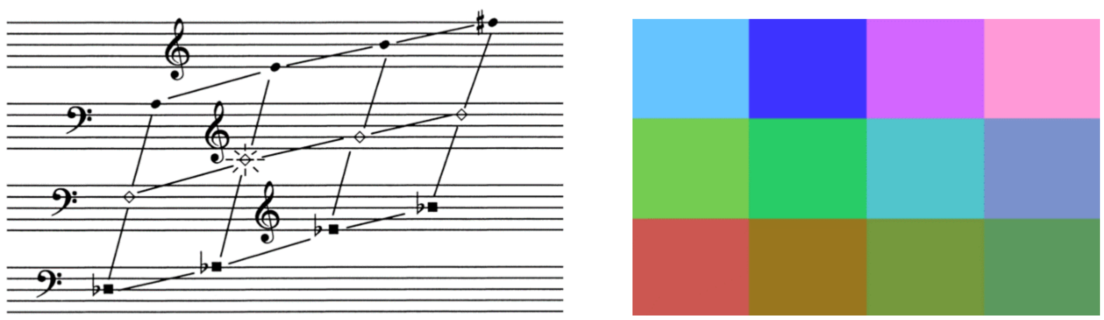

Figure 3. An example of a sound-color lattice. The arrangement of the notes on the left, derived from a central note, is equated to the color palette on the right, also derived from a central color.

An important distinction here is between what is idiosyncratic, and what is deduced from intervallic relationships: The initial statement of “C is Green” is completely arbitrary. However, the other colors are derived from this statement and are based on the relationships between notes and their ratios. In this way of working it is possible to consolidate the individual associations and to derive a consistent bigger picture of sound-color relationships, which might be used as a basis of further elaboration.

Exploring audiovisual relationships in this fashion, through an understanding and implementation of synaesthetic and cross-modal principles, applied through a knowledge of music theory, can make more intricate and intuitive sound-color systems and artworks possible.

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References

Curwen, Caroline. 2020. “Music-Colour Synaesthesia: A Sensorimotor Account.” *Musicae Scientiae* 26, no. 2: 388–407. https://doi.org/10.1177/1029864920956295.

Eldem, Umut. 2019. “Knooppunt Van Zintuigen. Synesthesie En Cross-Modaliteit in Muziek / Junction between the Senses: Synaesthesia and Cross-Modality in Music.” *Forum+* 26, no. 2: 44–50. https://doi.org/10.5117/forum2019.2.elde.

Jewanski, Jörg. 2013.“Synesthesia in the Nineteenth Century.” *Oxford Handbooks Online*. https://doi.org/10.1093/oxfordhb/9780199603329.013.0019.

Mathieu, W. A. 1997. *Harmonic Experience: Tonal Harmony from Its Natural Origins to Its Modern Expression.* Rochester, Vt: Inner Traditions International.

Rimington, A. Wallace, and Hubert von Herkomer. 2005. *Colour-Music: The Art of Mobile Colour*, 43–48. Chestnut Hill, MA: Adamant Media.

“Rimington's Mobile Color Music.” *The Times*, July 28, 1985.

Shallow Steps. Umut Eldem, October 5, 2021. https://www.youtube.com/watch?v=hOyTexY-1e4.

Whipple, Guy Montrose. 1900. “Two Cases of Synaesthesia.” *The American Journal of Psychology* 11, no. 3: 377. https://doi.org/10.2307/1412749.

My Thoughts Appeared in the Sky: A Synesthete Meets the Aurora

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Abstract

My synesthetic ability to perceive sound as abstract shapes with movement and colour on the dark canvas of my mind's eye has been the primary basis of my digital art and design practice. I spent two months in the Norwegian arctic, studying the scientific basis, cultural connections, and human experience of the Northern Lights. Along with an essay on these topics, I produced photographs and time lapses of the Northern Lights, which served as reference material for four digital art pieces. These motion graphics videos visually interpret clips of ambient instrumental music, chosen for their ability to trigger visuals with similarities to the aurora according to my sound–visual synesthetic experience.

Seeing the aurora's colour and movement, I was struck by a rare, specific state of awe and recognition, until then only felt when viewing artworks by synesthetes which related to my own experience. It is the only time nature has created such an encounter, and it was stronger than expected. This project has brought together art, design, music, science, history, and anthropology to explore the value of individuals and intersectional inquiry.

Keywords: *synesthesia, aurora, northern lights, perception*

A Synesthete Meets the Aurora

It is dark and quiet, except for the hum of the engine. I am standing on the deck of a boat, my latitude is something a bit above 78° North and the air temperature is in the single digits (Fahrenheit) and not rising. The other passengers murmur to each other, searching the sky. We are still at least an hour from docking in Longyearbyen, the world's most northern permanent settlement. I briefly think of that thick, cozy duvet back in my room, and wiggle my toes to keep them with me. I swear the sky doesn't look completely smooth, and there aren't clouds on this clear night.

A few pale green rays appear, somehow both quickly and slowly. They shimmer slightly and fade to make room for others. Just as suddenly as they flickered into view, they're gone. The murmurs of the passengers swell and there are desperate attempts at taking pictures. The darkness returns, along with the quiet.

What did I just see? It seemed familiar, yet I've never seen the Northern Lights before.

And then, *memories of my mind's eye* appear across the arctic sky.

A faint green band forms above us; it stretches, thickens, then curves on one end. The band brightens as it begins to dance a bit more, and then bunches up in a zigzag pattern. There's a mix of gasps and hushed exclamations around me, but I stay silent because my heart is pounding. I know these things. There is silent music in the sky, and it feels like it's a recording of my mind's eye.

The lights fade and the sky goes dark except for a faint, slowly morphing patch far to the right. A few of the other passengers decide to go back into the warm cabin, but I can't move my feet because my mind is racing as fast as my heartbeat. After a short wait, that patch grows and transforms into graceful wispy green curtains, gently moving as if pulled by an other-worldly breeze.

Murmurs and points from fellow passengers make me tear my gaze away and look up into a beautiful corona, blooming into a complete, irregular ring of slightly milky green rays reaching down toward us with tinges of reddish purple at the top. Sometimes the rays look like they're on their way down to join us before withdrawing, shifting, fading, and regaining their glow. I can't tell how far away any of it is, but the corona is nearly directly overhead, and I can't look away. Because I've seen it before… in my mind's eye.

Synesthesia and Neurodiversity

As a synesthete, I experience automatic, consistent cross-sensory experiences. One way these manifest is that all sounds, and especially music, are accompanied by an abstract display of colour, shape, and motion to me. It's always been this way, but I didn't know that I was in the minority of the population until I was in my mid-20s. This is a common anecdote among synesthetes. The scientific community studying this estimates between 1% and 4% of the population are synesthetes (Cytowic and Eagleman 2010, 7-8; Asher 2009, 279-85). There are dozens of types of synesthesia currently identified, a list that has been growing during the past 30 years' resurgence in study.

Many societies are just starting to recognize neurodiversity. This term, coined in the late 1990s by autistic Australian sociologist Judy Singer (1999), refers to the natural variation among human brains (59-67). This includes recognizing the reality of differing tendencies in learning, sociability, attention, sensory processing, and other mental functions. It is not meant to be a buzz-word or a pathology, as things under this umbrella are not truly diseases or illnesses. Instead, the term highlights that the so-called "normal" human brain is an illusion and a social construct. Just as humanity is a sea of skin tones, hair textures, eye colours, and body shapes, each brain is unique to each individual. Two people who express the same type of neurodiversity may have it impact their lives in different ways, due to reasons of both nature and nurture.

We now understand autism as a spectrum, where one person may struggle modestly with interpreting social cues, and another may have considerable difficulty understanding and processing their own emotions. This is a good model for other types of neurodiversity as well. Some synesthetes can be highly prone to sensory overload, depending on the type and strength of their synesthesia. There are certain commonalities between autism and synesthesia, and synesthesia appears to be more common in those on the autistic spectrum than the general population (Baron-Cohen 2013). Imagine each word you hear experienced as a strong taste, feeling everything that occurs in a violent television show, or having your quiet, inner world pierced by a blinding white, razor-like cut when a child screams. While that last one is personal to me, the first two examples are from my synesthete friends—we can empathize deeply with each other. Our synesthete brains are working overtime to process these multi-sensory experiences.

Unexpected colour in and far above our heads

To the majority of people, the great overhead expanse reflects the weather felt below, the time of day, and one's direction and location. But it isn't supposed to turn green and host light shows during the darkest months, which has seemed to delight and terrify in equal measure. We synesthetes can relate.

Beliefs and names for the polar lights existed among cultures across the world long before Europeans created the terms we use today. Many relate to spirits of the dead, foretelling events, or tying into existing mythologies. Some cultures still hold their beliefs as part of folklore. The term aurora borealis was coined by Galileo in the early 17th century, and British explorer Captain James Cook added aurora australis during a trip to Australia in the late 18th century. These terms have roots in Latin, with Aurora meaning dawn (and the Greek goddess of the dawn), and borealis and australis meaning northern and southern, respectively.

Table 1. Compiled chart of recorded beliefs related to the aurora (Petrie 1963; Savage 2001; Hamacher 2013; Hearne 1958; Brekke and Broms 2013).

People	Location (in modern terms)	*Name*/Description for aurora	Positive	Negative	Neutral	Fire	Animal	Spiritual	Ancestral	Predictiv
Gunditjmara	Western Victoria, Australia	puae buae, ashes			x	x				
Gunai	Eastern Victoria, Australia	bushfires in the spirit world		x		x		x		
Dieri	South Australia	*kootchee,* an evil spirit creating a large fire		x		x		x		
Ngarrindjeri	South Australia	the campfires of spirits in the 'Land of the Dead'			x	x			x	
Aboriginal People of Queensland	Southwest Queensland, Australia	Fires of the Oola Pikka, ghostly spirits who spoke to the people through auroras. Only male elders were allowed to watch and interpret these messages.		x				x		
Native People of Ceylon	Sri Lanka	Buddha lights, interpreted by priests as signifying displeasure at the sinfulness of the people		x				x		
Chipewyan Dene	Western Canada	Spirits of the dead dancing in the sky; brighter lights indicated heightened happiness	x						x	
Mandan Native Americans	North Dakota	Fires in pots for simmering dead enemies, presided over by medicine men and warriors	x			x		x		
Alaskan Eskimo, Canadian and Greenlandic Inuit, Sami, Siberian Natives	Alaska, northern Canada, Greenland, Norway, Sweden, Finland, Russia	Represent souls of those who died through loss of blood, playing a game of soccer. The ball is in some areas reported to be a human skull, in others the head of a walrus. The "ball" is not always deceased.			x		x	x	x	

Greenlandic Inuit	Greenland	Spirits of stillborn and deceased children dancing/playing	x					x	x	
Eskimo	Northern Alaska, northern Canada, northeast Siberia, and Greenland	*keoeeit* Torches held by spirit guides to lead the souls of the recently deceased to the afterlife	x					x	x	
Eskimos of the Lower Yukon River	Alaska	Dancing souls of their favorite animals (deer, seals, salmon, and beluga whales)	x				x	x		
Eskimos in the Kodiak Islands	Alaska	Used by healers in the treatment of heart ailments	x							x
Nunamiut	North and northwest interior of Alaska	A good hunt the next day if the sky is divided in half by the aurora	x							x
Inuit of the Central Canadian Arctic	Central Canadian Arctic	Helping spirit harnessed by healing shamans for guidance on treatments or the rescue of souls	x					x		
Finns and Karelians (as recorded in the *Kalevala*, the national epic poetry piece of the 1800s)	Finland and the Republic of Karelia (an autonomous region that is a federal subject of Russia) bordering the lower half of Finland to the east)	The gates of the north, tied to the literary stories of travel and typical depiction of people in the north as enemies. In some Karelian dialects, the aurora is still called “fiery pillars.”		x	x	x				
Northern Sami	Northern Norway, Sweden, and Finland	*Guovssahasat*, morning/evening glow	x							
Lapland Sami	Northern Finland	*revontulet*, fire fox Magical animals lit up the sky with the sparks flying off their fur	x			x	x			

Vikings	Norway, Denmark	Reflections off the shields of the Valkyries, who choose which warriors will enter Valhalla (honored afterlife); or reflections of deceased maidens			x			x		
Swedes	Sweden	Polka/folk dance Prediction of good harvest	x							x
Scandinavian Fishermen	Norway, Sweden, Denmark	The sun reflecting off the backs of large schools of herring, indicating a good catch to be had	x							x
Danes	Denmark	Folklore says the lights are reflections caused by swans caught far north in ice, flapping their wings		x			x			
Estonians	Estonia	The glow from a celestial wedding	x					x		
Russians	Russia	Associated with *Ognenniy Zmey*, the fire dragon, which seduced wives while husbands were away		x		x	x			
Hebrides, Shetland, and Orkney Islands	Northern Scotland	“Nimble ones/dancers,” a tribe of shining fairies	x					x		
Scots	Scotland	Merry dancers	x							
French, Italians, and Greeks	Citations as late as the Franco-Prussian War in 1870-71	Red aurora illuminating the sky without much specific shape indicated bloodshed to come		x						x
French Canadians	Quebec, Canada	Marionettes	x							
Confederate American Troops	Virginia, during the Battle of Fredericksburg (Dec. 14, 1862)	Reported in many letters and diaries, a rare southern aurora appeared red (see above) and the Confederates took this as an indication that God was on their side. They were victorious the next day.	x					x		x

It was well into the 20th century when we arrived at our fairly solid scientific understanding of the polar lights. As our sun storms and surges, it releases ultra-excited particles into space in the form of plasma. Plasma is the fourth state of matter; it is a highly charged gas that behaves differently than a neutrally-charged one. As solar winds sweep these particles past the earth, most are bounced off of the earth's protective magnetic field, but some infiltrate the atmosphere around the poles, where the field is weakest. As the particles transfer their energy into oxygen and nitrogen, light is emitted as the new energy is quickly spent in order to return to their neutral, stable states, resulting in the polar lights. The most common green or yellow-green colours are the result of the interaction with oxygen, while blue and purple hues occur at different altitudes and indicate that nitrogen is involved. Reddish light is also the product of oxygen, but at a much higher altitude than the reactions causing green light (Brekke and Broms 2017).

Does the Aurora Make Sound?

Throughout history, there have been oral accounts and written descriptions of the polar lights emitting sound. As a cross-sensory person, I was intrigued to look into this aspect. The reports are all surprisingly similar, mentioning faint swishing, crackling, or rustling—sonic descriptions one would expect from an event involving electrical charges. Even with today's researchers having access to incredibly sensitive recording equipment, the data collected during several 20th century studies only indicated sub-audible noise. Given that the auroras are at minimum 60 miles/96.5 kilometers above the earth's surface, it's not likely that sound is coming from them and reaching our human ears. It would take about five minutes for them to do so, but the written reports indicate it is in sync with the movement of auroral forms. These sounds can sometimes be picked up by special radios and amplified so that people can hear them. Theorists have attributed these sounds to the change in electrical conditions during a solar event like the polar lights, which may affect materials in soil and rock that react to charges, a buildup of static electricity in the atmosphere, or even a related phenomenon that occurs in our ears rather than as waves from an external source (Petrie 1963, 90-91).

It is only recently that auroral sounds have garnered scientific attention. Unto Laine of Aalto University in Finland has been working on an inversion layer hypothesis. The inversion layer occurs anywhere from 60-400 meters above the ground, and is measurable with the right equipment, especially on a calm, clear night (which is when auroras are best seen). This layer is like an isolating lid between rising warmer air particles that carry negative charges and the positive charges above it, and it occurs from the rising conductivity caused by geomagnetic storms. Laine's research (2016) shows that the height on the inversion layer and the source of audible sound are the same, meaning this layer of the atmosphere is the likely source of the sound, and that it is close enough to the ground to be perceived as simultaneous with the visual aurora display. This sound, however, is more like a clap than the rustling often reported and sometimes picked up with special radios. On his website, Laine makes the incorrect and offensive claim that synesthesia is an illness (2012), and perhaps is in need of some education on neurodiversity while we are digesting his fascinating work on auroral sound.

The Philosophical Conclusion: Do you see what I hear? (No, but that's okay.)

The parallels between neurodiversity and the auroras are striking. Myths were created to explain the polar lights before modern science could explain the phenomenon. Humans existing on the noticeable parts of the neurodiversity spectrum have been similarly fictionalized. Those with dyslexia, dyscalculia, ADHD, and autism (just to name a few) have been treated as unwilling to learn and perform in traditional ways, rather than unable to learn in one specific way, regardless of other gifts and talents. Many synesthetes have shared stories about their sensory phenomenon clashing with teaching methods that use a set colour, shape, or sound pairings that may enhance memory for non synesthetes, and thus being labeled as lying about their perceptions in order to cover up cognitive weakness. I hope that the recent progress in learning more about our complex brains, coupled with a growing awareness of the truth behind the normalcy of neurodiversity, mirrors the shift away from the misunderstanding of the aurora. The fully-understood polar lights are now a global delight, sought after and appreciated by millions of people seeking to observe them as they are. Not to change them to fit what a typical sky looks like, but to see, know, and experience each unique display of the aurora. Imagine if humanity could apply that same admiration toward the entirety of itself–how lives would be changed!

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References

Asher, Julian E. et al., "A Whole-Genome Scan and Fine-Mapping Linkage Study of Auditory-Visual Synesthesia Reveals Evidence of Linkage to Chromosomes 2q24, 5q33, 6p12, and 12p12." *The American Journal of Human Genetics* 84, no. 2 (February 2009): 279-85, https://doi.org/10.1016/j.ajhg.2009.01.012.

Baron-Cohen, Simon et al. "Is synaesthesia more common in autism?." *Molecular Autism* 4, no. 40, (November 2013): https://doi.org/10.1186/2040-2392-4-40.

Brekke, Pål and Fredrik Broms. *Northern Lights: A Guide.* Oslo: Forlaget Press, 2013.

Brekke, Pål and Fredrik Broms. “The Northern Lights Explained.” YouTube video, 3:12. December 6, 2017. https://www.youtube.com/watch?v=0I1hZCD7sT0.
Cytowic, Richard E., and David M. Eagleman. *Wednesday Is Indigo Blue: Discovering the Brain of Synesthesia.* Cambridge: MIT Press, 2010.
Hamacher, D.W. “Aurorae in Australian Aboriginal Traditions.” *Journal of Astronomical History and Heritage* 16, no. 2 (2013): 207-219.
Hearne, Samuel. A Journey to the Northern Ocean: A Journey from Prince of Wales’ Fort in Hudson’s Bay to the Northern Ocean in the Years 1769, 1770, 1771, 1772. Edited by Richard Glover. Canada: MacMillan, 1958.
Laine, Unto. “Auroral Acoustics project – a progress report with a new hypothesis.” Presentation at the Baltic-Nordic Acoustic Meeting, KTH Royal Institute of Technology, Stockholm, Sweden, June 22, 2016.
Laine, Unto. “Latest News of the Project.” *Auroral Acoustics–Aurora Related Sounds–News*. July 2, 2012. http://research.spa.aalto.fi/projects/aurora/ASoundsNews.html.
Petrie, William. *Keoeeit: The Story of the Aurora Borealis.* Oxford: Pergamon Press, 1963. Ebook.
Savage, Candace. *Aurora: The Mysterious Northern Lights.* Richmond Hill, Ontario: Firefly Books, 2001. Ebook.
Singer, Judy. “‘Why can’t you be normal for once in your life?’ From a ‘problem with no name’ to the emergence of a new category of difference.” In *Disability Discourse,* edited by Mairian Corker and Sally French, 59-67. United Kingdom: Open University Press, 1999.

The Colour Sensation in the Art of Maria Tomasula

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Abstract

Maria Tomasula (b. 1958), a prominent Mexican American painter and Professor of Art at the University of Notre Dame, has produced Neo-Baroque still life paintings over three decades. Her paintings are intriguing due to the unusual arrangement of flowers, fruits, insects, and inanimate objects, and highly attractive due to the application of sumptuous colours. The artist employed vibrant colours to sensationalize, but also to evoke a spiritual or invisible force in the images. She attributes this to the art works of the Catholic churches that she attended as a child. Her objectives of the usage of colours evolved as she adopted certain philosophical views, particularly Spinoza's theory of immanence, Deleuze's account of sensation in relevance to colour and various concepts of material vitality, as addressed by the advocates of New Materialism. This paper explores the origin and influences on Tomasula's use of sensational colours that impart varied meanings to her still life paintings.

Keywords: *still life, force, immanence, thing-power*

Figure 1. Tomasula, *By Hands Unknown*, 2000, oil on linen, 42 x 42"

Maria Tomasula produces Neo-Baroque still life paintings composed of flowers, fruits, insects, and inanimate objects. Her still lifes also typically contain some disturbing features such as binding or piercing as seen in *By Hands Unknown* of 2000 (Figure 1). Here the glove, flowers, and butterflies are connected through strings and are nailed against the wall. Following the traditional vanitas, the painting communicates the transience of life: the cut flowers will soon expire, dead butterflies are pinned down, and the glove is empty. Yet all these dying or dead elements seem fiercely alive, apparently still blooming, seemingly flying, and rising up. The application of brilliant colours, especially the fuchsia backdrop, is what transforms the inert materials into vibrant objects of sensuous delight. There were three major sources that affected the particular use of colours in the art of Tomasula. These were Catholic art that the artist encountered as a child, the theory of immanence advocated by Spinoza and Deleuze, and the emerging philosophy of New Materialism. This paper explores how these influences impacted and shaped the evolution of Tomasula's use of sensational colours.

Tomasula (b. 1958), a prominent Mexican American painter and Professor of Art at the University of Notre Dame, points to the religious images in the Mexican Catholic churches that she attended as a youth as the seminal bedrock of her art. Although second-rate Baroque derivatives, they were spectacular in appearance with overflowing adornments and dashing colours. Most prominent were depictions of martyrs who appeared to be in spiritual ecstasy in spite of physical persecution, as evidenced by torn or disFigured limbs, eyes, and breasts. Even with the bodily damages, the Figures were still appealing due to the rendering of ethereal faces and idealized bodies draped in attractive clothing. The artist found these images "amazing," "incredible," and "powerful," understanding the sublime embedded in the object. In a 2017 lecture at the Institute for Latino studies, Notre Dame, she shared that "The visual rhetoric of sumptuousness is so powerful and the tradition of opulence in those churches made me understand the link between luxuriousness and transcendence."

Shortly after her graduate studies, she decided to paint metaphorical still life: "I started using objects from the natural world - like bugs and flowers - as stand-ins for the human Figure" (2002). *Recure* of 2002 (Figure 2), for instance, represents a bearded iris that was originally torn into pieces, then sewn together and held up by strings tied to hooks that pierce the petals. The inspiration for this work is the images of martyrs that she grew up with, literally replacing an idealized, but suffering saint with a damaged plant that is nevertheless an enticing vision to behold. The subtle changes from white to purple across the illuminated surface of the flower against the pitch-black backdrop transform the ruined article of pain into a vital force of spiritual embodiment.

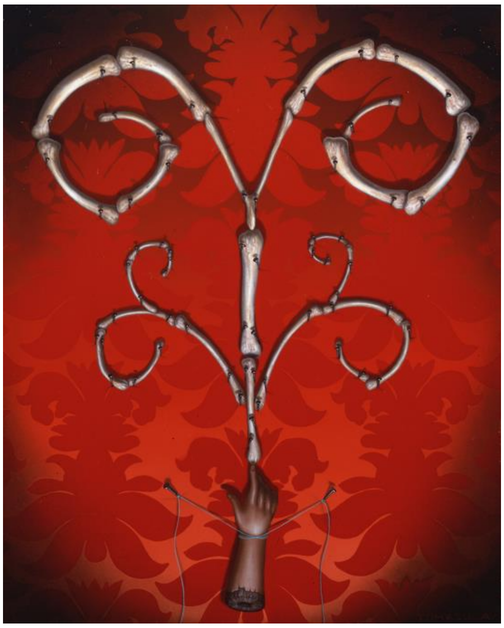

Figure 2. Tomasula, *Recure*, 2002 oil on panel, 16 x 14". (l)
Figure 3. Tomasula, *As No Gives Way to Yes*, oil on panel, 10 x 8". (r)

As No Gives Way to Yes of 2002 (Figure 3) has no living entities, being composed of a broken doll's hand that is tied to the wall and placed below an alignment of bones each nailed against the back. Yet the painting seems animated with the touch of the finger apparently causing life and activating the bones to create a burst of spirals. This illusion is made possible only because of the sumptuous orange backdrop with leafy decorations. Both *As No Gives Way to Yes* and *By Hands Unknown* are based on a well-known religious representation of Mano Poderosa, the All-Powerful Hand. In the traditional work, the mighty hand of God which is simultaneously the pierced hand of Christ that is topped by the tiny Figures of Christ, Joseph and Mary, and Mary's parents. This was the ultimate symbol of power that the believers prayed to for healing, protection, and action. Such power is invoked in Tomasula's paintings too, but not by means of an overwhelming, dominating hand, but by means of conspicuous, intense colours.

Tomasula first applied sensational colours to transmute the mundane still life pieces into spiritual vessels, but then began to imply meaning directly through colours that were shaped by her new philosophical standing. She came to believe in the doctrine of immanence through her perusal of Baruch Spinoza and Gilles Deleuze, who advocated the presence of God or a being or a force not as transcendent, but immanent within the material realm. In the seventeenth century, Spinoza caused great uproar in the Netherlands through his declaration that God is synonymous with nature in his famed publication, *Ethics*. This equation dispenses with the anthropomorphism of God and accepts him as an inherent force that permeates all matter.

Figure 4. Tomasula, *The Music of Chance*, 2004, oil on panel, 24 x 18”. (l)
Figure 5. Tomasula, *Claim*, 2004, oil on panel, 14 x 11”. (r)

Music of Chance of 2004 (Figure 4) intimates a supernatural potence within and without an enticing hanging plant composed of a sepal and petals of different irises strung together. The illuminated colours that transition from reds to yellow and white do not appear to be externally applied, but instead seem to stream out of this flower, producing even a halo effect around it. As a result, an energy source is assumed within, affecting the collaged bloom to stand tall and even other plant segments grafting onto it below to extract nutrients. To speak for the ever-expanding force that is permeating through the entire space are the numerous tiny light dots that are rising from the flower and spreading in all directions in the air.

In *Claim* of 2004 (Figure 5), the gleaming particles this time descend from above, landing as dew drops on the magnificent pinkish white stargazer lily with pronounced dark pink guide lines and speckles. While hanging literally by fragile threads, the cut flower nevertheless exudes confidence and potency, relayed through the invigorating colours. A force is connoted in the spatial backdrop as well, with the changing hue of blues insinuating a far-reaching depth.

Such direct use of colours to signify an innate vigor is explained by Deleuze. This twentieth-century French philosopher declared his allegiance to Spinoza and developed his own theories on the imminent existence of being in all matter that includes the inorganic. Deleuze also wrote extensively on the arts, notably in *What Is Philosophy?* which is written with Félix Guattari, and *Francis Bacon: the Logic of Sensation*, in which he elevates art as a special conduit whereby a plenary force is made visible through the materiality of art production. According to him, an artist is essentially a cosmic artisan, who is capable of seizing the non visible élan through sensation (1994: 171, 182). And of all the means of the artist, Deleuze stresses, colour foremost embodies sensation that harnesses the invisible existence (1994: 181-82; 2002: 121). Tomasula subscribed to these ideas of Deleuze: following his logic, she has captured the cosmic force through sensation, which is released on the panel through art making, notably through colours, which indeed infuse an undeniable energy into the images.

The artist's interest in ontology eventually led to New Materialism, the twenty-first posthumanist philosophy that promotes agential materialism, believing all matter to be vital and interconnected. Much of its theories are grounded in the ideas already expounded by Spinoza and Deleuze. It acknowledges all the forerunners of its stance but emphasizes the "material turn" that is driven by the primacy of the material.

The inherent inseparability of all forms is the major theme of Karen Barad's groundbreaking publication, *Meeting the Universe Halfway. Quantum Physics and the Entanglement of Matter and Meaning*. Trained as a quantum physicist, Barad analytically explains the phenomenon of diffraction, where sound, light, and water change from the projected course due to obstructions and slits, such as waves spreading around or bending over a rock. She concludes that all particles essentially interact with such wave activity and the constant reconfiguration of the boundaries disrupts the limits of the individual properties of materials, thereby confirming the fundamental inseparability of all entities. Barad sees this diffraction phenomenon as a pre-existing active process, thereby undergoing "intra-action," where fragments merge to form a unit, instead of "interaction," which implies already intact substances coming together (2007: 132-85). The intra-activity produces an ever-entanglement of all matter.

When I Was You of 2014 (Figure 6) demonstrates intra-action through a contraption of twisted bird heads, an opened cantaloupe with drooping seeds, dangling flowers and small milagro legs and hands all connected by nails and strings. The usual suspension of the objects is made far more evident in this work, suggesting movement. Even the encircled twigs that mimic a crown of thrones imply circular motion. Vivacity and dynamism are further accentuated through the saturated colours within each segment as well as through the arresting splash of diluted reds and purples across the wall. This illogically entangled concoction is an active agent of life.

Figure 6. Tomasula, *When I Was You*, 2017, oil on panel, 42 x 42”. (l)
Figure 7. Tomasula, *Echo*, 2016-18, oil on panel, 20 x 16”. (r)

While the historical Materialism conceived matter as inert, intact, controllable substances, New Materialism views matter as inherently vital, animated, and regenerative. This is the core message of Jane Bennett, whose *Vibrant Matter* advances the notion of “enchanted materialism,” where all the material agents have capacities to change and organize, as they constitute the “thing-power” within (2010: xvi).

The thing-power is connoted in another work of the artist, *Echo* of 2016-18 (Figure 7), where the disparate elements are densely compacted. A piece of fresh meat forms the core to which an oval turquoise is added at the top, flanked by a pair of milagro hands on the sides, while a multitude of unrelated items are assembled and overlap: flowers, plants, a pear, a mushroom, a wooden piece, a bird, insects, seeds, and opaque as well as crystallized stones. They are tightly placed to compose a pyramidal unit, yet each one of them is very identifiable due to the distinct vibrant colours and textured surfaces, which repackage the still substances as enchanted agents of life.

Tomasula’s hyperrealist, Neo-Baroque paintings are no ordinary still lifes. The most trivial objects are transformed into magical talismans capable of transmitting transcendental experience, embodying an encompassing innate force as well as exuding a sense of life in each entity, whether organic or inorganic. And the invisible presence or energy, albeit channeled from different frameworks and objectives, is communicated through the powerful use of arresting colours. The artist grew up with spectacular colours, knew their potency and learned to unleash it in her own creations. Her colours are attractive and embellish the images, but more importantly empower them to connote a force beyond the surface value of the paintings. The sensational colours of Tomasula are a thing-power themselves.

References

Barad, K. 2007. Meeting the Universe Halfway. *Quantum Physics and the Entanglement of Matter and Meaning*. Durham: Duke University Press.

Bennett, J. 2010. *Vibrant Matter. A Political Ecology of Things*. Durham: Duke University Press.

Bennett, J. 1984. *A Study of Spinoza's Ethics*. Indianapolis: Hackett.

Curley, E., ed. 1994. *A Spinoza Reader*. *The Ethics and Other Works*. Translated by E. Curley. Princeton: Princeton University Press.

Deleuze, G. 2002. *Francis Bacon: The Logic of Sensation*. Translated by D. Smith. Minneapolis: University of Minnesota Press.

-- -- and F. Guattari. 1994. *What Is Philosophy?* Translated by H. Tomlinson and G. Burchell. New York: Columbia University Press.

Dolphijn, R., and I. Tuin. 2012. *New Materialism: Interviews & Cartographies*. Ann Arbor: Open Humanities.

Ellenzweig, S., and J. Zammito. 2017. The New Politics of Materialism. History, Philosophy, Science. New York: Routledge.

Forum Gallery. 2003. *Maria Tomasula: Second Nature*. Essay by D. Maxwell. New York: Forum Gallery. Exhibition catalogue.

-- --. 2004. *Maria Tomasula: Vast*. Los Angeles: Forum Gallery. Exhibition catalogue.

-- --. 2018. *Maria Tomasula: All the Breath We Can Hold*. Essay "Maria Tomasula's Art of Immanence" by S. Kang. New York: Forum Gallery. Exhibition catalogue.

Micaela Giovannotti, M., and J. Korotkin. 2005. *Neo-Baroque!* Milan: Charta. Exhibition catalogue.

Kang, S. 2018. Embedded Still Lifes: Mexican American Heritage in the Art of Maria Tomasula. *Journal of Contemporary Painting* 40, no. 2: 363-380

-- --. 2019. Flowers Disguised: Woman's Voice through the Catholic Tradition in the Art of Maria Tomasula. *Religion and the Arts* 23: 100-123.

Tomasula, M., and J. Farstad. 2002. Word for Word: Artists and Their Influences Trade Tape. *Mouthtomouth*. http://mouthtomouthmag.com.

Zolla/Lieberman Gallery. 2000. *Maria Tomasula: Accretion*. Essay "Fire and Ice" by J. Yood. Chicago: Zolla/Lieberman Gallery. Exhibition catalogue.

-- --. 2005. *Maria Tomasula: Meridian*. Essay by J. Brunetti. Chicago: Zolla/Lieberman Gallery. Exhibition catalogue.

A History of Azo Pigments – for Color in all Applications

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Abstract:

An important chemical bond existing in many organic pigments often used in paint applications is called the *"azo"* chromophore. Johann Peter Griess discovered the first *azo* compound in 1858. His discovery subsequently resulted in the multi-billion-dollar industry we know today! The first synthetic *azo* pigments of commercial significance were manufactured over 100 years ago. Since that time, several different classes of azo pigments have been discovered and mass produced for use in all types of coatings including liquid (aqueous & non-aqueous), powder, automotive, industrial, road markings, and many other special applications. Even today, work goes on to develop *azo* pigments representing new unique chemical structures.

This paper will discuss the beginnings of *azo* chemistry. Different classes of azo pigments commonly used today in the worldwide coatings industry. Starting raw materials, pigment synthesis, processing, and finishing to be briefly covered. Examples of how chemical and physical differences of pigments can affect their overall performance properties in polymers will also be illustrated. Finally, some recent developments in *azo* pigment chemistry, and the current and future role of azo pigments in coating applications of plastics will be discussed.

Session 11
Colour Science - II

Measuring Display Observer Metamerism

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Abstract

Observer metamerism refers to a situation in which some observers with normal color vision see two colors as identical while others see them appear mismatched. In recent years, some issues with metameric failure have been exacerbated by displays with more saturated primaries and narrower emission spectra. Classic trichromatic colorimetry cannot predict this effect because of the typical reliance on a single standard observer – a Color Matching Function (CMF) averaged across the population. In this paper, we present a new experiment that uses unique hues as an intrinsic reference to measure the amount of metameric failure of a single display for real observers without comparisons to other reference displays.

Keywords: *Observer metamerism, Unique hues*

Introduction

Metamerism is a property of the human visual system (HVS) that allows colors with different spectra to visually match as long as they cause the same responses in the HVS. Such spectra are known as metamers or metameric pairs. Metamerism is caused by the fact that each of the three cone cell types (long-, medium- and short-wavelength sensitive) in the eye can be excited by photons spanning a wide range of wavelengths, with the probability of photon capture determined by the optical, chemical, and physiological properties of individual components of the HVS. As long as the different spectra cause the same excitations in all cone types, they will match under the same viewing conditions. Metamerism allows display devices to reproduce colors accurately without requiring identical spectral power distributions (SPDs) between the reference color and its reproduction. To determine which spectra are metamers, color matching functions (CMFs) are used that map the spectral radiance of perceived light into a trichromatic representation. The most commonly used CMFs are CIE 1931 Standard Colorimetric Observer.

Observer metamerism could be assessed via a psychophysical experimental procedure with a real observer with normal color vision. While in color-critical applications, the CMFs of individual observers can be measured and compensated for, this process is time-consuming and must be repeated for each observer. In situations where approvals across multiple observers and devices are expected, it might be preferable to instead use displays that minimize the perceivable differences resulting from observer metamerism.

A common problem with experiments trying to establish the amount of OM induced by a display is that any such attempt relies on the use of a reference color, usually provided on a separate display or as a hardcopy, whose appearance is matched on a tested display. However, the test spectra used as reference vary between the experimental setups, and their influence affects the test results, reducing its generality. The chosen spectrum can be considered to act as a bias in the experiment, and therefore the results from different experiments are not interchangeable.

In this paper, we present a new experiment, without comparisons to other displays, to measure the amount of metameric failure of a single display for real observers by using unique hues as intrinsic reference. This is because the variations in selecting unique hues are mainly independent of the sensitivity (CMFs) differences across observers (Webster,2000), and the encoding of unique hues happens at high-order color mechanisms (Wuerger,2005). Therefore, the authors came up with a hypothesis that the observer variability when selecting unique hues in the display is related to three aspects: observer noise, unique hue differences across observers, and observer metamerism. We assume the observer noise, as well as the unique hue difference across observers, are the same, and any increase in observer variability is due to observer metamerism.

Unique hues experiment

Five displays (display #1, #3,#4,#5,#6) which use different display technologies, were selected for the experiment. The observers also selected four unique hues from the Farnsworth Munsell 100-hue test for color vision deficiencies color plates (display #2) under simulated D65 lighting conditions.

Three 1D look-up tables (LUTs) were used to characterize the displays (Day et al., 2004). The characterization results were then verified using a set of test patches. Table 1 shows the minimum, mean and maximum CIEΔE2000 prediction accuracy measured on the four displays for 216 random verification colors.

The characterization results all met the accuracy level of our subsequent psychophysical testing, with the exception of the Display4, which is expected of a consumer-grade display. However, these LUTs were still used when rendering colors in the experiment. To ensure the accuracy of the experimental results, unique hues chosen on Display4 by the experiment participants were measured with a spectroradiometer during the investigation rather than relying on the characterization results.

Statistic	Display1	Display2	Display3	Display4
Mean	0.54	0.35	2.05	8.61
Minimum	0.14	0.04	0.38	0.28
Maximum	1.04	1.21	4.92	38.70

Table 1. Characterization accuracy (CIEΔE2000) of LUTs model for each display.

Experimental Stimuli and Procedures

The experiment was conducted in a dim environment with a D65 ambient light source positioned behind the displays. This was determined to help stabilize adaptation and improve observer precision in pilot experiments. The experiment user interface (UI), which was designed in MATLAB, is shown in Figure 1. Each stimulus was displayed in the center of the screen, overlayed over a luminance noise background. The observers were seated in front of the display at a distance such that each color stimulus covered 2° of visual angle.

In the first part of the experiment, observers were asked to select unique hues on display. Using the arrow keys on the keyboard, viewers adjusted the hue angle of a randomized color patch, with a fixed lightness and chroma value, until the desired unique hue was achieved. Table 2 lists the chroma (C* from CIELAB L*C*h) and lightness (L* from CIELAB) values of the color patches shown on each display. Two chroma (C*) values, high and low, were created for Display1 in order to verify the relationship between chroma and unique hue angle. Each observer made 36 selections - 4 different hue hues, each with nine repetitions.

In the second part of the experiment, observers selected unique hue colors from a set of physical samples. The observers selected four unique hues from Farnsworth Munsell 100 (FM-100) hue test for color vision deficiencies. The color plates were viewed under simulated D65 lighting in a Macbeth Spectralight booth, with each observer making 36 selections - 4 unique hue colors, each with 9 repetitions.

Ten observers (four female and six male) participated in the experiment. One observer was unable to complete the psychophysical experiment on Display4. All observers were evaluated to have normal color vision. Four of the ten observers were color science experts, and the others were naïve observers.

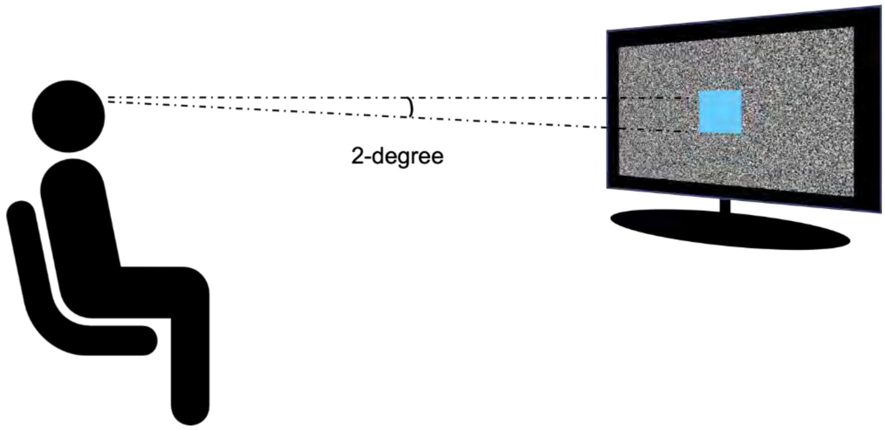

Figure 1. The setup of the psychophysical experiment. Color stimuli were shown on display against a noise background. Observers were sitting in front of the display and using the keyboard to change the color. The test patches spanned a visual angle of 2 degrees.

	Red(C*/L*)	Green(C*/L*)	Yellow(C*/L*)	Blue(C*/L*)
Display1 (high chroma)	90/53	60/80	80/75	40/74
Display1 (low chroma)	25/53	25/80	25/75	15/74
Display2	90/53	60/80	80/75	40/74
Display3	80/58	60/80	60/86	40/67
Display4	75/50	30/85	75/80	30/85

Table 2. Chroma and lightness value of five different display experiment sessions. C* and L* are CIELAB L*C*h chroma and lightness respectively, relative to the actual display white point (nominally D65). HC: High chroma and LC: Low chroma.

Experimental Results

Figure 2 shows the violin plots of unique hue selections (hue angle from CIEL*C*h) across the display. However, we can't expect that individual differences in unique hue perception would serve as a metric of metameric stability of a display because of no clear relationship between observers' variation and display.

A two-way ANOVA was used to determine whether observers and displays affect the selection of unique hues. Table 3 describes the result of ANOVAs. We could determine that observers, different types of displays, and interactions affect all the unique hue selection.

The above analysis (both violin plot and ANOVAs) would let us closely investigate the Intra- and Inter-Observer variations. The Intra- and Inter observation values (shown in Figure 3) identified that the within-individual variation (observer noise) in setting a unique hue in this experiment is more significant than the variation between observers. In other words, the differences from the same observer conducting the same experiment multiple times are higher than the differences measured between the different observers.

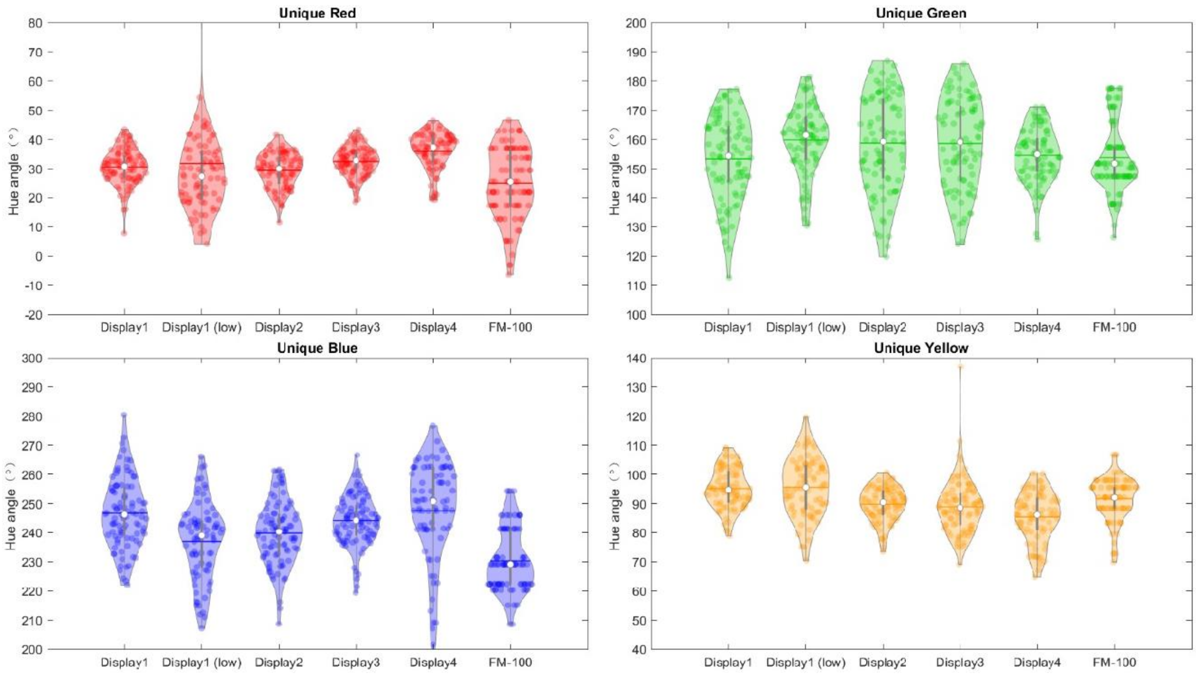

Figure 2. Violin plots of the hue angle from CIEL*C*h for each unique hue selection.

Source	SS	df	MS	F	Prob>F
Observer (UR)	10850.6	8	1356.33	50.15	<0.001
Display (UR)	5038.8	5	1007.76	37.26	<0.001
Interaction (UR)	10038.5	40	250.96	9.28	<0.001
Observer (UG)	43592.9	8	5449.12	81.72	<0.001
Display (UG)	3508.4	5	701.68	10.52	<0.001
Interaction (UG)	15455.5	40	386.39	5.79	<0.001
Observer (UB)	16334	8	2041.75	25.4	<0.001
Display (UB)	19424.3	5	3884.87	48.32	<0.001
Interaction (UB)	20118.3	40	502.96	6.26	<0.001
Observer (UY)	5646.7	8	705.83	17.08	<0.001
Display (UY)	6010.6	5	1202.11	29.09	<0.001
Interaction (UY)	6871.4	40	171.78	4.16	<0.001

Table 3. Statistical significance of the effect of the independent variable (observer and display) on the dependent variable unique hue

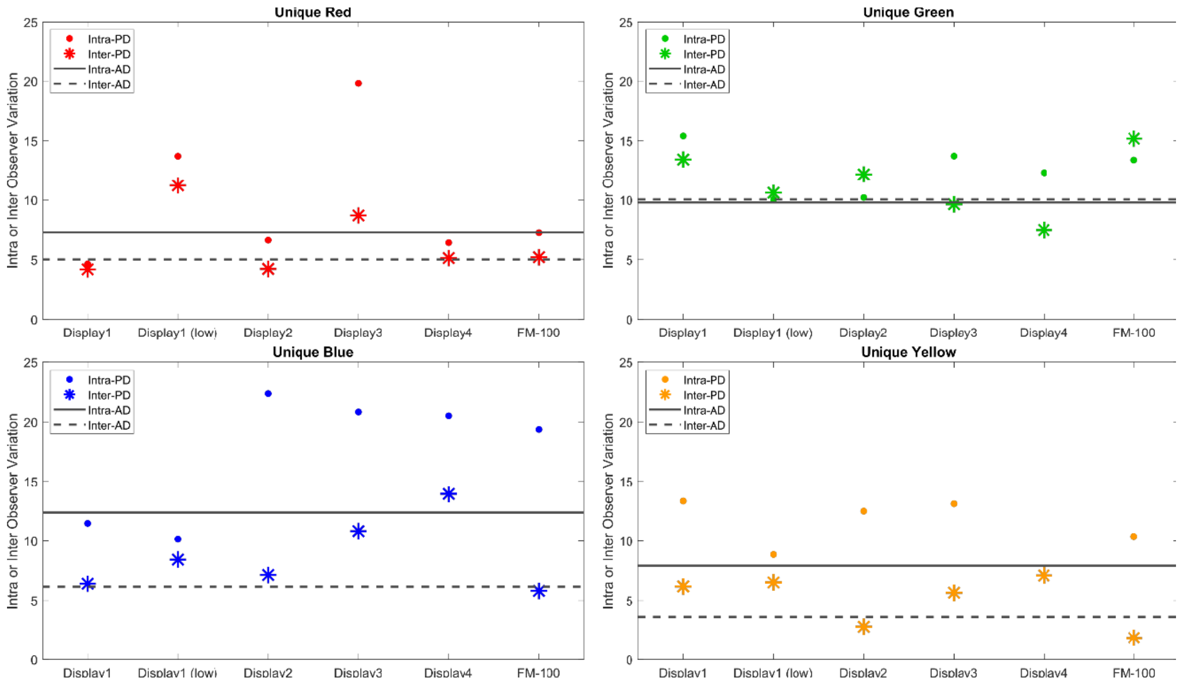

Figure 3. Intra- and Inter observer variation value per/across the display (PD: per display; AD: across the display).

Unique hues experiment

This research suggests that the proposed approach cannot be used to measure the added variation due to observer metamerism. To use the technique, we need the individual variation in the setting to be lower than the variation between observers. Because the opposite is true, separating the experimental noise from the individual observer differences is impossible. Based on our results, detecting observer metamerism in chromatic colors when displays are viewed individually with no reference stimuli remains a difficult task.

Acknowledgements

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References

Webster, M. A., Miyahara, E. Malkoc, G, and E. Raker, V. E.. "Variations in normal color vision. II. Unique hues." *JOSA A* 17, no. 9 (2000): 1545-1555.

Wuerger, S. M., Atkinson, P., and Cropper, S. "The cone inputs to the unique-hue mechanisms." *Vision Research* 45, no. 25-26 (2005): 3210-3223.

Day, E.A., Taplin, L., and Berns, R.S. "Colorimetric characterization of a computer-controlled liquid crystal display." *Color Research & Application* 29, no. 5 (2004): 365-373.

Quantifying and Evaluating Colour Appearance Models based on Helmholtz Kohlrausch Effect

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Abstract

The brightness sensation of a colour source depends in part on colour purity, and this colour appearance phenomenon is defined as the Helmholtz-Kohlrausch effect. With the recent advancement in HDR and WCG displays, greater brightness and contrast will make the Helmholtz-Kohlrausch effect more noticeable. An experiment using magnitude estimation was conducted to evaluate the Helmholtz-Kohlrausch effect. Twenty-one observers participated in the experiment and judged the brightness of the test colour samples in relation to achromatic samples. Saturated colour samples were judged by the observers with high brightness values as compared to less saturated colour samples with the same luminance, and a small deviation in observers' predictions of lightness was observed on chromatic backgrounds. The performance of several existing colour appearance models was investigated. The lightness values predicted by CAMs on all backgrounds were lower than perceptual lightness values returned by the observers. CAMs were quantitatively assessed based on CV statistics showing higher variations between predicted lightness values and the observers' perceptual lightness judgements. In addition to lightness, the chroma channels were also shifted in the case of CIECAM02, CAM16 and $Jzazbz$. However, in $ICtCp$ chroma shift was minimal because of decorrelation between achromatic and chromatic components due to constant luminance.

Keywords: *Helmholtz-Kohlrausch effect, Colour appearance, Magnitude estimation, Brightness*

Introduction

The CIE (2020) defines lightness as brightness of an area assessed in relation to the reference brightness of similarly illuminated white or highly transmitting areas. As well as luminance, colour purity of an object or light source also influences perceived brightness for samples of equal luminance. Helmholtz was the first to notice the effect of colour purity on brightness, and Kohlrausch was the first to explore it experimentally (in Fairchild (2013)). The Helmholtz-Kohlrausch (H-K) effect is a colour sensation phenomenon in which a coloured object appears brighter than less saturated objects of equal luminance values

(Donofrio (2011); Fairchild (2013); Withouck et al. (2014)). Wyszecki and Stiles (1982) showed through contours of brightness-to-lightness ratio with constant luminance that perceived brightness not only increases as the colour purity increases despite having the same luminance intensity, but it also has hue dependent properties. Efforts have been made in the past to compensate for the H-K effect. CIE TC1-03 (1986) recommended a brightness-lightness conversion factor based on Ware and Cowan's work. Fairchild and Pirrotta (1991) showed that the H-K effect also exists for related colours and provided a well-fitted model that adjusted the CIE L* lightness metric to account for the H-K effect. Kim et al. (2019) proposed a solution to correct for the H-K effect in CIECAM02, by incorporating Fairchild and Pirrotta's equation, which was previously used for compensating H-K effect in the CIELAB colour space.

Nayatani (1997) proposed variable-achromatic-colour (VAC) and variable-chromatic-colour (VCC) methods of adjustments for quantifying the H-K effect. In case of VAC, achromatic test samples are adjusted to match chromatic references. Conversely, chromatic samples are matched with a reference white in case of VCC. Fairchild and Pirrotta (1991) employed the VAC method to adjust an achromatic stimulus to match different Munsell patches in a viewing booth. High and Green (2021) used both VAC and VCC methods of adjustment in order to quantify the impact that the H-K effect has on the appearance of near-white paper colours.

The magnitude estimation strategy was adopted by Luo et al. (1991a), in which observers were asked to estimate the magnitudes of several perceptual attributes like lightness, colourfulness, and hue. Luo et al. (1991b) then examined multiple colour appearance models based on lightness, colourfulness, and hue attributes under a wide range of viewing conditions based on the psychophysical experiment conducted in their previous study. For judging the brightness of multiple unrelated, self-luminous stimuli set against a dark background and for investigation of the H-K effect on an AMLCD display, Withouck et al. (2014) and Kim et al. (2019) also used magnitude estimation to derive perceived lightness from observer judgements.

Recent colour appearance models predict a wide range of colour appearance attributes based on the optimization and evaluation of different experimental data. However, the H-K effect is largely neglected in colour appearance models. In display applications, this could be due to the colour saturation represented by legacy display devices being limited due to previously smaller available colour gamuts. However, Kim et al. (2019) recorded the H-K effect using a liquid crystal display (LCD) with a colour gamut similar to the sRGB standard. Currently, consumer displays are achieving a peak luminance of 500 cd/m^2, while some high-end displays on the market can achieve a peak luminance of more than 1000 cd/m^2 Nilsson (2015) and to satisfy 90% of viewers, the dynamic range should be from 0.005 cd/m^2 to 3000 cd/m^2 for the diffuse white according to the study by Dolby (in Daly et al. (2013)).

Dependence on chromatic backgrounds for the perception of lightness attribute was investigated by Wyszecki and Sanders (1957). In this study, in addition to a neutral background, two colour backgrounds were used to find whether simultaneous contrast has an influence on the H-K effect.

In this present paper, colour appearance models (CIECAM02, CAM16, Jzazbz and ICtCp) are evaluated based on the H-K effect, and magnitude estimation is used to quantify perceived lightness relative to a set of achromatic reference patches.

Psychophysical Experiment Layout

Our subjects evaluated and quantified the lightness of the test colours compared to the achromatic reference samples. Colour patches were placed in the upper middle section of the screen, and the achromatic patches featuring lightnesses from L*=35 to L*=100 (relative to the display white point, and at an interval of 10 L* units) were placed below the chromatic test sample as shown in Fig. 1. The reference achromatic patches remained unchanged during the whole experiment.

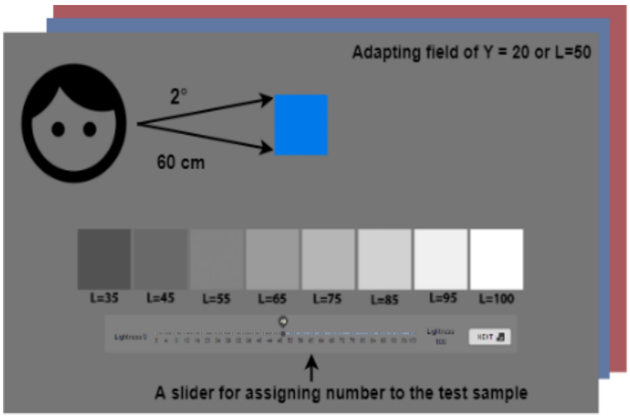


Figure 1. Depicts the overall layout of the psychophysical experiment.

The test colour samples were shown randomly on a background with lightness of L*=50. A slider was used to assign value to the test samples in relation to the achromatic patches with minimum and maximum values of [0-100].

Main Experiment

The experiment was divided into three parts, with 20 samples being shown randomly on each of three backgrounds (grey, red, and blue). Detailed instructions were given to observers before performing the experiment. 15 male and 6 female normal colour vision observers took part in our psychophysical experiment. The average age of the subjects was 25.85 years. All subjects were familiarized with the proposed method of judgement. Additionally, before performing the main experiment a short training session was conducted to make observers familiar with the experiment.

The test colour samples were selected along 4 hue angles (at approximately 27°, 90°, 153°, 274°) and colours were sampled at 5 chroma levels (with C* of around 15, 30,50,60 and 70). A constant lightness value of L*=50 was used for creating all the test samples in our experiment. A total of 80 colour stimuli were used, with 20 test colour samples used for the training session part, and the remaining colour samples were divided into three parts for the three backgrounds. We verified that all the saturated test colour samples were within the display's colour gamut to avoid any possible gamut clipping. Colour patches were created by converting LCh values to XYZ and then to display RGB using a D65 illuminant as the adapting white point. Test samples are listed in Table 1.

		Test Patch			Observed Lightness				Interobserver variability Std.Dev		
S.No	Colour centers	L*	C*	h_{ab}	Red BG	Grey BG	Blue BG	Mean Lightness	Red BG	Grey BG	Blue BG
1	Blue	50	69	277	91.60	91.35	91.60	91.51	6.01	8.45	12.74
2	Green	50	73	156	85.05	78.35	78.30	80.56	15.18	11.94	12.38
3	Red	50	71.23	29	81.65	78.70	85.45	81.93	15.27	17.07	16.66
4	Yellow	50	65	92	62.55	62.45	68.45	64.48	20.05	17.72	15.66
5	Blue	50	58	274	87.45	83.55	82.00	84.33	8.07	12.57	14.99
6	Green	50	65.89	149	77.60	70.40	71.10	73.03	13.00	16.85	14.77
7	Red	50	62	27	72.85	77.70	79.75	76.76	17.53	15.05	13.78
8	Yellow	50	59.71	88.4	59.60	59.50	65.25	61.45	18.61	17.32	15.07
9	Blue	50	46.26	271	78.20	72.95	69.15	73.43	9.94	14.26	14.41
10	Green	50	48.61	155	68.85	59.65	62.50	63.66	10.91	12.19	12.34
11	Red	50	53.4	26	53.35	67.95	75.05	65.45	16.53	16.06	12.28
12	Yellow	50	47.03	90	59.40	55.40	65.55	60.11	13.56	13.12	15.26
13	Blue	50	31.87	273	70.00	61.90	56.85	62.91	12.04	11.36	11.46
14	Green	50	32.5	153	60.95	54.65	54.65	56.75	8.96	10.82	10.42
15	Red	50	30.33	25.5	56.20	57.10	63.05	58.78	14.31	10.76	13.10
16	Yellow	50	31.5	89.4	56.05	53.50	61.20	56.91	13.63	14.03	10.93
17	Blue	50	15.2	274	55.50	53.45	52.35	53.76	10.22	11.69	12.67
18	Green	50	13.6	153	56.50	50.40	51.45	52.78	8.31	11.08	10.03
19	Red	50	15	25	50.75	51.45	56.60	52.93	8.26	8.13	7.85
20	Yellow	50	15.87	93.5	55.00	49.85	57.25	54.03	11.90	6.98	8.62
	Average Std.dev for three backgrounds								12.77	12.87	12.61

Table 1. Test colour samples with observed lightness and interobserver variation based on standard deviation on three backgrounds.

The experiment was conducted on an EIZO 279X-BK IPS display panel. The display was calibrated and profiled with a D65 white point at a target luminance of 160cd/m^2. The experiment was performed in a darkened room, and the experiment layout was shown normal to the observer's resting line of sight at a distance of 60 cm. Test patches subtended a visual angle of 2° from the observer.

Results and Discussion:

Overall, observers judged higher lightness for high chroma samples as compared to less saturated samples with an equal colorimetric lightness of L* =50. The mean visual lightness results are plotted in Fig. 2. The mean interobserver standard deviation of 21 observers on all the three backgrounds was 12.75. Fairchild and Pirrotta (1991) quantify H-K effect in physical samples using VAC and got mean interobserver standard deviation of 4.2, while High and Green (2021) using both VAC and VCC with a display recorded a mean standard deviation of 5.85 and 7.37 respectively. This indicates that judging visual lightness on a display system using magnitude estimation leads to greater uncertainty than method of adjustment and is thus a harder task for observers to perform. Additionally, observers performed more consistent judgments using physical samples as compared to samples shown on displays. The reason could be the self-luminous property of digital display. Another explanation is that physical samples such as Munsell patches have broad spectral reflectance curves, whereas displays tend to use narrow band primaries. This is known to accentuate observer metamerism, particularly when using WCG displays.

The results in Table 1, are also consistent with simultaneous contrast, and in agreement with the Wyszecki and Sanders (1957) results. Green patches are judged consistently brighter on the red background, whilst yellow patches are judged consistently brighter on the blue background. This is also reflected in the average lightnesses shown in Fig 3. Where red patches appear darker on the red background than on the grey background, and blue patches appear darker on the blue background than on the grey background.

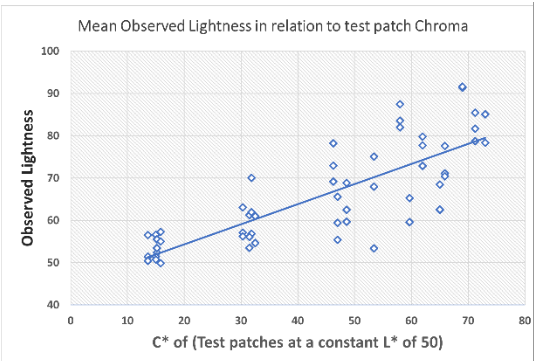


Figure 2. Observed lightness plotted against Chroma for all three backgrounds with a linear fit trendline.

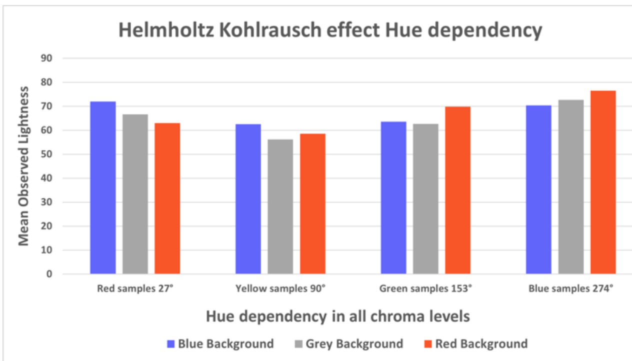


Figure 3. Represents H-K hue angle dependency in mean observed lightness at all chroma levels.

Hue-dependency was also seen in observed lightnesses at different hue angles, as shown in Fig .3. Mean observed lightness at all chroma levels in case of the yellow hue is scaled comparatively lower than the other three hues (red, green, blue), as has been reported in previous studies (please see Fairchild and Pirrotta, 1991; Wyszecki and Stiles, 1982; High and Green, 2021).

Visual Evaluation and Comparison:

Appearance co-ordinates predicted by the CAMs are visualized in Fig 4. The test colour patches in Table 1 are compared with samples featuring a modified lightness attribute derived from observer magnitude estimation. It can be clearly seen that all the models do not predict the increase in lightness that the visual observations would indicate as the saturation of the test colours is increased.

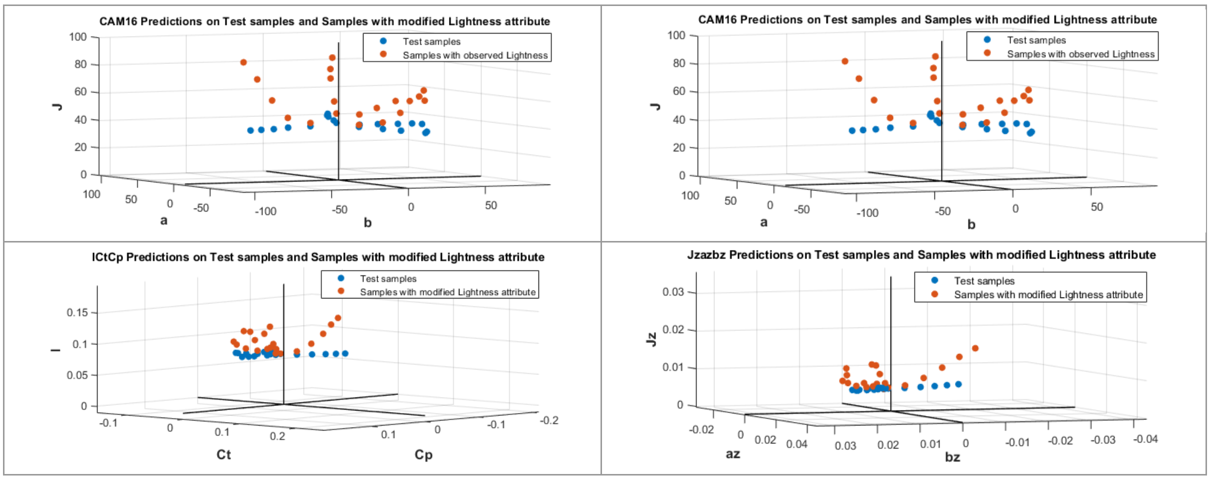
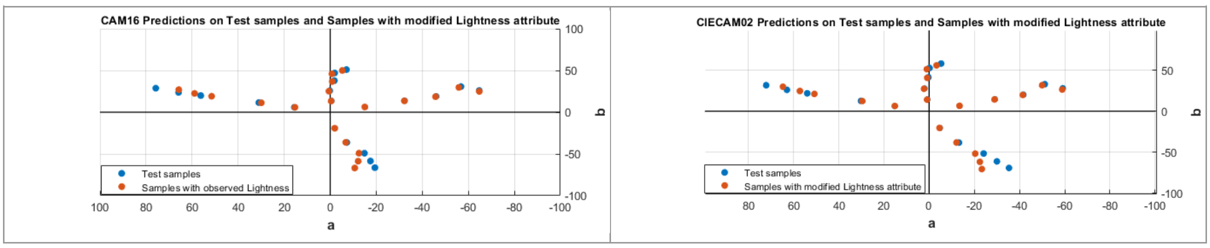


Figure 4. Row 1 specify CAM16 and CIECAM02 predictions while Row 2 represents ICtCp and $Jzazbz$ predictions.

One other interesting thing which is observed is that the chromaticity of the modelled samples with modified lightness attribute derived from observations shift away from the test samples of high chroma test colours. $Jzazbz$, CIECAM02 and CAM16 models show a greater shift in chromaticity at all four hues as shown in Fig 5. $ICtCp$ predictions show a smaller shift in chromaticity due to the property of constant luminance which provides better decorrelation between chromatic and achromatic components (in ITU (2018)).



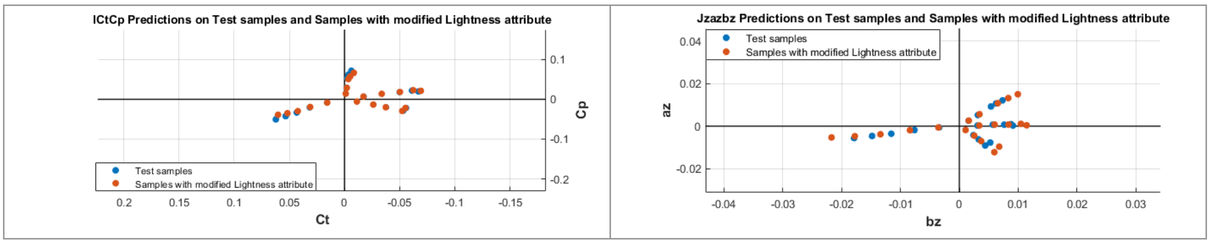


Figure 5. Row 1 specify CAM16 and CIECAM02 predictions while Row 2 represents $ICtCp$ and $Jzazbz$ predictions.

Statistical Evaluation of CAMs based on CV

The selected CAMs were assessed by calculating Coefficient of Variation which is a statistical metric, and it is used here for evaluating and finding the agreement between predictions of CAMs on actual test stimuli and the observer's visual observations of equivalent achromatic luminance of those test samples. For CIECAM02 and CAM16, an average surround with parameters, F=1.0, c=0.69 and Nc=1.0 and an adapting luminance of 160 cd/m^2 with background luminance Yb =20 was used.

Models	CV in Gray Background	CV in Red Background	CV in Blue Background
IC_tC_p	29.001	31	30.54
Ja_zb_z	44.63	47.72	44.95
CIECAM02	36.1	37.86	38.32
CAM16	34.85	36.34	36.76

Table 2. CAMs performance based on coefficient of variation. Lower CV indicates better performance.

Overall, the CV was high for all the colour appearance models used under this study which confirms that none of the models are compensating for the H-K effect (please see Table 2). However, $ICtCp$ showed lower coefficients of variation on all three backgrounds as compared to the other models. The difference in CV values between CAMs is due to the shift which is observed in chroma channels mentioned in Fig .5. $Jzazbz$ and then CIECAM02 and CAM16 showed higher shifts in chromaticity of high chroma colours. In case of $ICtCp$ the Chroma shift was least due to the use of a crosstalk matrix which makes the model near constant luminance, providing strong decorrelation between chromatic and achromatic channels.

Conclusion:

WCG and HDR are becoming commonplace in the display industry. Recent devices display higher brightness and contrast, and this trend will likely continue. As a result, in order to expand the usability of colour appearance models as a standard for describing WCG and HDR display systems, compensating for the H-K effect becomes a critical topic that requires thorough investigation. In this study recent colour appearance models' performances were examined based on the H-K effect. A psychophysical experiment was conducted using magnitude estimation. The observers estimated high chroma test samples to have higher perceived lightness as compared to the less saturated test colour samples with an equal colorimetric lightness L* of 50. Hue dependency was also observed in observer judgements. CV statistics showed that none of the colour appearance models compensate for the H-K effect. Apart from the error in lightness attributes, the chromaticity of samples having a modified lightness attribute (derived from observer magnitude estimation) was shifted. However, a smaller shift in chromaticity was observed in $ICtCp$ predictions due to its constant luminance attribute. It is important to integrate proper parameters specific to the H-K effect in colour appearance models.

References:

CIE. 2020. CIE S 017/E:2020: ILV: International Lighting Vocabulary, 2nd Edition. Vienna: International Commission on Illumination (CIE).

Daly, S., T. Kunkel, X. Sun, S. Ferrell, and P. Crum. 2013, June. 41.1: Distinguished paper: Viewer preferences for shadow, diffuse, specular, and emissive luminance limits of high dynamic range displays. In *SID Symposium Digest of Technical Papers* (Vol. 44, No. 1, pp. 563-566). Oxford, UK: Blackwell Publishing Ltd.

Donofrio, R.L. 2011. Review Paper: The Helmholtz-Kohlrausch Effect . *Journal of the Society for Information Display*, *19*(10), pp.658-664.

Fairchild, M.D. 2013. *Color appearance models.* 3rd ed. Chichester, UK: John Wiley & Sons.

Fairchild, M.D., and E. Pirrotta. 1991. Predicting the lightness of chromatic object colors using CIELAB. *Color Research & Application*, *16*(6), pp.385-393.

High, G., and P. Green. 2021. The impact of the Helmholtz-Kohlrausch effect on the appearance of near-white paper colours. In *Color and Imaging Conference* (Vol. 2021, No. 29, pp. 241-246). Society for Imaging Science and Technology.

Kim, M., J.H. Jo, Y. Park, and S.W. Lee. 2019. Amendment of CIECAM02 with a technical extension to compensate Helmholtz-Kohlrausch effect for chromatic characterization of display devices. *Displays*, *56*, pp.1-10.

Luo, M.R., A.A. Clarke, P.A. Rhodes, A. Schappo, S.A. Scrivener, and C.J. Tait. 1991. Quantifying colour appearance. Part I. LUTCHI colour appearance data. *Color Research & Application*, *16*(3), pp.166-180.

Luo, M.R., A.A. Clarke, P.A. Rhodes, A. Schappo, S.A. Scrivener, and C.J. Tait. 1991. Quantifying colour appearance. Part II. Testing colour models performance using LUTCHI colour appearance data. *Color Research & Application*, *16*(3), pp.181-197.

Nayatani, Y. 1997. Simple estimation methods for the Helmholtz—Kohlrausch effect. *Color Research & Application*, *22*(6), pp.385-401.

Nilsson, M. 2015. Ultra high definition video formats and standardisation. *BT Media and Broadcast Research Paper*.

International Telecommunication Union. 2018. Recommendation ITU-R BT.2100-2. Geneva.
CIE TC1-03. 1986. Models of heterochromatic brightness matching. *CIE J.*, *5(2)*, pp.57-59.
Withouck, M., K.A. Smet, W.R. Ryckaert, G. Deconinck, and P. Hanselaer. 2014. Predicting the brightness of unrelated self-luminous stimuli. *Optics express*, *22*(13), pp.16298-16309.
Wyszecki, G. and C.L. Sanders. 1957. Correlate for lightness in terms of CIE-tristimulus values. Part II. *JOSA*, *47*(9), pp.840-842.
Wyszecki, G. and W. S. Stiles. 1982. Color Science: Concepts and Methods, Quantitative Data and Formulae. 2nd ed. New York, NY: John Wiley & Sons.

Perceived Speed in Transitions between Neutral and Chromatic Illumination

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Abstract

Dynamic lighting is an integral part of our experience of illumination, both in daylight and increasingly in artificial lighting. Previous research has focused either on daylight or chromatic illumination, and most studies examined speeds near detection thresholds. This experiment investigated transitions between neutral and chromatic illumination to expand upon these findings. The perceived speed of lighting changes to and from the chromaticity of D65 in eight radial hue directions was measured in a two-interval forced choice task. The relative perceived speed, computed as the point of subjective equality (PSE), of transitions moving away from D65 differed by radial hue direction, indicating that CIELAB is temporally nonuniform. Results show that the yellow-blue opponent color component contributes less to speed perception, in line with previous literature. The experiment did not yield PSEs for many transitions moving towards D65, likely because the comparison was too difficult, an improper range of speeds was studied, or both.

Keywords: *color science, lighting, speed perception*

Introduction

Dynamic lighting changes gradually over time. Advancements in LED control systems have led to their increased use in a wide variety of applications, such as photography and museum lighting (Lee et al.). Dynamic lighting is an important aspect of entertainment as well, which relies on changes in lighting to set the scene and direct the audience's attention. Studies including one by Zhang et al. have also found it to have a psychological impact with effects such as increased alertness and improvement in mood in office workers.

With increasing applications of dynamic lighting, it has become important to characterize color differences in the temporal domain. While there is much research on speed perception of grating stimuli, described in degrees per second, there is little focus on spatially homogeneous chromaticity changes. Such changes are described by $\Delta E_{ab}^*/s$, based on the assumption that CIELAB is approximately perceptually uniform. This uniformity in the spatial domain, of course, does not imply anything about temporal perceptual uniformity. Indeed, those who have studied the topic so far have found CIELAB to be far from a temporally uniform color space. Sekulovski et al. (2007) first used the ΔE_{ab}*/s description of temporally changing stimuli to examine preferences in dynamic lighting. Other studies by Sekulovski et al. (2011) and Murdoch et al. have investigated various aspects of dynamic lighting, such as smoothness perception and visibility and subtlety thresholds, finding differences in perception depending on chromaticity and lightness.

Kong et al. (2019, 2020) first directly investigated speed perception of chromaticity changes around medium-saturation colors at the five Munsell principal hues, finding that speed perception depended on both the base hue and whether the transition changed in chroma or hue. Pastilha et al. examined stimuli varying along the daylight locus, finding that detection thresholds depended not only on the base chromaticity, but also the direction of change relative to D65.

This experiment built off of these studies on the perception of dynamic lighting. The experimental methods were similar to those utilized by Kong but examined transitions between lighting with the chromaticity of D65 and more chromatic lighting to connect the two areas of color space. The stimuli were also linear rather than periodic, following the methods of Pastilha so as not to confound the possible effect of the orientation of the transition relative to the neutral D65 chromaticity.

Methods

Lighting System

The experiment took place in the Dynamic Visual Adaptation Lab at the Rochester Institute of Technology. The laboratory is lit by 14 Philips SkyRibbon ceiling-mounted light fixtures directed at the matte white walls to yield smooth, though non-uniform, illumination. The fixtures are LEDs, addressable at 40 Hz, with five primaries: red, green, blue, mint green, and white. This immersive setting, rather than a smaller stimulus patch, was used because of the interest in more natural, dynamic lighting applications. This setup has been characterized before by Murdoch, and his model was used to create stimuli with the desired colorimetry. The model was verified using a Konica Minolta CS2000 spectroradiometer. For the stimuli used in the experiment, measured color errors had a mean ΔE_{00}* of 0.77, with a standard deviation of 0.46, which is very good.

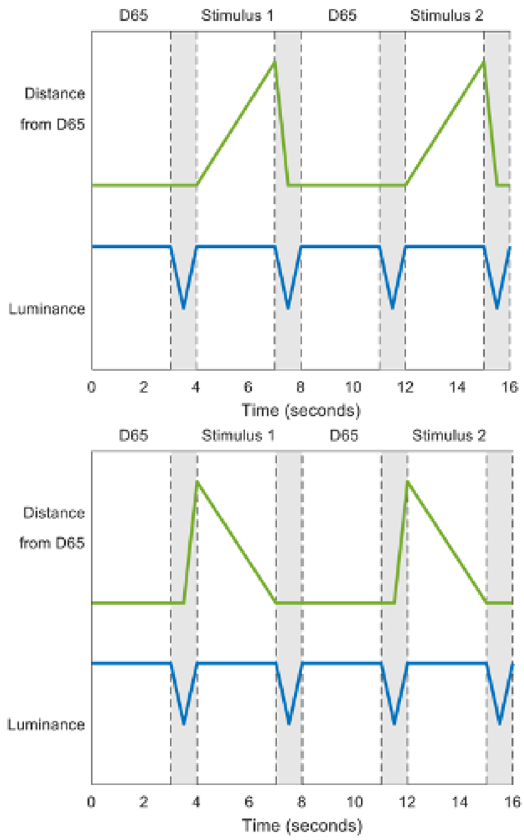

Figure 1. Relative change in chromaticity and luminance over time during presentation of one stimulus pair for transitions away from D65 (top) and towards D65 (bottom).

Procedure

A two-interval forced choice (2IFC) task was designed using the method of constant stimuli, in which the observer was shown the reference stimulus and a test stimulus sequentially and reported which appeared faster. The chromaticity of CIE standard illuminant D65 was chosen as the adaptation point and neutral endpoint of the stimuli because Pastilha found the detection thresholds of transitions depended on their orientation relative to this chromaticity. The observer was first adapted to constant D65 illumination while instructions and an Ishihara test to screen for color vision deficiencies were given. Subsequent trials began with three seconds of D65 illumination to 'top up' adaptation. The beginning of the first stimulus was denoted with an audio cue, after which the first three second transition was presented. After three seconds of D65 illumination, another audio cue marked the beginning of the second three second transition. Transitions were flanked by a one second dip in intensity before and after. These dips were used to cue the observer to the beginning and end of the transition as well as to interrupt the change from the adaptation state to the stimulus and vice versa; a direct comparison of the two could provide the observer information about the amplitude of the color change, which could influence speed perception. Transitions that moved towards D65 were also found to cause afterimages, which the dip in intensity helped to mitigate. Chromatic noise, which was utilized in a similar manner by Pastilha, was considered first, but was found to be disorienting.

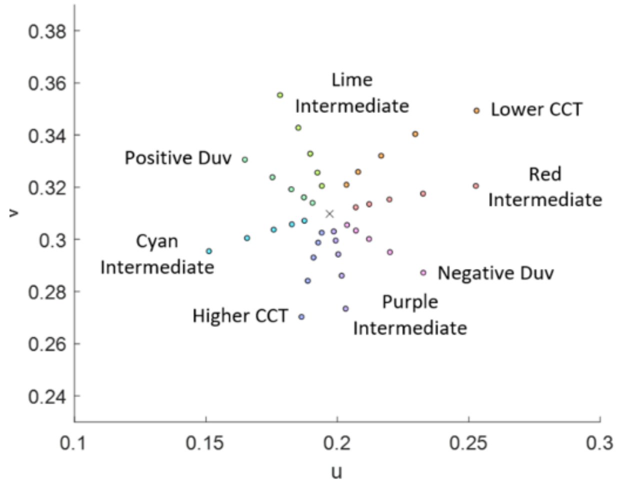

Figure 2. Endpoints of all simuli, plotted in u, v chromaticity coordinates. X marks D65.

Stimuli Definition

Stimuli were equiluminant and transitioned to or from D65 in one of eight radial hue directions. The orange and blue transitions followed the daylight locus, and the pink and green transitions followed the line of Duv perpendicular to the daylight locus in CIE 1960 u,v space. The intermediate directions were linear in CIELAB with a hue h_{ab} at the midpoint between the daylight and Duv lines. Transitions of five speeds in ΔE^*_{ab}/s, all three seconds in length, were created.

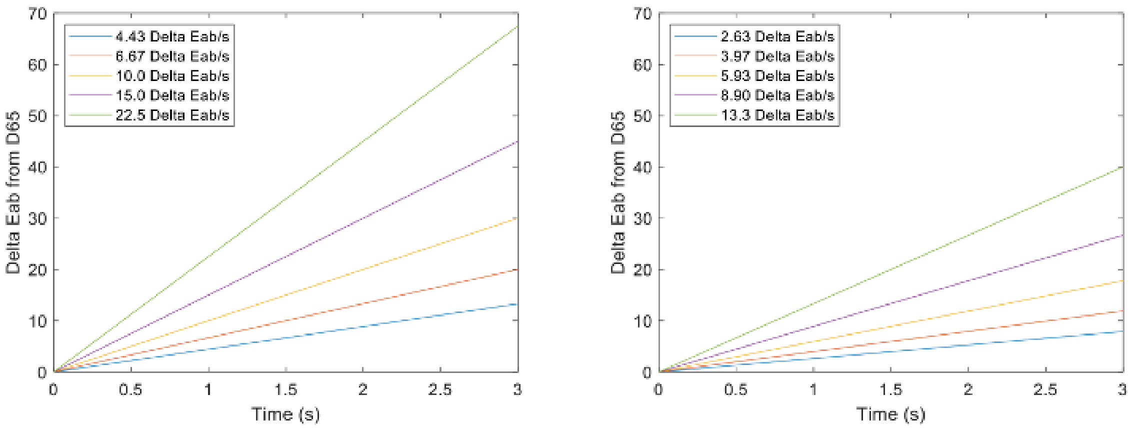

Figure 3. Plots of ΔEab* from the starting point versus time for the five different speeds of transitions in each.

The reference stimulus, chosen to be from D65 to decreasing CCT at the middle speed, was set at 10 ΔE^*_{ab}/s for better comparison with previous studies. The speed increased by a factor of 1.5 with each step, from 4.4 to 22.5 ΔE^*_{ab}/s. When these stimuli were tested, the warm daylight and lime intermediate transitions appeared notably slower. The other transitions were scaled back to a maximum of 40 ΔE^*_{ab} total, ranging from 2.6 to 13.3 ΔE_{ab}*/s, to make the range of speeds more perceptually even across all hues. There were 80 stimuli in total (8 radial hue directions x 2 orientations relative to the chromaticity of D65 x 5 speeds). Each was presented once to each observer, paired with the reference, with the reference interval randomly chosen. Presentations were blocked by orientation relative to neutral and randomly presented within that orientation.

Results

Data were collected from 34 observers, 10 male and 24 female, with an average age of 22 years old. The proportion of times each test stimulus was judged faster than the reference stimulus was calculated. Psychometric curves were fitted for each of the 16 transition directions using a probit regression model as a function of the logarithm of ΔE^*_{ab}/s. Log scale was chosen because it better matches perception and was used to select the speed of the stimuli. The point of subjective equality (PSE) was calculated for each by interpolating the speed at which the proportion of times the test stimulus was judged faster was equal to 0.50. The PSE for each transition direction represents the speed required to appear the same speed as the reference stimulus.

Figure 4 directly compares the PSEs across hues. Error bars represent the 95% confidence intervals calculated through Monte Carlo resampling. For all transitions towards D65 except the blue higher CCT and purple intermediate transitions, PSEs were not calculable because the slowest speed tested was already judged faster than the reference in more than 50% of the observations. The psychometric curves of the transitions moving towards neutral were all quite flat, which was unexpected. This might have occurred because the task of comparing a reference transition moving away from D65 and a test transition moving towards D65 was too difficult to yield meaningful results or because the true PSEs lay outside the range of stimuli used.

To obtain thresholds from these transitions, observers who behaved differently than expected were identified and removed from the calculations. Observers with the lowest number of transition directions for which all five speeds were judged faster than the reference or the lowest speed was judged slower and the greatest speed faster than the reference were removed until PSEs were calculable for all transitions. All but five observers had to be removed. These PSEs should not be taken as actual values of the relative perceived speed of these transitions. Rather, they should be interpreted as upper bounds for these thresholds to be studied further. As plotted in Figure 6, comparing the PSEs calculated for the transitions away from D65 with all of the observers, all eight calculated with the reduced number of observers are higher in value, supporting this interpretation.

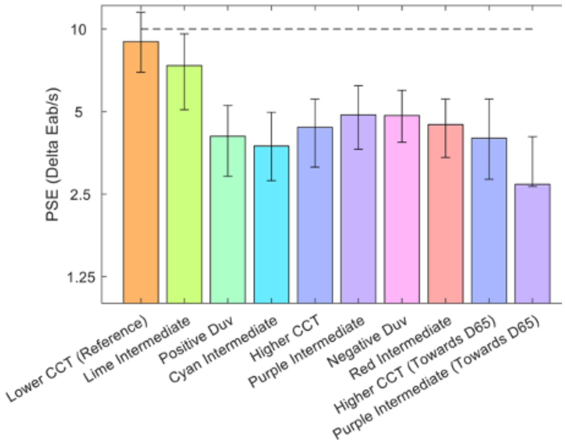

Figure 4. PSEs for each transition direction with error bars representing 96% confidence intervals. All but the rightmost bar represents transitions away from D65, The dotted line represents the speed of the reference.

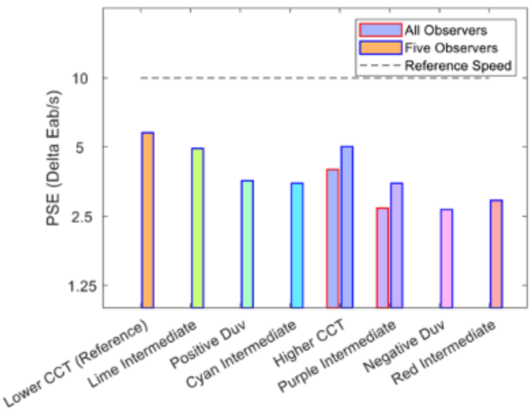

Figure 5. Bar charts comparing the PSEs using all observers (red outline) to those using five observers (blue outline) for transitions away from (top) and towards (bottom) D65.

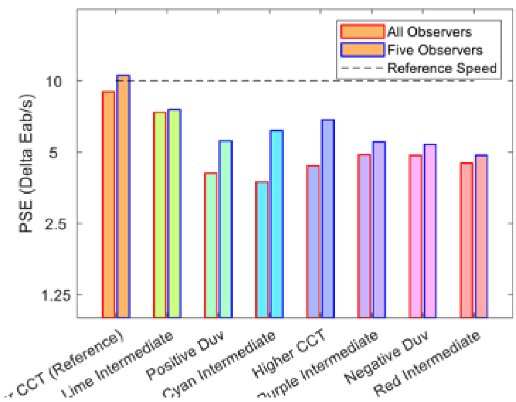

Figure 6. Bar charts comparing the PSE's using all observers

Discussion

These results confirm CIELAB is not a temporally uniform color space, as found previously in Kong's speed perception experiments. For the transitions away from D65, the lower CCT radial hue direction was not significantly different from the reference speed. As this was the hue used as the reference, this indicates that observers were able to correctly accomplish the task. The only hue with a threshold not significantly different from that of the reference hue was the lime intermediate hue direction. All of the remaining hue directions had PSEs lower than the reference speed, indicating that they are perceived as faster than the reference. The thresholds of these six hue directions were not significantly different from each other. In Kong's study focusing on medium-saturation Munsell principal hues, the highest PSE was around the blue hue and the lowest around the red hue. In contrast, this data had the highest PSE at the orange hue and the lowest at the green hue. This suggests that the dependency of speed perception on hue varies with chroma level. However, the results do line up when considering color opponent axes: both have the smallest PSEs around the red-green axis and the largest around the yellow-blue axis.

Scaling Color Spaces

In a temporally perceptually uniform color space, all of the PSEs would be equal, so their standard deviation would be zero. A simple alteration to CIELAB to make it more uniform, first computed by Kong, is to weight Δa^* and Δb^* so as to minimize the standard deviation of the PSEs. ΔL^* was not included because all transitions were designed to be equiluminant. ΔE_{ab}^* was weighted by

$$\Delta E_{ab}^* = \sqrt{(1-\alpha)(\Delta a^*)^2 + \alpha(\Delta b^*)^2} \qquad (1)$$

The values for Δa^* and Δb^* for each transition were the overall change along these axes from the beginning to the end of the transition. As the transitions were designed to be linear in $\Delta E_{ab}^*/s$, the weighted speed was calculated by dividing by three seconds. The standard deviation of the PSEs was minimized at $\alpha = 0.159$. This analysis aligns with Kong's result that the standard deviation is minimized when $\Delta b^*/s$ is given a much smaller weight, suggesting that it contributes less to speed perception.

Kong also performed similar analysis in other color spaces. In LMS cone space, the minimum standard deviation of the PSEs was found to be when the weights of both the M and S responses were zero, an unsatisfying result; consequently, this space was not considered. The other color space utilized by Kong was DKL space, in which the axes are linear combinations of cone responses: L + M, L – M, and S – (L + M). The L + M axis is taken to be the luminance axis, which was held constant. The LMS signals of the transitions were calculated using Stockman and Sharpe cone fundamentals and the measured spectra of the transition endpoints. Δ(L –

M) and Δ(S – (L + M)) values were computed from the beginning to the end of each transition, and the weighted ΔDKL values were calculated by

$$\Delta DKL = \sqrt{(1-\alpha)\left(\Delta(L-M)\right)^2 + \alpha\left(\Delta\left(S-(L+M)\right)\right)^2} \qquad (2)$$

The ΔDKL values were divided by three seconds to yield the weighted speeds. The standard deviation of the PSEs was found to be minimized at $\alpha = 0.013$. Kong's analysis similarly gave a very small weight to Δ(S – (L + M)), suggesting that Δ(S – (L + M))/s is less important to speed perception. The results in CIELAB and DKL space, therefore, both indicate that the yellow-blue component contributes less to the perception of dynamic lighting.

Comparison of Orientations Relative to Neutral

Although the thresholds of the transitions towards D65 cannot be analyzed directly, some discussion of these results can be had based on the interpretation of the PSEs computed using five observers' data as upper bounds, though further investigation is needed to verify this. These transitions towards D65 have lower PSEs across the board and must therefore be slowed down even further to match the perceived speed of the reference. Interestingly, Pastilha found that detection thresholds were lower for transitions away from D65. This yields the unintuitive result that we are more sensitive to the set of transitions with a lower perceived speed. However, Pastilha was investigating transitions exclusively along the daylight locus. The only PSEs that remained high enough to be calculable with all observers' data in the transition towards D65 were the lower CCT transition and one of the hue directions adjacent to it. Consequently, it seems plausible that the perception of transitions along the daylight locus may differ from those of other radial hue directions. This would align more intuitively with Pastilha's results and suggest that phenomenon may be limited to the daylight locus.

Conclusion

This study investigated speed perception of low chroma transitions. For transitions away from D65, the PSEs of the lower CCT transitions and lime intermediate transitions were not significantly different from the reference speed. The PSEs of the transitions in all of the six remaining radial hue directions were lower than the reference speed and not significantly different from each other, indicating that they are perceived as faster than transitions in the reference direction. The PSEs for the transitions towards D65 were incalculable for all but two hue directions, possibly because the task was too difficult or because the PSEs lie outside the range of speeds tested. Using the data of only five observers to calculate an estimated upper bound on these PSEs, all but the higher CCT transition had lower thresholds than their counterparts transitioning away from D65. Standard deviation analysis was performed in CIELAB and DKL space, suggesting that $\Delta b^*/s$ and $\Delta(S - (L + M))/s$ contribute less to speed perception, closely aligning with past results.

References

Kong, X., Murdoch, M. J., Vogels, I., Sekulovski, D., Heynderickx, I. 2019. Perceived speed of changing color in chroma and hue directions in CIELAB. *J. Opt. Soc. Am. A*, 36(6) 1022–1032.

Kong, X., Wei, M., Murdoch, M. J., Vogels, I., Heynderickx, I. 2020. Assessing the temporal uniformity of CIELAB hue angle. *J. Opt. Soc. Am. A*, 37(4) 521–528.

Lee, A. T. L., Chen, H., Tan, S. C., & Hui, S. Y. 2016. Precise Dimming and Color Control of LED Systems Based on Color Mixing. *IEEE Transactions on Power Electronics*, 31(1), 65–80.

Murdoch, M. J., Sekulovski, D., Seutiëns, P. 2011. The Influence of Speed and Amplitude on Visibility and Perceived Subtlety of Dynamic Light. *19th Color and Imaging Conference Final Program and Proceedings*, 265–269.

Murdoch, M. J. 2017. Characterization and control of a multi-primary LED light lab. *Opt. Express 25*, 29605–29616.

Pastilha, R., Gupta, G., Gross, N., Hurlbert, A. 2020. Temporal dynamics of daylight perception: Detection thresholds. *Journal of Vision*, 20(13) 1–18.

Sekulovski, D., Vogels, I. M., Van Beurden, M., Clout, R. 2007. Smoothness and flicker perception of temporal color transitions. *Color and Imaging Conference*, 112–117.

Sekulovski, D., Seuntiens, P., Hartog, M. 2011. Measuring Dynamic Lighting Atmospheres. *Proc. AIC*, Zurich.

Stockman, A., & Sharpe, L. T. 2000. The spectral sensitivities of the middle- and long-wavelength-sensitive cones derived from measurements in observers of known genotype. *Vision Research*, 40(13), 1711–1737.

Zhang, R., Campanella, C., Aristizabal, S., Jamrozik, A., Zhao, J., Porter, P., Ly, S., & Bauer, B. A. 2020. Impacts of dynamic led lighting on the well-being and experience of office occupants. *International Journal of Environmental Research and Public Health*, 17(19), 1–27.

Visual judgement of the tactile properties of fabrics by altering colours

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Abstract

This paper presents the results of experiments to evaluate the human perception of visual-tactile properties: flexible-stiff, smooth-rough, and soft-firm of both images of flattened fabrics and draped fabrics on the professional BenQ display. The aim of the study was to evaluate the differences of the perception between the different shapes of the fabrics, i.e., flattened or draped. 128 fabric images representing different shapes (flattened and draped fabrics), four different fabric materials and 16 fabric colours, were used in this study. Their visual-tactile properties were accessed by human subjects using psychophysical experiments. The results showed that the difference of the perception of these properties between images of flattened fabrics and draped fabrics was huge, except for smoothness and roughness on Fabric 1 and Fabric 2. More colours showed significant effects on human responses of smoothness, roughness, softness, and firmness on images of draped fabrics than flattened fabrics, while the perception of flexibility and stiffness was not significantly affected by colours.

Keywords: *Visual-tactile properties, Colour, Perception*

Introduction

Human beings are surrounded by colours in every moment of their lives. When people look at an object or the scenery, the colours will be a significant stimulus to the eyes, and thus affect human visual sensation and perception. In the fashion industry, fabrics attract great attention to be used as samples in experiments to study their colour appearance and their tactile properties. (Xiao et al., 2016; Mirjalili and Hardeberg, 2019) In previous work, Li et al. (2021) conducted a psychophysical experiment, and the results showed that some colours significantly affected the human perception of the smoothness, roughness, softness, and firmness of flattened woollen wool fabrics when perceived as images on a mobile phone. The concept of the experiment was based on the fact that the decision to make an online purchase must rely on the images of the product viewed on that display. However, the fabrics and the garments can show various shapes for the purpose of advertising and selling, for example, whether it is flattened or draped, whether a model wears it or not, and whether showing it in a stationary or dynamic condition, etc. How shape affects human perception of visual-tactile properties of fabrics in different colours has not been studied before.

The aim of this study was to evaluate whether shapes have significant effects on the human perception of visual-tactile properties of both flattened and draped fabrics displayed on a professional display.

Experiment

Four fabrics were selected in the experiment due to their various appearance and texture. To capture the images of flattened and draped fabrics, the fabrics were placed on a triangle and cylindrical stand separately in the D65 lighting booth. SONY ILCE-7RM4A camera with the settings of 1/200 second, f/5.0, ISO-500, white balance 6200K was used to capture the images, and the distance between the fabric and the camera was set to 45cm. Table 1 showed the captured flattened and draped fabric images. Ten images of flattened fabrics and draped fabrics were captured in total.

To produce images of fabrics in different colours, images of each fabric were rendered to obtain 16 differently coloured images of each, as shown in Table 2, giving 64 images of flattened fabrics and draped fabrics separately. The final images of the samples appeared to represent 'real' fabric samples when displayed, which is necessary to enable products to be sold online. Four colours of different chroma and lightness were set close to the CIE reference colour centre grey, and three colours were set close to red, yellow, green, and blue. (Robertson, 1973) The colours gave an average distribution in CIELAB colour space, as shown in Figure 1.

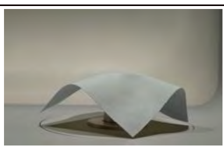
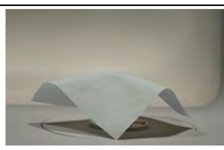
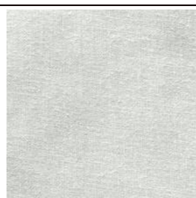
Fabric 1 - Coated cotton duck PK44 white	Fabric 2 - Milk twill white	Fabric 3 - Coated cotton twill SG78 white	Fabric 4 - Plain cotton white
			
			

Table 1. Figures of the original flattened fabric images and draped fabric images.

Colour		Colour	
1		9	
2		10	
3		11	
4		12	
5		13	
6		14	
7		15	
8		16	

Table 2. Specification of 16 colours.

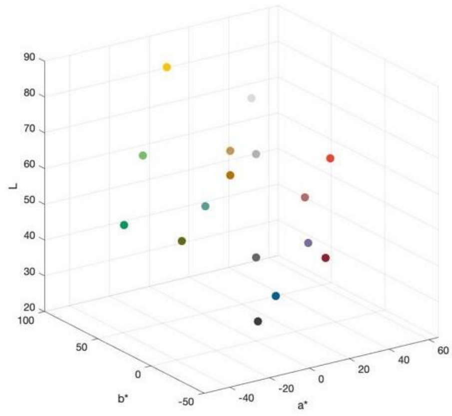


Figure 1. Location of the 16 colours in the CIELAB colour space.

Three pairs of descriptors of the visual-tactile properties of fabrics were selected based on Touch Perception Task (TPT) and the instrumental measurement system LUFHES: flexible-stiff, smooth-rough, and soft-firm. To aid the observers, they were given the same instructions on how to physically perceive each descriptor as defined in LUFHES.

Nine observers with ages ranging from 21 to 25 years were invited to carry out the experiment, which was performed in a dark room, on the BenQ display with the gamma of 2.2, brightness of 24, contrast of 50, and sharpness of 5. The distance between the observer and the display was set to approximately 45 cm. Each observer made assessments of each property with no time constraints.

Observers were asked to read the instructions on how to physically perceive the descriptors first. The 64 images were then displayed on the BenQ display one at a time in random order. The observers were asked to make a judgement on the assigned visual-tactile properties of the fabric on an integer scale from one to nine. Based on the law of categorical judgement, the meanings of each value are shown as follows:

- Value 1: completely flexible/smooth/soft
- Value 2: very much flexible/smooth/soft
- Value 3: moderately flexible/smooth/soft
- Value 4: slightly flexible/smooth/soft
- Value 5: neither flexible/smooth/soft nor stiff/rough/firm
- Value 6: slightly stiff/rough/firm
- Value 7: moderately stiff/rough/firm
- Value 8: very much stiff/rough/firm
- Value 9: completely stiff/rough/firm

Results and discussion

Inter-observer variability

Based on the law of categorical judgement, the mean category value c was used to calculate the interobserver variance for the three separate assessments, (Torgerson, 1996) and the values were as in Table 3. In general, inter-observer variability for all assessments is smaller than 30%, indicating a good agreement between different observers in terms of visual judgement of images of both flatted fabrics and draped fabrics. It can also be found that observer variability for draped fabric is better than that for flattened fabric for *flexible-stiff* and *soft-firm* judgement.

	Flexible-stiff	Smooth-rough	Soft-firm
Flattened fabric	28%	24%	24%
Draped fabric	12%	28%	15%

Table 3. Inter-observer values.

The effects of shapes on visual-tactile properties

The experimental data were recorded as integer values that indicated the perception of visual-tactile properties of the fabrics. For each image, the integer values of each assessment given by nine observers were converted into statistical z-scores based on the law of categorical judgement. A higher z-score represents the image perceived as either stiffer, rougher, or firmer, whereas a lower z-score indicates the image was more flexible, smoother, or softer

Figures 2, 3 and 4 were plotted to illustrate perceived visual-tactile properties for *flexible-stiff*, *smooth-rough* and *soft-firm*, respectively. In each Figure, each column represents a perceptual visual tactile property for one fabric in a particular shape for a specific colour. Blue columns represent flattened fabrics and the orange columns represent draped fabrics. Sub-Figure A to D represents results for four different fabrics, respectively. A 95% confidence interval was calculated and plotted as error-bar for each of the images. For z score of each of the image, the value of 95% confidence interval was ± 0.46.

Almost all samples indicated that there is a huge difference in human perception of visual-tactile properties between images of flattened fabrics and draped fabrics, except for smoothness and roughness on Fabric 1, Figure 3 (A) and Fabric 2, Figure 3 (B).

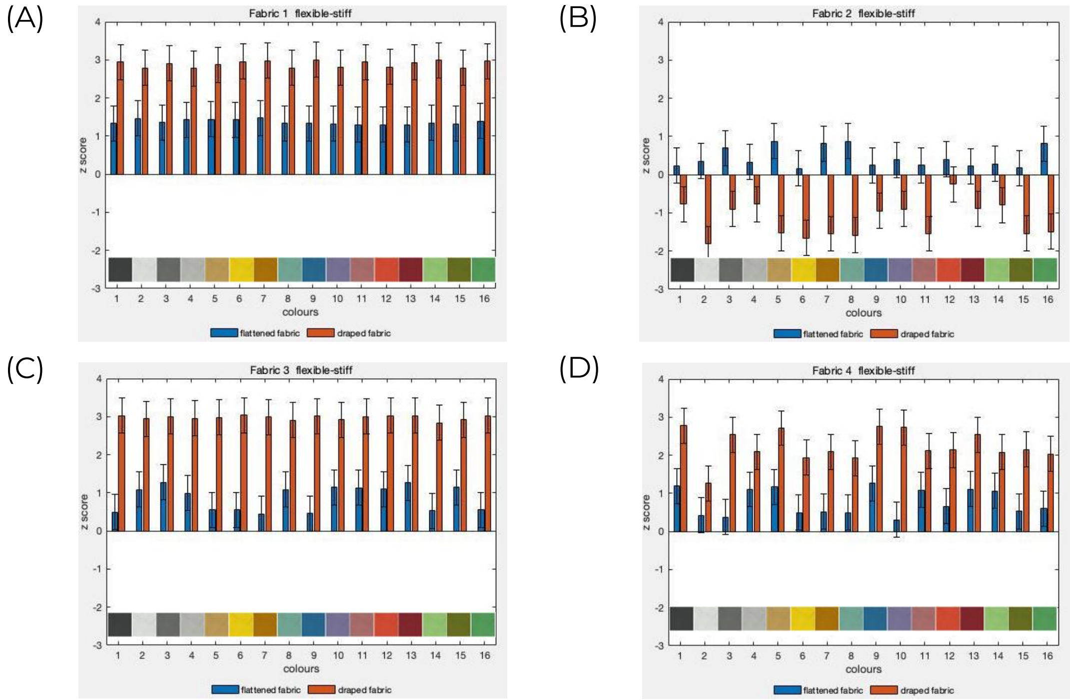


Figure 2. z-score of flexible-stiff on fabric 1 (A), fabric 2 (B), fabric 3 (C), and fabric 4 (D).

For the perception of flexibility and stiffness, shape showed significant effects on all colour samples due to the non-overlap of 95% confidence intervals in Figure 2. For fabric 1, fabric 3, and fabric 4, the images of draped fabric were perceived significantly stiffer than that of flattened fabrics for all colours. For fabric 2 however, draped fabrics were perceived significantly more flexible than flat samples for most colours.

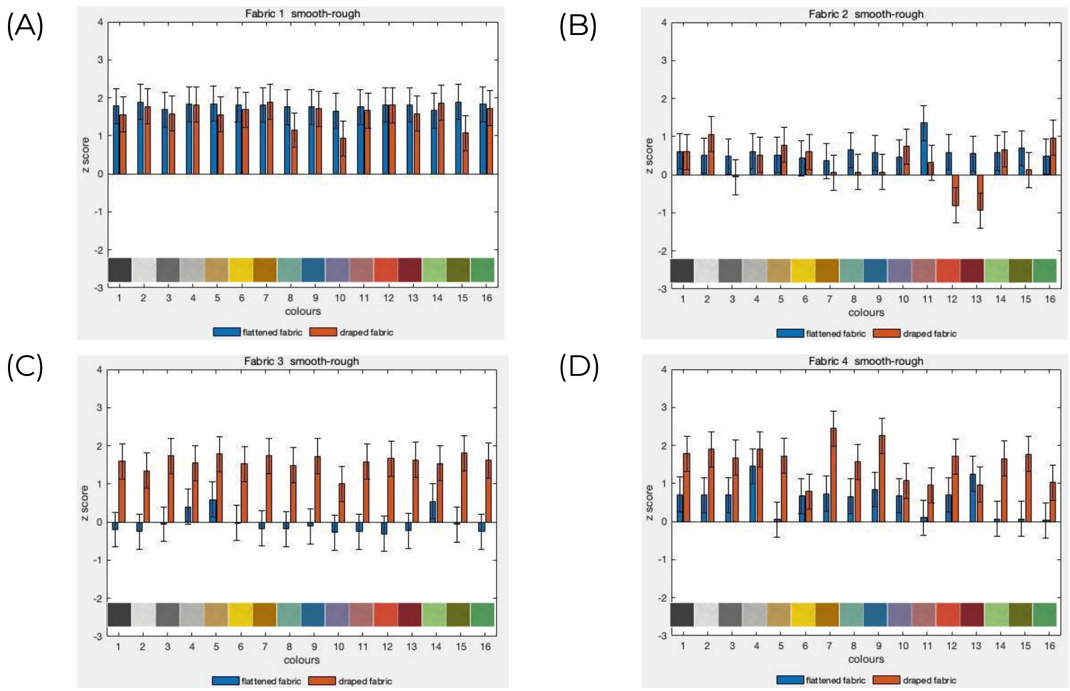


Figure 3. z-score of smooth-rough on fabric 1 (A), fabric 2 (B), fabric 3 (C), and fabric 4 (D)

For the judgement of smoothness and roughness, shape played significant effects on the visual perception on fabrics 3 and 4, in which images of draped fabrics were perceived rougher than that of flattened fabrics in general. For fabrics 1 and 2, there is no significant difference for the majority of colour samples, indicating that shape had no significant effects on the perception of smoothness and roughness.

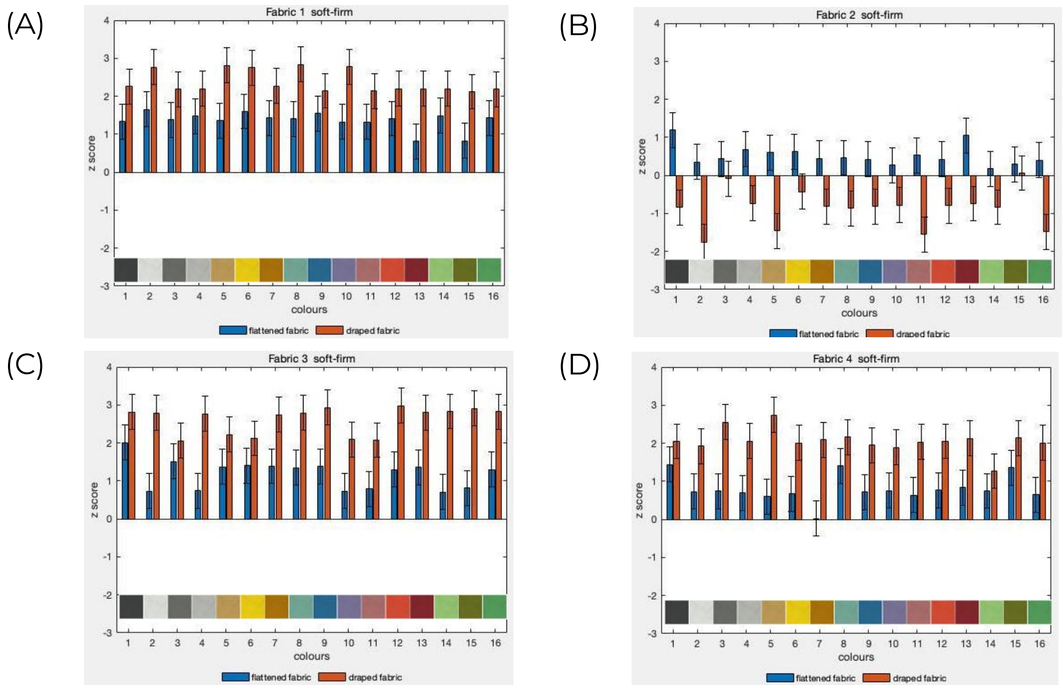


Figure 4. z-score of soft-firm on fabric 1 (A), fabric 2 (B), fabric 3 (C), and fabric 4 (D)

Figure 4 illustrates the perception of *soft-firm*. The non-overlap of 95% confidence interval occurred on all colour samples of the images of both flatted and draped fabrics, indicating that shape has significant effects on the visual perception of *soft-firm*. For images of draped fabrics 2, they were perceived much softer than the images of flattened fabrics, while for fabric 1, 3, and 4 the draped fabrics were firmer.

Conclusion

In this study, four fabrics in flat shape and draped shape, were captured respectively using a high-end digital SLR camera under a viewing cabinet. Each fabric image was further rendered in 16 colours using colour texture mapping. A psychophysical experiment was conducted to assess the perception of visual-tactile properties for these 128 fabric images on display. Visual-tactile properties refer to the fabric handling properties that were evaluated visually through images with no actual touch involved. Three pairs of descriptors, flexible-stiff, smooth-rough, soft-firm, were used to judge the visual-tactile properties. Results shown for the same fabric, when the shape changes from flat to a 3D draped shape, their visual tactile properties change significantly. The changes can be fabric dependency although consistent with different fabric colour in general.

References

Li, Q., Liang, J., Lu, Y., Xiao, K., & Pointer, M. 2021. Quantification of the effect of colour appearance and materials on the visual-tactile properties of fabrics. *In Proceedings of the AIC 14th Congress 2021*, 167-172.

Mirjalili, F. and Hardeberg, J.Y. 2019. Appearance perception of textiles: a tactile and visual texture study. In: *Color and Imaging Conference: Society for Imaging Science and Technology,* 43-48.

Robertson AR. CIE Guidelines for Coordinated Research on Colour-Difference Evaluation. *Color Research & Application*. 1978: 3-3.

Torgerson WS. A law of categorical judgment. *Consumer behavior*. 1954:92-93.

Xiao, B., Bi, W., Jia, X., Wei, H., & Adelson, E. H. 2016. Can you see what you feel? Color and folding properties affect visual–tactile material discrimination of fabrics. *Journal of Vision*, 16(3), 34-34.

Session 12
Colour Science - III

A Weighted Goodness-of-Fit Metric for Comparison of Spectra

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Abstract

Spectral estimation methods are being increasingly used to create spectral data for colour reproduction applications. Therefore, a good spectral matching metric is required that can minimize colour differences, metamerism as well as errors in the spectral domain. A goodness-of-fit metric is proposed that applies weights to different metrics based on selected criteria and combines them to a single value to assess the fit between two spectra. Acknowledging that for different applications the individual criteria may be more or less relevant, we propose the components of this metric are weighted according to their relative importance in a given application.

Keywords: *Spectral matching, quality metric, spectral estimation, metamerism*

Introduction

Spectral data is of increasing importance in colour reproduction, and in certain cases it is desirable to use spectral data in a workflow when the available source data is colorimetric. In such cases spectral estimation procedures can be used to generate spectral data. When considering such methods, the challenge is to evaluate their ability to predict the original spectra. Neither visual colour difference nor curve fitting approaches can by themselves provide sufficient information, but the relative importance of the two approaches may vary depending on the application, Imai et al. (2002).

Nimeroff, & Yurow (1965) developed a metamerism index which is a weighted sum of the absolute difference between two spectra that correlates well to the chromaticity spread found among observers. Based on similar principles, Viggiano (1990) developed a Spectral Comparison Index (SCI) that derives weights depending on the CIELAB values of the observed spectrum. This metric was further evaluated using non metameric pairs in Viggianno (2004) and it was found that this index assumed values around 2.6 times of total colour difference of CIELAB. According to Imai et al. (2002) the advantage of this metric is that it considers human vision and differences between light and dark colours although the resulting unit could be more intuitive. López-Álvarez (2005) et al. proposed a metric that calculates both the spectral and colorimetric similarity of any pair of skylights by optimizing with annealing search algorithms which has a specific and limited application.

Our goal is to propose a spectral estimation metric that considers both colorimetric and spectral differences, whose unit is intuitive, and it can be adjusted to minimize attributes depending on the target application. To achieve that, we establish criteria for spectral matches that relate to real-world colour reproduction objectives, including minimization of colour difference, spectral difference, hue difference, metameric mismatch, non-smoothness, and wavelength inaccuracy for spectral features. We then select or define metrics corresponding to each of these criteria and compute them for a large set of original spectra and their corresponding spectra estimated from tristimulus values using a range of different spectral estimation methods. We observe that most of the metrics tend to rank the estimation methods similarly. These values are then combined to give a single Figure of merit to describe the fit between two spectra. The metric weights are adjusted such that it correlates well to Viggiano's Spectral Comparison Index due to its advantages. The proposed metric provides a useful means of comparing spectra which can be adapted to a wide range of applications.

Spectral and Colorimetric Comparison Indices

For a good spectral match both spectral and colorimetric comparisons have to be carried out. Different metrics are used for spectral and colorimetric comparisons that are discussed as follows.

Mean Absolute error

Mean absolute error (ΔR) is the mean of the sum of the absolute difference between two spectra.

Root mean square error

Root mean square error (RMSE) is the square root of the mean of the squared difference between the reference and test spectra. It measures accuracy of an estimation method however as it is scale dependent it cannot compare results obtained between datasets with different scales.

Metameric Difference

Metameric Difference (ΔM) quantifies the difference in colour between two spectra under a source illuminant and a test illuminant. The squared difference between the L^*, a^* and b^* of the test and reference spectra are calculated under a source illuminant and the same is calculated under a test illuminant. ΔM is given by the square root of the sum of these squared differences.

Colour Inconstancy Index

Colour Inconstancy Index (CII) quantifies the degree to which the colour appearance of a spectrum differs under a source illuminant and a test illuminant, Luo (2003) & Derhak (2020). In manufacturing it is often desired that objects are colour constant i.e. the object does not change its appearance appreciably from one illuminant to another for e.g. illuminant D65 to A, Luo et al (2003).

The tristimulus value of a spectrum is calculated under a source illuminant and then a chromatic adaptation transform is applied to calculate the corresponding colour under a test illuminant. CII is obtained by calculating the colour difference between the corresponding colour and tristimulus value of the spectrum calculated under the test illuminant. ΔCII is the absolute difference between CII obtained for the reference spectra and CII obtained for the estimated spectra.

Smoothness Index

Green (2008) defines a smoothness metric for evaluating the smoothness of a colour transform. The second derivative of the points that lie on a curve is calculated and the median of the second derivative describes the smoothness of a curve. The same can be applied to evaluate the smoothness of a reflectance spectrum and we call it the Smoothness Index (SI). ΔSI is the absolute difference between SI obtained for the reference spectra and SI obtained for the estimated spectra.

Spectral Comparison Index

Viggiano (1990,2002) describes a metric for comparison of radiance ratio spectra based on both spectral and colorimetric principles. It is called the Spectral Comparison Index (SCI) and can be used as a metric to evaluate metamerism between two spectra. A spectral match between two spectra is considered excellent if the SCI is less than 3. SCI is computed as below:

$$M_v=\sum_{\lambda=1}^{n} w(\lambda)||\Delta\beta(\lambda)|| \qquad (1)$$

Where, $\Delta\beta(\lambda)$ is the difference between the two spectra and the weights $w(\lambda)$ are computed as below:

$$w(\lambda) = \sqrt{\left(\frac{dL^*}{\Delta\beta(\lambda)}\right)^2 + \left(\frac{da^*}{\Delta\beta(\lambda)}\right)^2 + \left(\frac{db^*}{\Delta\beta(\lambda)}\right)^2} \qquad (2)$$

Method

In our experiment, we have selected four different metrics to be combined namely RMSE, ΔM, CII, and SI. RMSE is the most common metric to evaluate two different spectra. ΔM and CII evaluate the colorimetric performance of the estimated spectrum under different illuminants. CII is calculated for each reference and test spectra. The goal is to minimize ΔCII, the difference between the two colour inconsistencies. Smoothness is another desirable property in a surface reflectance spectrum, manipulating which can cost accuracy. Therefore, minimizing ΔSI or SI, one can choose the smoothness of the spectrum to be like that of the reference spectrum or better respectively. We introduce weights to combine each of these metrics into a new goodness-of-fit metric, and we call it the Combined Index (CI). These weights were obtained by adjusting until CI values correlated well to SCI. Thus, CI is made up of RMSE, ΔM, ΔCII and ΔSI as shown in equation 3.

$$CI = 10*RMSE+(\Delta M_{D65}+\Delta M_{E}+\Delta M_{A}+\Delta M_{F12}) +(\Delta CII_{D65} +\Delta CII_{E}) +100*\Delta SI \qquad (3)$$

Ten different classical spectral estimation methods were tested to generate spectra from tristimulus values which produce ΔE_{00} of around 1e-13 i.e. approximately 0 under the same source illuminant (D50) and colour matching functions (CIE 1931 2-degree observer) used for the estimation process. Therefore, the estimated spectra generated by each of these methods are metameric to the reference spectral data. These spectral estimation methods were also evaluated based on their ΔM, RMSE, ΔCII and ΔSI. In this paper, we use the top two performing spectral estimation methods namely, weighted pseudo inverse method (WPI) and third order polynomial (Poly 3) to create the estimated spectra for a reflectance dataset. These estimated spectra are then used to calculate CI and SCI and their correlation with individual metrics ΔR, RMSE, ΔM_{D65}, ΔM_{E}, ΔM_{A}, ΔM_{F12}, ΔCII and ΔSI.

The above spectral estimation and evaluation of metrics are carried out using three reflectance datasets, cold-set offset on newsprint (D1), digital print on textile (D2) and web offset on lightweight coated (D3) as shown in Table 1. Three cases are considered, (1) test dataset and training dataset are part of the same reflectance dataset D1, i.e. the estimated spectra are close metamers of the reference, (2) the test dataset is D1, and training dataset is D3 where D1 and D3 have similar spectral curves i.e. the estimated spectra are metamers resembling the spectral characteristics of the training data D3 thereby increasing the degree of metamerism slightly and (3) the test dataset is D2 and training dataset is D3 where D2 and D3 have quite different spectral curves i.e. the estimated spectra are metamers resembling the spectral characteristics of the training data D3 thereby creating a higher degree of metamerism.

Dataset	Range	Description
Cold-set offset on newsprint (D1)	380nm-730nm interval 10 nm	Training and test
Digital print on textile (D2)	380nm-780nm interval 10 nm	Training and test
Web offset on lightweight coated (D3)	380nm-780nm interval 10 nm	Training

Table 1. Reflectance datasets used for spectral estimation from tristimulus value

Results and Discussion

Table 2 lists the different cases of spectral estimation workflow and the overall mean RMSE, ΔM_{D65}, ΔM_E, ΔM_A, $\Delta M_{F1,}$ ΔCII, ΔSI, SCI, and CI. A CI of 2 units is a very good spectral match and its value increases gradually as the metamerism under various illuminants and RMSE increases (table 2).

Training	Test	Method	RMSE	ΔM_{D65}	ΔM_E	ΔM_A	ΔM_{F12}	ΔCII	ΔSI	SCI	CI
D1	D1	Poly 3	0.0047	0.1038	0.0197	0.3090	0.4284	0.0910	0.0007	1.6478	1.0829
D1	D1	WPI	0.0056	0.1220	0.0386	0.3569	0.4776	0.0981	0.0009	1.9291	1.2586
D3	D1	Poly 3	0.0120	0.2205	0.1420	0.5660	0.8630	0.1798	0.0018	3.3585	2.4449
D3	D1	WPI	0.0113	0.2777	0.1204	0.8056	1.1078	0.1432	0.0016	3.0770	2.0629
D3	D2	Poly 3	0.0362	0.6468	0.5396	1.6395	2.3409	0.3794	0.0032	13.4026	6.4989
D3	D2	WPI	0.0357	0.6262	0.5627	1.5438	2.2359	0.3182	0.0028	9.8336	6.2093

Table 2. The average metric values for each type of spectral estimation workflow

The correlation values are calculated for SCI and CI with other metrics, viz. ΔR, RMSE, ΔM_{D65}, ΔM_E, ΔM_A and ΔMF_{12}. In Figures 1a,1b and 1c, the graphs show the correlation obtained between SCI and other metrics depicted using bars with slanted lines while the correlation values obtained between CI and other metrics are depicted with solid bars. The blue bars correspond to estimated spectra created using third order polynomials and orange bars correspond to estimated spectra created using weighted pseudo inverse method. The correlations show that the weights chosen for CI makes it correlate to other metrics the same way SCI correlates to those metrics for all the three different cases of metameric spectra generation. SCI and CI showed no correlation with ΔCII and ΔSI.

The results suggest that both CI and SCI can determine metamerism under various illuminants for all the three cases of estimated spectra with different degrees of metamerism. CI can also be used for optimization, where depending on the application the weights can be adjusted to minimize the desired attribute.

In Figure 1a, the results correspond to estimated spectra obtained using dataset D1 as training and test data. In this case, the RMSE and overall ΔM obtained was very low. Both SCI and CI have a strong correlation with ΔM_{D65}, ΔM_{A} and ΔM_{F12} i.e., greater than 0.9 and a good correlation with ΔR and RMSE i.e., between 0.8 - 0.9.

In Figure 1b, the results correspond to estimated spectra obtained using dataset D3 as training data and D1 as test data. In this case, the RMSE and overall ΔM obtained was low. Both SCI and CI have a strong correlation with ΔM_{D65}, ΔM_{A} and ΔM_{F12} i.e., greater than 0.9 and a less than moderate correlation with ΔR and RMSE i.e., between 0.7-0.5.

In Figure 1c, the results correspond to estimated spectra obtained using dataset D3 as training and D2 as test data. In this case, the RMSE and overall ΔM obtained was slightly high. Both SCI and CI have a good correlation with ΔM_{D65}. SCI has good correlation with ΔM_{A} and CI has moderate correlation i.e. between 0.7-0.8. While CI has good correlation with $\Delta M_{F12,}$ and SCI has less than moderate correlation. Both SCI and CI have less than moderate correlation with ΔR and weak correlation with RMSE i.e., less than 0.5. In all the three cases the correlation of SCI and CI with ΔM_{E} has been weak or less than moderate.

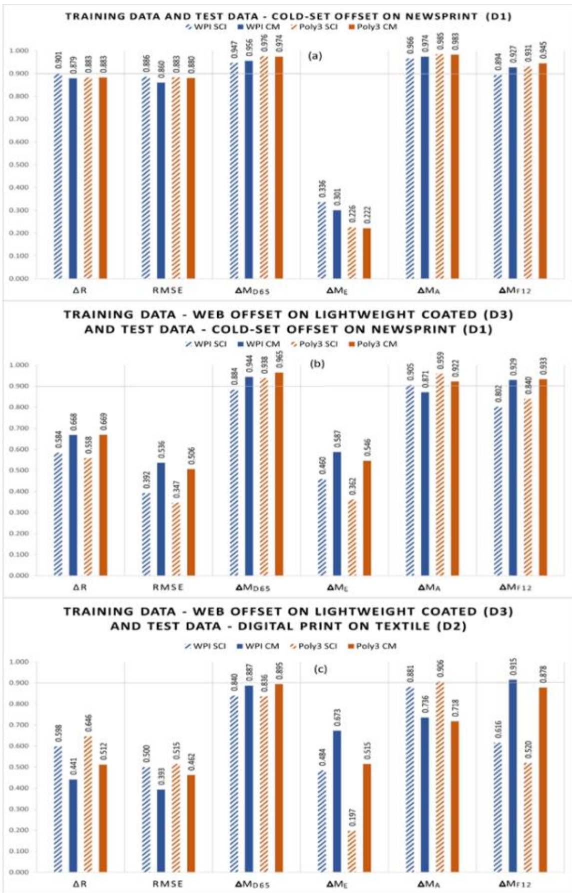

Figure 1. Graph of metric correlations obtained for spectra estimated using (a) D1 as both training and test data, (b) D1 as test data and D3 as training data and (c) D2 as test data and D3 as training data – where spectral estimation methods used WPI (blue) and Poly 3 (orange). Slanted lines depict SCI and solid depict CI correlations to metrics ΔR, RMSE, ΔM_{D65}, ΔM_{E}, ΔM_{A} and $\Delta M_{F12,}$ respectively.

Figure 2 shows an example of reference spectra vs estimated spectra plot when metric values are (a) low and (b) high.

Conclusions

The new goodness-of-fit metric, CI with adjusted weights behaves like SCI while evaluating estimated spectra with various degrees of metamerism. Both SCI and CI can determine metamerism well between two spectra under source illuminant D50 and test illuminants D65, A and F12. The weights of CI can be adjusted to optimize the outcome to a desired attribute such as smoother spectra, low RMSE, metamerism or colour inconstancy based on the target application.

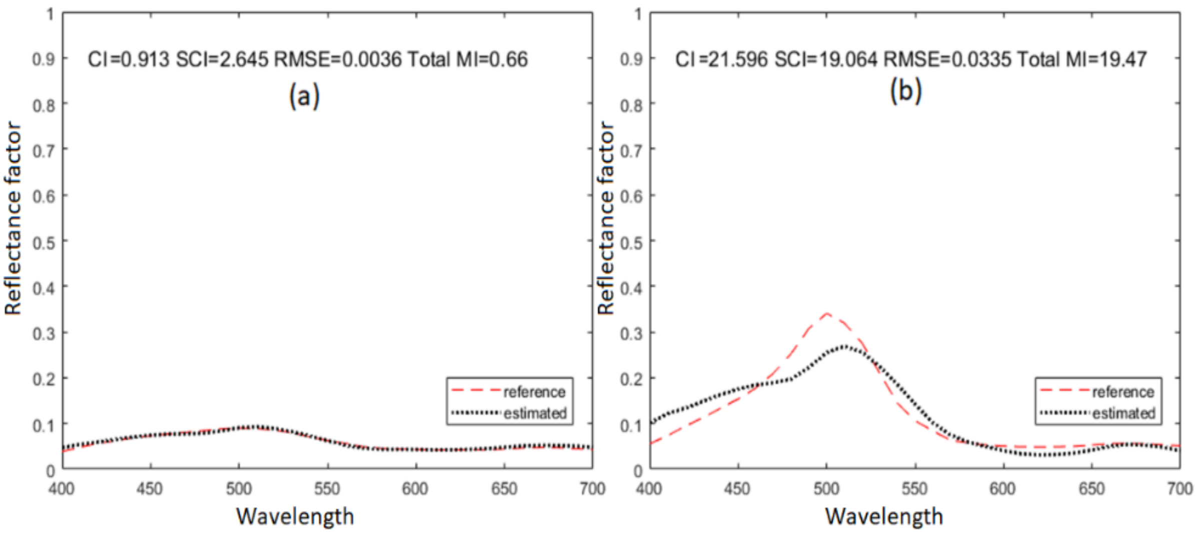

Figure 2. Example of reference vs estimated spectra plot when metric values are (a) low and (b) high.

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References

Derhak, M. W. et al. 2020. Wpt (waypoint) shift manifold difference metrics for evaluation of varying observing-condition (observer+illuminant) metamerism and color inconstancy. *Color Research & Application*, 45(6), 1005-1022.

Green, P. J. 2008. A smoothness metric for colour transforms. In *Color Imaging XIII: Processing, Hardcopy, and Applications* 155-159. SPIE.

Imai, F. H., Rosen, et al. 2002. Comparative study of metrics for spectral match quality. In *Conference on colour in graphics, imaging, and vision*, 492-496. Society for Imaging Science and Technology.

López-Álvarez, M. A. et al. 2005. Colorimetric and spectral combined metric for the optimization of multispectral systems. In *Proceedings of the 10th Congress of the International Colour Association*, 1685-1688. USA: Association Internationale de la Couleur.

Luo, M. R. et al., K. J. (2003). CMC 2002 colour inconstancy index; CMCCON02. *Coloration Technology* 119(5), 280-285.

Nimeroff, I. & Yurow, J. A. 1965. Degree of metamerism. *JOSA*, 55(2), 185-190.

Viggiano, J. S. 1990. The comparison of radiance ratio spectra: Assessing a model's "goodness of fit". In *Advanced Printing of Conference Summaries: SPSE's 43rd Annual Conference*, 222-225.

Viggiano, J. S. 2002. Perception-referenced method for comparison of radiance ratio spectra and its application as an index of metamerism. In *9th Congress of the International Colour Association*, 701-704. International Society for Optics and Photonics.

Viggiano, J. A. 2004. Metrics for evaluating spectral matches: a quantitative comparison. In *Conference on Colour in Graphics, Imaging, and Vision,* 286-291. Society for Imaging Science and Technology.

Simulating the Effect of Camera and Lens Choice for Color Accurate Spectral Imaging of Cultural Heritage Materials

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Abstract

Spectral sensitivity measurements from a set of 43 different professional level consumer cameras were used to assess the effects of factors including brand, model, lens, and internal IR filter removal on the simulated color accuracy of these cameras when used in a practical spectral imaging approach involving the collection of six spectral channels under two optimized lighting conditions. The findings offer insight into the robustness of the two-light method to such variables, suggesting that two-light spectral imaging using multichannel tunable LEDs is a reliable means of introducing practical, highly color accurate spectral imaging into cultural heritage studio photography workflows, regardless of the camera equipment used to carry out imaging.

Keywords: *cultural heritage, conservation science, spectral imaging, color accurate imaging*

Introduction

Over the past several decades, in the field of conservation science, spectral imaging has become synonymous with material characterization and mapping. As an analytical technique that is routinely employed in laboratory-based studies of artworks and artifacts to better understand their constituent components, it is well known as a powerful tool for noninvasively assessing these objects' construction and condition (Favero et al. 2017; Striova et al. 2018; Delaney et al. 2020). This association with one-off technical research studies has for the most part siloed the practice of spectral imaging at select institutions and research centers that have access to the expertise and specialized equipment necessary to carry out these advanced analytical initiatives. Recognizing this, there have been increasing efforts to make spectral imaging more accessible to the broader field of cultural heritage. Some of these have explored practical methods of implementing spectral imaging outside of strictly scientific settings, focusing instead on the viability and advantages of building spectral imaging into more routine digitization and archiving workflows carried out in photography studio environments (Berns 2018).

Recent efforts have focused on using cameras and imaging equipment that are either already found in or could be easily obtained by cultural heritage photography studios to carry out efficient spectral capture strategies that emphasize the advantage of collecting spectral master files for highly color accurate reproduction and archiving (Kuzio and Farnand 2022). In fact, the creation of color accurate spectral image archives was one of the early motivations for exploring the technique's utility within the context of cultural heritage imaging (Saunders and Cupitt 1993; Imai and Berns 1998). The capture and storage of spectral images rather than conventional color images is a more robust and flexible archival solution, because it enables the possibility to re-process the captured data later to meet various future reproduction and conservation needs (Berns 2005).

The work described herein builds on initial experiments that followed a color accuracy-guided framework for defining a more practical approach to spectral imaging (Kuzio and Farnand 2021a, 2021b). The previous work investigated a strategy which turned a commercially available three-channel color camera into a six-channel spectral imaging system by capturing pairs of RGB images under two different optimized lighting conditions provided by tunable LED light sources. The spectral power distributions of these lighting conditions were designed using a computational simulation to determine what two combinations of three out of ten narrow band LED channels in the tunable lights maximized the calculated imaging system colorimetric accuracy based on the spectral sensitivity properties of the particular camera and lens combination used. The theoretical colorimetric accuracy was assessed by simulating the rendering of a color target under all possible pairs of these lighting conditions and the optimal pair was deemed to be that which resulted in the rendering with the lowest mean DE_{00} with respect to the measured reference values of the target.

The current research applied the same computational optimization procedure to the spectral sensitivities measured from a larger set of commercially available, professional level ("prosumer") cameras, in order to study the generalizability of the two-light spectral capture strategy to more imaging systems. The spectral sensitivities of a total of 43 cameras of different brand, model, lens, and IR filter modification were used as inputs to the simulation, and the results have been examined toward determining the differences in color reproduction accuracy among or between:

- cameras of different brands/different models of the same brand
- a single camera outfitted with different lenses
- and IR modified and unmodified cameras

The findings presented below are informing ongoing endeavors to lower the barrier-to-entry for the integration of spectral imaging within routine cultural heritage digitization workflows. By emphasizing the ability to use the kinds of cameras photography studios are already equipped with, this work aims to communicate accessible scientific imaging practices to cultural heritage institutions that have been traditionally underrepresented in access to advanced imaging capabilities.

Equipment & Methods

Spectral Sensitivity Measurements

The spectral sensitivities of six cameras were measured in-house and are listed in Table 1 with details about whether the camera's IR filter had been removed or not, and the focal length of the prime lenses that were on the cameras during measurement. The measurements were taken following the setup and procedure described in (Tominaga, Nishi, and Ohtera 2021) using an Oriel Cornerstone monochromator, an Oriel Xenon source, and a Photo Research PR-655 spectroradiometer.

Brand	Model	IR filter?	Lens(es)
Canon	EOS 5D	Yes	85 mm
Canon	EOS 5D	No	85 mm
Canon	EOS 5D Mark II	No	85 mm
Canon	60D	No	50 mm, 85 mm, 100mm, 135 mm
Fujifilm	X-T100	Yes	14 mm
Sony	a7R III	No	24 mm, 50 mm, 90 mm

Table 1. Details about the six cameras from which spectral sensitivity measurements were made in-house.

The analysis also included the spectral sensitivity measurements of prosumer cameras available in the Image Engineering Spectral Sensitivity Database, which provided an additional 37 sets of camera sensitivities, and included nine Canon cameras, six Fujifilm cameras, ten Nikon cameras, and twelve Sony cameras. Further details about the cameras included in this set and the measurement procedures are available upon request (please contact the author[s]).

Simulation Design & Optimization Procedure

The simulation at the center of this study was designed to identify the two ideal lighting conditions to pair with an RGB camera's spectral sensitivity in order to capture two images (providing six spectral channels) that, when combined through colorimetric calibration, give a high color accuracy rendering. The two-light spectral capture strategy is based on the dual-RGB method developed and described in (Berns et al. 2005; Berns 2016). It is the focus of the current research due to its practicality and efficiency: it utilizes a familiar, affordable RGB camera, and enables the collection of six spectral channels through two captures taken using different filters or lighting conditions.

The optimization identifies two lighting conditions that are each made of illumination from three narrowband LEDs chosen from a larger pool of ten, which represent the ten channels available in a set of tunable LED lights, described previously (Kuzio and Farnand 2021a) and plotted in Figure 1.

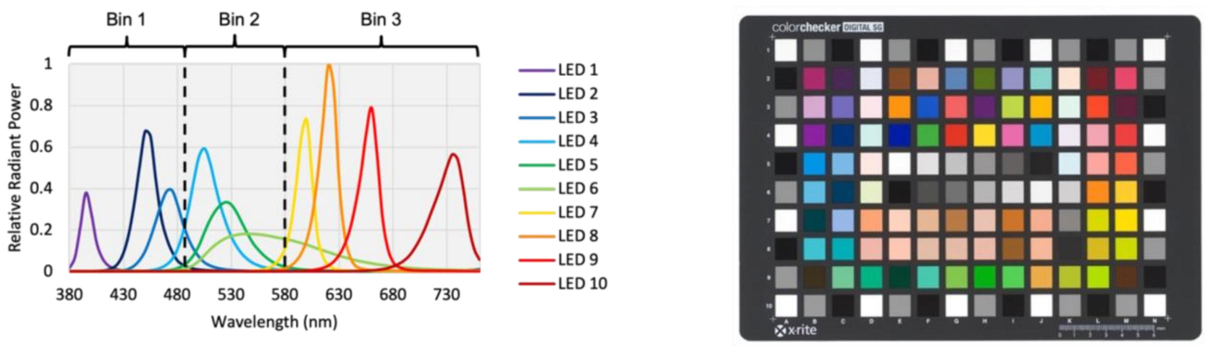

Figure 1. Spectral power distributions of the ten LED channels in the tunable LED lights (left), from which optimal combinations were determined based on the simulated reproduction of the Color Checker SG calibration target (right) when paired with each of the 43 sets of camera spectral sensitivity measurements.

While the details of the simulation have been described and depicted in detail in previous work (Kuzio and Farnand 2022), the high-level steps are:

1. The ten LED channels were separated into three bins according to peak wavelength (Figure 1).
2. The 36 possible combinations of three LEDs, upon choosing one from each bin, were listed.
3. The 630 possible pairs of the 36 three-LED combinations were enumerated, representing the 630 pairs of lighting conditions for carrying out two-light imaging.

Then, for each of the 43 sets of camera spectral sensitivities in turn,

4. The camera response was calculated for each of the 630 pairs of lighting conditions for a color calibration target, the Color Checker SG (CCSG) (Figure 1), according to the relationship: where the camera responses t_1 and t_2 under each lighting condition are the product of the spectral sensitivity of the camera T, the spectral power distributions of the first (S_1) and second (S_2) lighting conditions, and the spectral reflectance of the target patches (R). The CCSG was chosen as the calibration target because it is familiar in cultural heritage studio photography.

5. The combined six-channel camera response acquired between the two lighting conditions was used to predict, through a pseudoinverse relationship, the CIEXYZ tristimulus values of the target. The CIEXYZ values were then converted to CIELAB coordinates and compared to the target's measured CIELAB values using the CIEDE2000 formula.
6. The mean DE_{00} was compared across all 630 pairs of lighting conditions. The optimal pair for each of the 43 sets of camera sensitivities was that which gave the lowest mean DE_{00}, and therefore, the highest simulated average color accuracy.

Results & Discussion

Conventional RGB Imaging vs. Two-Light Spectral Imaging

To first make clear the advantage of the two-light spectral imaging strategy over conventional RGB imaging, Figure 2 is presented, which uses the spectral sensitivity of the Sony a7RM2 found in the Image Engineering Database as an example. The imaging system sensitivity, represented as the product of the light source(s) and the sensitivity of the camera, is given for the camera as paired with 1) an HMI studio lamp for conventional color imaging, and 2) the camera paired with the optimal two-light LED combinations found in the simulation for this camera. The heat maps indicate the simulated reproduction accuracy of the CCSG based on the respective imaging system sensitivities, in terms of color-coded DE_{00} values indicating the color difference between the measured and reproduced colors.

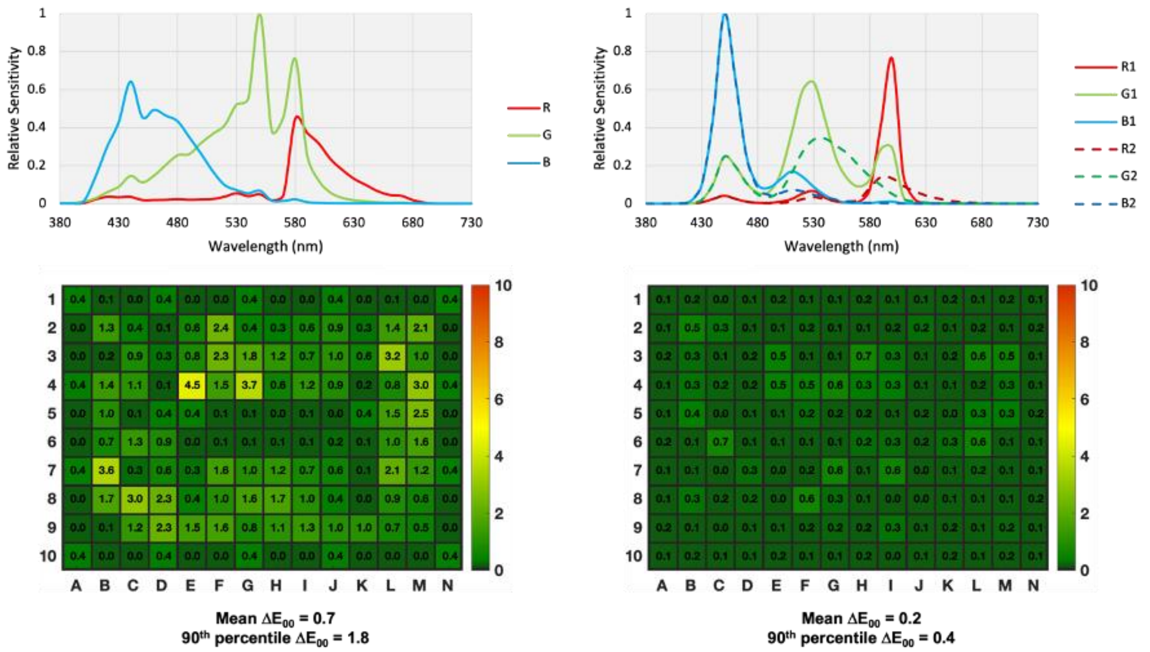

Figure 2. System sensitivities calculated when using the Sony a7RM2 as a conventional color camera paired with an HMI studio lamp (top left) and in the optimized two-light tunable LED spectral imaging approach (top right) with their corresponding simulated color reproduction of the CCSG target, illustrated with color coded DE00 heat maps (bottom).

While the mean DE_{00} values for the two methods are not very different (0.7 versus 0.2), especially when considering that a just noticeable color difference in digital images is considered to be about 2 DE_{00} units (Stokes, Fairchild, and Berns 1992), comparing the 90th percentile DE_{00} achieved by each (1.8 versus 0.4) makes it is clear that the two-light approach outperforms conventional color imaging in this representative example. Simple visual inspection of the DE_{00} heat maps reveals the presence of several outlier patches having DE_{00} values of 3 or more in the conventional color imaging reproduction, which is the cause of the difference between the 90th percentile DE_{00} values for the two imaging approaches. These outliers represent colors that are difficult to reproduce with the trichromatic sensitivity of conventional RGB imaging, but which are better characterized through the increased sampling afforded by spectral imaging using as few as six channels, as shown here.

Effects of Camera Brand, Model, Lens, and IR Modification

The means of the mean DE_{00} values for the cameras of each brand in the Image Engineering dataset are listed in Table 2. To two significant figures, they are nearly identical, indicating that on average, there is little practical difference in color reproduction accuracy based on camera brand alone.

Brand	Number of Cameras	Mean of Mean DE_{00}
Canon	9	0.19
Fujifilm	6	0.20
Nikon	10	0.21
Sony	12	0.19

Table 2. Comparison of the average color difference obtained across each set of cameras of the same brand.

To assess the relative performance of cameras of the same brand, but different model, as well as the effects of different lenses on the same camera, and the removal of the camera's internal IR filter, Kruskal-Wallis nonparametric analysis of variance testing was performed on the simulated DE_{00} values of these datasets. The results are summarized in Table 3. While some of the differences in mean DE_{00} values were identified as statistically significant, in practice, the difference in color reproduction accuracy indicated by, for example, 0.15 versus 0.25 DE_{00}, is not perceptually relevant.

Given the degrees of freedom that the ten-channel tunable LED light sources give to the optimization of two lighting conditions for high-accuracy color reproduction, it is unsurprising that the simulated results indicate that the studied variables have little practical effect on the average performance. While it may be desirable to reduce the number of LED channels in a tunable light source to bring down the cost of manufacture, a greater number of available channels in turn lends greater flexibility to the creation of two optimal lighting conditions, regardless of the spectral sensitivity of the camera being used. While these findings point toward a tradeoff in the universality of the tunable light source and its affordability, they support the claim that the two-light spectral capture strategy as investigated is a robust method to improve the reproduction of a larger gamut of colors, better characterizing some outliers that were difficult to reproduce with conventional color imaging.

Effect Studied	Mean DE_{00} Values	Significant Difference(s) Identified?	Notes
Camera model	Canon: 0.15 to 0.25 Fujifilm: 0.20 to 0.23 Nikon: 0.18 to 0.23 Sony: 0.17 to 0.22	Yes	Data from the IE database only; significant differences found between specific cameras giving the lowest and highest mean values, e.g. in the set of Canon cameras with the largest range
Lens choice	50 mm: 0.21 85 mm: 0.20 100 mm: 0.15 135 mm: 0.19	Yes	Data from the Canon 60D measured with four different lenses (see Table 1); 100 mm lens significantly different from the others
IR filter	In place: mean DE_{00} = 0.21 Removed: mean DE_{00} = 0.21	No	Comparison between IR modified and unmodified Canon 5D cameras

Table 3. Details about the analysis of variance testing performed to assess the differences in the average color accuracy based on the factors of camera model, lens choice, and IR filter removal.

Conclusions

The effectiveness of an optimized two-light spectral imaging strategy for cultural heritage studio photography has been studied through simulated color accuracy experiments that aimed to assess the effects of camera brand, model, lens choice, and IR modification on the performance of the setup. While some statistically significant differences were identified in the mean color difference obtained within some of these groups, the differences are so small perceptually that they are insignificant in practice. Of greater importance is the advantage of the two-light strategy over conventional color imaging, which illustrates the ability of this spectral imaging approach to reduce the number of outlier colors that are reproduced inaccurately.

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References

Berns, R. S. 2005. "Color-Accurate Image Archives Using Spectral Imaging." In *Scientific Examination of Art: Modern Techniques in Conservation and Analysis*, 105–19. Washington, DC.

———. 2016. "Theory and Practice of Dual-RGB Imaging." Rochester Institute of Technology.

———. 2018. "Practical UV-VIS-NIR Multispectral Imaging." In *Archiving 2018 Final Program and Proceedings*, 47–52. Washington, DC.

Berns, R. S., L. A. Taplin, M. Nezamabadi, M. Mohammadi, and Y. Zhao. 2005. "Spectral Imaging Using a Commercial Colour-Filter Array Digital Camera." In *The 14th Triennial ICOM-CC Meeting*, 743–50.

Delaney, J. K., K. A. Dooley, A. van Loon, and A. Vandivere. 2020. "Mapping the Pigment Distribution of Vermeer's Girl with a Pearl Earring." *Heritage Science* 8 (1): 1–16.

Favero, P. A., J. Mass, J. K. Delaney, A. R. Woll, A. M. Hull, K. A. Dooley, and A. C. Finnefrock. 2017. "Reflectance Imaging Spectroscopy and Synchrotron Radiation X-Ray Fluorescence Mapping Used in a Technical Study of The Blue Room by Pablo Picasso." *Heritage Science* 5 (1): 1–19.

"Image Engineering Camera Spectral Sensitivity Database." 2021. https://www.image-engineering.de/library/data-and-tools.

Imai, F. H., and R. S. Berns. 1998. "High-Resolution Multi-Spectral Image Archives: A Hybrid Approach." In Final Program and Proceedings - IS&T/SID *Color Imaging Conference*, 224–27.

Kuzio, O., and S. Farnand. 2021a. "Color Accuracy-Guided Data Reduction for Practical LED-Based Multispectral Imaging." In *Archiving 2021 Final Program and Proceedings*, 65–70.

———. 2021b. "LED-Based versus Filter-Based Multispectral Imaging Methods for Museum Studio Photography." In *Proceedings of the International Colour Association Conference 2021*, 639–44.

———. 2022. "Comparing Practical Spectral Imaging Methods for Cultural Heritage Studio Photography." *Journal on Computing and Cultural Heritage*, in press.

Saunders, D., and J. Cupitt. 1993. "Image Processing at the National Gallery: The VASARI Project." Edited by Ashok Roy. *National Gallery Technical Bulletin* 14: 72–85.

Stokes, M., M. D. Fairchild, and R. S. Berns. 1992. "Precision Requirements for Digital Color Reproduction." *ACM Transactions on Graphics* 11 (4): 406–22.

Striova, J., C. Ruberto, M. Barucci, J. Blažek, D. Kunzelman, A. Dal Fovo, E. Pampaloni, and R. Fontana. 2018. "Spectral Imaging and Archival Data in Analysing Madonna of the Rabbit Paintings by Manet and Titian." A*ngewandte Chemie - International Edition* 57 (25): 7408–12.

Tominaga, S., S. Nishi, and R. Ohtera. 2021. "Measurement and Estimation of Spectral Sensitivity Functions for Mobile Phone Cameras." *Sensors* 21 (4985).

An Investigation on Visual Colour Difference of 3D Printed Objects

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Abstract

This study aimed to investigate visual colour differences of 3D objects based on 42 pairs of 3D printed spherical samples with predominant lightness, chroma, or hue differences, ΔL^*_{10} $(or\ \Delta C^*_{ab,10}\ or\ \ \Delta H^*_{ab,10})$ / $\Delta E^*_{ab,10}$ ≥ 0.85. A psychophysical experiment with the grey scale method was conducted to collect visual colour-difference data assessed by human observers. It was found that it was generally easier to assess lightness and hue differences of 3D spherical objects but not chroma differences, and the results indicated that the parametric factors related to lightness, chroma and hue-differences in colour-difference formulas should be optimized specifically for 3D objects. To fit the visual data, the optimal parametric factors in CIELAB colour difference formula were recommended as k_L = 1.4, k_C = 1.9 and k_H = 1.

Keywords: *3D objects, colour difference, visual assessments, STRESS*

Introduction

Since 3D colour printing technologies have been developed rapidly, the colour measurement and colour-difference evaluation on 3D printed objects require further studies and quantitative methods to achieve faithful colour appearance reproduction of 3D objects (Walters et al. 2009 and Yuan et al. 2017). Moreover, the reproduction and measurement of 3D objects has been defined as one of top priority topics by CIE and listed as a Research Strategy, and the CIE TC 8-17 was established to develop methods for evaluating colour difference between 3D colour objects, investigating the effects on visual perception of colour difference caused by different 3D shapes, gloss, and materials.

To understand the basic visual perception of viewing coloured 3D objects, Hung et al. (2018) conducted a series of psychophysical experiments to quantify visual colour differences of 3D objects using a 7-step grey scale. It was found that chroma differences for high chroma or dark colours are not easy to be aware of, and the authors suggested that the lightness and chroma must be further scaled to fit the visual data. Jiang et al. (2021) used 3D printed samples with two different shapes to investigate the change of perceived colour differences caused by two different illuminations. The findings showed that the visual results for 3D and 2D objects were more similar under diffuse lighting than that under spotlight, and the colour-difference formulas tested had better performance for spherical samples than for flat samples under both light sources, which is quite surprising. The authors explained that it is probably affected by the range of colour-difference magnitudes.

Considering that the current colour-difference formulas, such as CIELAB, CIEDE2000, were developed based on 2D colour samples (CIE 2001), while 3D printed objects have uneven surface and non-uniform colour appearance illuminated in comparison to flat samples, it is therefore unknown whether the perceived colour differences of 3D objects are different from those of 2D objects and how the current colour-difference formulas perform on 3D colour objects. A comprehensive knowledge of visual perception of colour difference for 3D printed objects is strongly desired.

The present study aims to investigate visual colour difference of 3D printed objects from lightness, chroma and hue dimensions. Based on the five CIE recommended colour centres, 45 spherical samples were printed using the Stratasys J750 3D colour printer, and a total of 42 pairs of 3D samples were produced to have predominant lightness chroma hue differences. Moreover, a psychophysical experiment with the grey scale method was conducted, and the CIELAB colour-difference formula was tested and optimized with the visual data collected.

Visual Experiments

Sample Preparation

The Stratasys J750 3D colour printer was calibrated and used to print 45 spherical samples with the diameter of 50 mm, based on the five CIE recommended colour centres: grey, red, green, yellow, and blue (Robertson 1978). A total of 42 pairs of 3D samples were produced to have colour differences mainly (at least 85%) come from lightness (ΔL), chroma (ΔC) or hue (ΔH) dimensions. Specifically, 6 pairs of 3D samples with very similar chroma and hue but different lightness for the grey centre; for each of the other four colour centres, 3 pairs have differences mainly in lightness, 3 pairs have major chroma differences and 3 pairs have predominant hue differences. The colour-difference magnitudes of these sample pairs range from 2 to 10 CIELAB units, as shown in Figure 1.

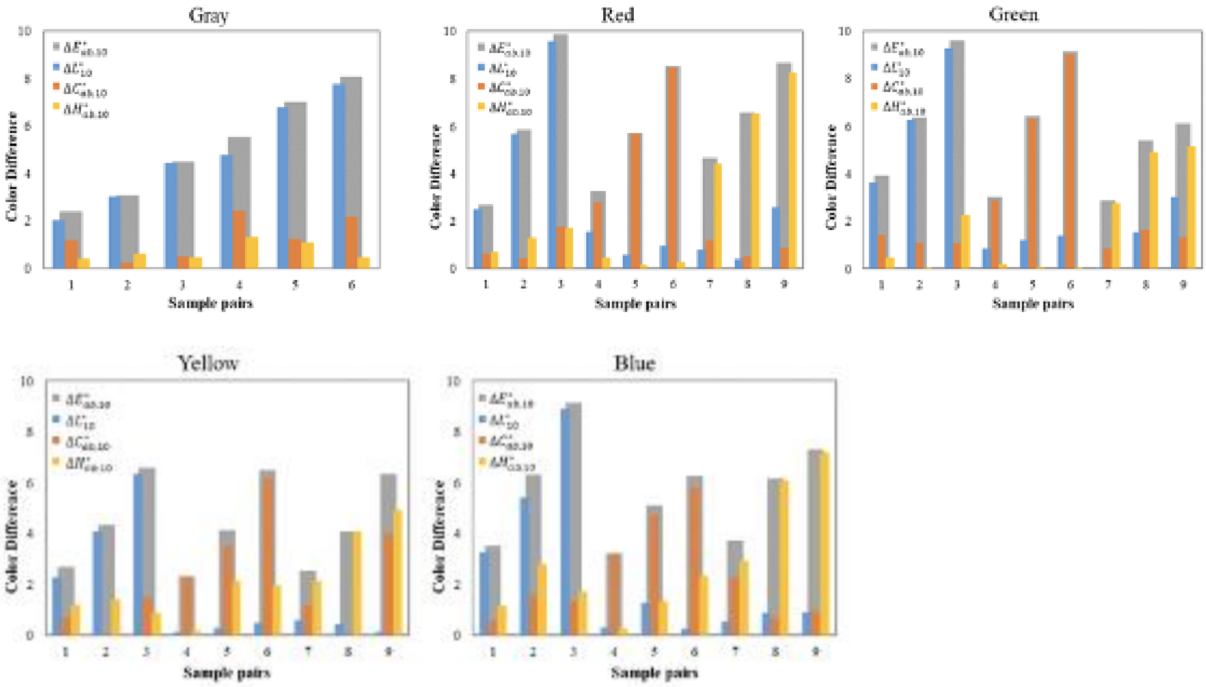

Figure 1. Values of $\Delta L^*_{10}, \Delta C^*_{ab,10}, \Delta H^*_{ab,10}, \Delta E^*_{ab,10}$ for the 42 pairs of 3D samples.

Visual Assessments

The *Grey scale for assessing change in colour* from the Society of Dyers and Colourists (SDC) was used in the psychophysical experiment, which consists of 9 scales of non-glossy neutral grey coloured chips. The colour difference of each scale measured using CM700d spectrophotometer is given in Table 1, and the relationship between each greyscale (GS) and the CIELAB colour difference (ΔE^*_{ab}) was fitted using the third polynomial regression, expressed as Equation (1).

Scale	L10*	a10*	b10*	ΔEab*	Scale	L10*	a10*	b10*	ΔEab*
0 (reference)	40.92	-0.47	-2.47						
1	54.27	-0.43	-2.76	13.36	3	44.23	-0.65	-2.85	3.34
1.5	50.35	-0.59	-3.23	9.47	3.5	43.32	-0.54	-3.01	2.47
2	47.65	-0.54	-3.28	6.78	4	42.55	-0.46	-2.81	1.67
2.5	45.61	-0.53	-3.6	4.83	4.5	41.76	-0.55	-2.64	0.87
3	44.32	-0.65	-2.89	3.44	5	41.09	-0.47	-2.48	0.18

Table 1. The CIELAB values and colour differences of each grey scale.

$$\Delta E^*_{ab} = -0.28 * GS^3 + 3.32 * GS^2 - 14.56 * GS + 24.85 \quad (1)$$

A VeriVide viewing cabinet fitted with a D65 simulator was used for the visual colour-difference assessment. The spectral power distribution of the D65 illumination was measured using a CS2000 spectroradiometer, and the correlated colour temperature and luminance measured in the centre of the viewing cabinet were 6519 K and 412.35 cd/m^2, respectively.

The visual experiments were conducted in a dark room, and each human observer was asked to adapt to the dark surroundings for two minutes. There was a pilot experiment to train observers for visual assessment using the grey scale method before the first assessment. The observer's task was to assess the magnitude of the colour difference in each pair of 3D samples which were placed in the centre of the viewing cabinet, compared to the perceived colour differences in the grayscale. All the 3D sample pairs were presented in a random order, and observers were asked to repeat the visual assessments three times.

Figure 2. An example of the visual colour-difference assessments.

In this study, 15 observers (10 females and 5 males) were invited to participate in the visual assessments, and a total of 1890 assessments (42 pairs × 15 observers × 3 times) were conducted. The participants were postgraduate students from the University of Leeds and had normal colour vision according to the Ishihara test.

Results:

The grey scale values given by human observers in the psychophysical experiment were converted to the visual colour-difference values by using the Equation (1), and the intra- and inter-observer variability was quantified using the *STRESS* index based on the visual colour-difference data (Melgosa et al. 2011), which were 24.8 and 25.2 units, respectively.

Figure 3 shows the plots of ΔV against $\Delta L^*_{10}, \Delta C^*_{ab,10}, \Delta H^*_{ab,10}$ of the 42 samples pairs, and three linear curves were fitted respectively for lightness, chroma and hue differences. It can be seen that the lightness, chroma and hue differences calculated using the CIELAB formula are almost in the same magnitude range, from 2 to 10 units, but the perceived visual colour differences are very different for these three components, which are approximately 1.0-3.0 units for chroma differences, 0.5-5.5 units for lightness differences, and 1.5-5.5 units for hue differences. This indicated that the human colour visual system has different responses to hue, lightness and chroma changes of 3D samples in CIELAB.

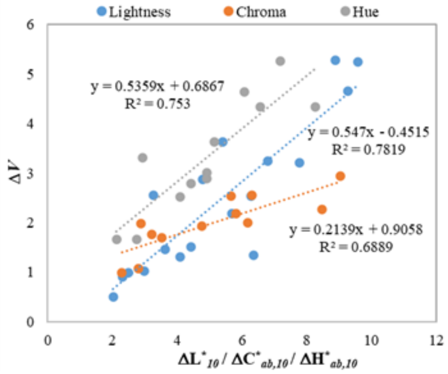

Figure 3. Plots and correlations of ΔV against $\Delta L^*_{10}, \Delta C^*_{ab,10}, \Delta H^*_{ab,10}$ of the 42 spherical samples pairs.

In addition, the fitted hue-difference linear line has a very similar slope with the light-difference linear line, but the hue-difference data is much closer to the visual results than the other two groups of data. Moreover, the slope and R^2 values of the fitted chroma-difference line are much smaller than those of lightness and hue-difference fitted lines, which indicates that the visual results of chroma difference have poorer agreement to the prediction and the colour-difference formula should be improved for 3D objects, especially in chroma scale.

In order to investigate the performance of CIELAB formula on predicting lightness, chroma and hue differences, the *STRESS* values were calculated between the visual results and the calculated CIELAB colour-difference values of the 42 sample pairs. The results obtained were given in Table 2, the smaller the *STRESS* values, the better the agreement between perceived and computed colour differences. It can be clearly seen that the *STRESS* values for lightness, chroma and hue differences are 23.7, 21.7 and 17.7, respectively, showing that the visual data are more consistent to the prediction in hue dimension than lightness and chroma dimensions.

	ΔL^*_{10} pairs	$\Delta C^*_{ab,10}$ pairs	$\Delta H^*_{ab,10}$ pairs
CIELAB	23.7	21.7	17.7

Table 2. The *STRESS* values in CIELAB units of the 42 pairs of 3D samples with predominant lightness, chroma and hue-differences.

The findings show the CIELAB formula should be improved in predicting colour differences of 3D objects. Considering that most current advanced colour-difference formulas were derived by modifying the CIELAB formula (Luo et al.

2001), following the generic Equation (2), the parametric factors, k_L, k_C, k_H, were optimized with the visual data collected from this study. The goal was to minimize the *STRESS* value between the visual data and the prediction calculated using a color-difference formula using the *fminsearch* function in MATLAB.

$$\Delta E = \sqrt{\left(\frac{\Delta L^*_{10}}{k_L S_L}\right)^2 + \left(\frac{\Delta C^*_{ab,10}}{k_C S_C}\right)^2 + \left(\frac{\Delta H^*_{ab,10}}{k_H S_H}\right)^2 + \Delta R}, \quad (2)$$

where $\Delta L^*_{10}, \Delta C^*_{ab,10}, \Delta H^*_{ab,10}$ are the CIELAB metric lightness, chroma, and hue differences, respectively, k_L, k_C, k_H and S_L, S_C, S_H are the three parametric factors and weighting functions for lightness, chroma, and hue differences, respectively, and ΔR is an interaction term between chroma and hue difference. In the CIELAB formula, $k_L, k_C, k_H, S_L, S_C, S_H$ were all set as 1 and $\Delta R = 0$.

Three optimizations were performed:

- Optimize k_L factor with $k_C = k_H = 1$
- Optimize k_C factor with $k_L = k_H = 1$
- Optimize both k_L and k_C factors with k_H =1

Table 3 gives the *STRESS* values and corresponding optimized factors for CIELAB formula. The *STRESS* value calculated using the original CIELAB formula (k_L = k_C = k_H = 1) is 28.6, after optimizing k_L and k_C factors separately, the corresponding *STRESS* values are 28.5 and 24.8, respectively. It is indicated that better improvement can be achieved by optimizing k_C factor than k_L factor in the CIELAB color-difference formula. It is not surprising because there are some problems for CIELAB in predicting chroma differences. By optimizing both k_L and k_C factors in CIELAB, the STRESS value decreased from 28.6 to 20.5, and the optimization of the CIELAB formula with k_L = 1.4 and k_C = 1.9 has significantly better performance than the original CIELAB formula.

	Original ($\boldsymbol{k_L}$=$\boldsymbol{k_C}$=$\boldsymbol{k_H}$=1)	Optimize $\boldsymbol{k_L}$	Optimize $\boldsymbol{k_C}$	Optimize $\boldsymbol{k_L}$ and $\boldsymbol{k_C}$
CIELAB	28.6	28.5 (k_L = 1.1)	24.8 (k_C = 1.5)	20.5 (k_L = 1.4, k_C = 1.9)

Table 3. The *STRESS* values and corresponding optimized parametric factors for CIELAB formula.

Conclusions

The visual colour-difference results show that human colour perception for 3D objects differs in lightness, chroma, and hue dimensions, where the STRESS values calculated are 23.7, 21.7 and 17.7, respectively. It is indicated that hue differences were more consistent with the visual data than lightness and chroma differences. The parametric factors in CIELAB colour difference formula were optimized to fit the visual data of 3D objects, and the STRESS value decreased from 28.6 to 20.5 with k_L = 1.4, k_C = 1.9 and k_H = 1 in CIELAB formula.

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References

Walters P., Huson D., Parraman C., and Stanić M. 2009. 3D printing in colour: Technical evaluation and creative applications. In: Impact 6 international printmaking conference, *Proceedings of the Impact. Bristol, UK*, 1-16.

Yuan, J., Zhu, M., Xu, B. and Chen, G., 2018. Review on processes and color quality evaluation of color 3D printing. *Rapid Prototyping Journal* 24(2): 409-415.

Hung, W., Sun, P., Lai, Y. and Chen, Y. 2018. A Visual Evaluation of Color Differences between 3D Objects. In: *Proceedings of CIE 2018. Taipei, Taiwan*, 362-368.

Jiang, L., Cui, G., Melgosa, M., Xiao, K. and Sueeprasan, S. 2021. Color-difference evaluation for 3D objects. *Opt. Express* 29, 24237–24254.

CIE. 2001. *Improvement to Industrial Color-Difference Evaluation.* CIE Central Bureau: Vienna, Austria.

Robertson, A.R. 1978. CIE guidelines for coordinated research on color-difference evaluation. *Color Res. Appl* 3, 149–151.

Melgosa, M., García, P.A., Gómez-Robledo, L., Shamey, R., Hinks, D., Cui, G., and Luo, M.R. 2011. Notes on the application of the standardized residual sum of squares index for the assessment of intra-and inter-observer variability in color-difference ex-periments. *J. Opt. Soc. Am. A* 28, 949–953.

Luo, M.R., Cui, G. and Rigg, B. 2001. The development of the CIE 2000 colour-difference formula: CIEDE2000. *Color Res. Appl 26*, 340–350.

The Luther Condition for All: Evaluating Colorimetric Camera Design for Personalized Color Imaging

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Abstract

The Luther condition has been a guideline for colorimetric camera design. However, the standard observer only represents an average observer without considering the inter-observer variability. Thus, there is still potential observer-camera metamerism between a camera colorimetric to the standard observer and an actual observer that has different CMFs. In this work, 1000 sets of CMFs were used to evaluate the RIT camera sensitivity dataset that includes 28 representative cameras. In general, it is found that the camera performances averaged across the individual observers can be predicted from the standard observer. However, the ranking by the standard observer would not be approved by some individuals; therefore, a camera less colorimetric to the standard observer can be more colorimetric to an individual observer. And two cameras that are similarly colorimetric to the standard observer can have different levels of variation for the whole population. Furthermore, when the individual observer's CMFs are unknown, the typical color characterization using the standard observer may likely cause higher mismatches between the camera and the individual observer. This work provides theoretical insights for personalized color imaging, where from camera to display, color can be consistently captured and rendered for any individual observer.

Keywords: *Camera Sensitivity, Luther Condition, Color Matching Functions, Individual Difference*

Introduction

Trichromacy, Metamerism, and Color Matching Functions

Human color vision is normally trichromatic; that is, the sensory inputs are based on three types of retinal photoreceptors whose sensitivities respectively peak in the long, medium, and short ranges of visible wavelengths. The physical stimuli are, therefore, transformed from a higher dimensional spectral space to a 3D space, represented as a triplet of cone responses on the retinal level. This dimensional collapse leads to the equivalence condition of different spectra with the same color, which is called metamerism. The standardization of colorimetry is based on metamerism and color matching experiments, resulting in the embodiment of standard observers and their color matching functions (CMFs).

Standard observers, such as CIE 1931 2-deg and 1964 10-deg observers, are statistically averaged results from the subjects in color matching experiments. Although they have been serving as decent representative observers and the cornerstone of colorimetry's success in color applications, recent work highlights their deficiency in color-critical situations where narrow-band spectra may be viewed as mismatches for individual observers that have different CMFs due to physiological variations. Knowing an individual's CMFs (together with the availability of spectral information) can help improve personalized color imaging and color management (Asano 2015); the color perceived in the physical world will be captured and rendered faithfully in the digital counterpart for this individual observer. Augmented reality, for example, is among many applications where metamers from different sources may be viewed simultaneously.

Camera Sensitivity and the Luther Condition

Cameras that are expected to record what trichromatic humans see have (at least) three channels with different sensor sensitivities, i.e., RGB cameras. The design of camera sensitivities is a multi-objective optimization process considering quantum efficiency, noise level, colorimetric accuracy, and spatial image quality together, given the practical constraints in manufacturing, etc. (Finlayson & Zhu 2020, Berns 2021). To optimize the colorimetric accuracy alone, the Luther condition has been a guideline for colorimetric camera design, which is fulfilled when a linear transformation between a given set of CMFs and camera sensitivity function exists (Luther 1927). Such a camera can be used as an imaging colorimeter, which can conveniently measure colorimetric information spatially. For any pixel, in other words, the metameric matches for the colorimetric camera are also matches for the corresponding observer. There is no observer-camera metameric failure, and the post-processing applied to the camera raw signals cannot distinguish and separate the metamers; thus the tristimulus matches stay undistorted.

To quantify the Luther condition fulfillment and the camera color quality in general, different metrics have been proposed, such as Vora value (Vora & Trussell 1993), metamer mismatch body (Roshan & Funt 2020), and various color difference statistics for a given set of illuminated targets (Berns 2021). They have different theoretical bases and can be interpreted according to the inputs and the calculations. Better metric performances mean the camera is closer to the Luther condition, thus more colorimetric. As there are several components in the optical path from the (illuminated) objects to the camera sensor, instead of changing the sensor mosaic, different optimizations are possible to improve the colorimetric camera as a system. Recently, Finlayson and Zhu have computationally demonstrated how to add a physical filter via optimizations in either Vora value or color difference metrics (Finlayson & Zhu 2020). They also considered the physical constraints such as smoothness.

Note that the original Luther paper predates the birth of CIE standard observers, which does not preclude itself from being generalized to any individual observer. However, previous work on colorimetric camera design has primarily focused on the standard observer without considering the individual difference in CMFs. While an imaging colorimeter that can report standard CIE XYZ values is desirable, in this paper, we are more interested in personalized color imaging, and the corresponding colorimetric (in a broader sense) camera design. Specifically, the generalized Luther condition, i.e., the colorimetric mapping relation between a given camera-observer pair was evaluated. In addition, the impact of color correction, one critical step in translating camera responses to tristimulus values, was investigated, especially when the individual CMFs were inaccessible. The next section describes the evaluation we conducted, followed by the results and the discussion. The key findings and their implications are summarized in the end.

Evaluation Methods

Dataset and Metrics

To evaluate how colorimetric the commercial cameras can be for each individual observer's CMFs, the RIT camera sensitivity dataset (Jiang et al. 2013), which includes 28 representative cameras and the individual observer dataset from (Asano et al. 2016) were used, from the latter of which 1000 sets of CMFs were generated for 2-deg visual field and age distribution from the US Census 2010. Therefore, 1000-by-28 combinations of colorimetric mapping relations needed to be evaluated. Following the computational procedures and settings (Finlayson & Zhu 2020), the degree of being colorimetric (or color verisimilitude) was quantified by Vora value and CIELAB-style color differences. For the Vora value, the inputs were one camera's sensitivity versus one individual's CMFs (without dependency on illuminant and reflectance information). When calculating color differences, the SFU datasets of 102 illuminants and 1995 reflectances (Barnard et al. 2002) were used. The camera responses under a given illuminant were transformed to the individual's tristimulus values with a corresponding color correction matrix (CCM) using least-square linear regression, assuming the individual's CMFs and other spectral information were known a priori. Then, the CIELAB-style color differences were calculated across all the illuminants, with the mean results reported. Similarly, the metrics for the 1931 standard observer were repeated for comparison.
Using a Fixed CCM

Since some of the assumptions above could not be practically met, here we consider the case that the individual CMFs were not known; thus, the CCM was not customized during the profiling step. That is, the converted XYZ values from camera responses are instead *standard-observer-referred*. And for calculating the color differences, those standard XYZs were compared against the individual observer's CMFs integrated with the illuminated spectra. Comparing tristimulus values across different CMFs is not common but can be thought of as the physical difference in the color matching weights of XYZ primaries, which is then propagated through the color correction transformation tailored only for the standard observer. The white point in CIELAB was set using the standard CMFs, which only served as a nominal choice. The mean color difference results are reported as done above.

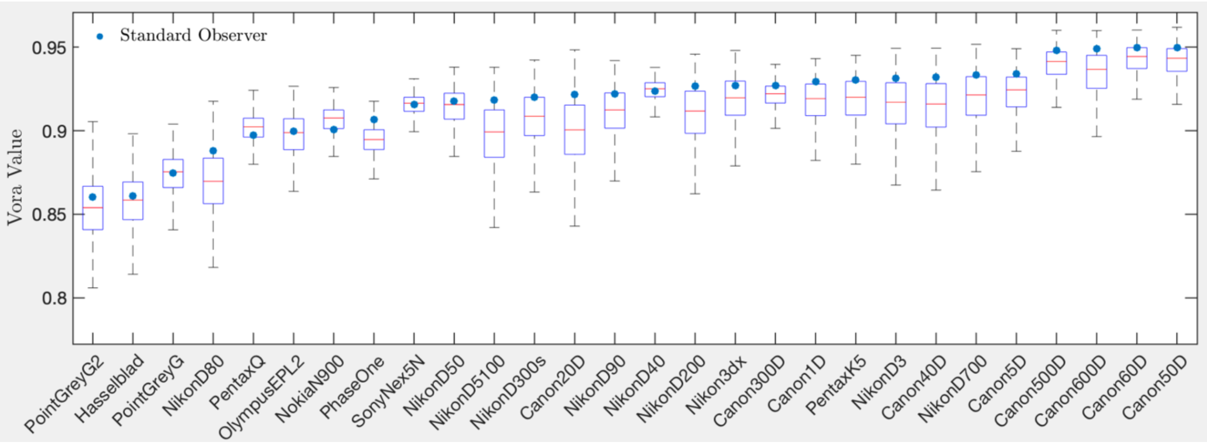

Figure 1. The distributions of Vora values for the 28 cameras are horizontally ordered based on the standard observer's Vora values, shown as blue dots. Each box corresponds to the Vora values of the 1000 observers for each camera. The red line is the median, and the bottom and top edges of the box indicate the 25th and 75th percentiles. If any, roughly a dozen of observer data were removed as outliers for visualization clarity.

Results and Discussion

As shown in Fig. 1, the Vora values expanded from 0.86-0.95 for the standard observer to 0.78-0.96 for all individual-camera combinations, and similarly, the CIELAB metric increased from 1.10-2.96 to 0.97-4.30 CIELAB units in Fig. 2. In general, the camera performances averaged across the individual observers can be predicted from the standard observer (the blue dots), with the Pearson correlation coefficients of 0.952 and 0.989 for the Vora value and the CIELAB difference, respectively. The standard observer may not fall into the range of 25th and 75th percentiles, especially for the color difference in Fig. 2. This is likely because the CIE 1931 observer is quite different from the average physiologically based observer (Xie et al. 2019). In addition, even if two cameras have similar Vora values for the standard observer, they may have different magnitudes of variations for a group of individual observers, for example, Nikon D40 versus

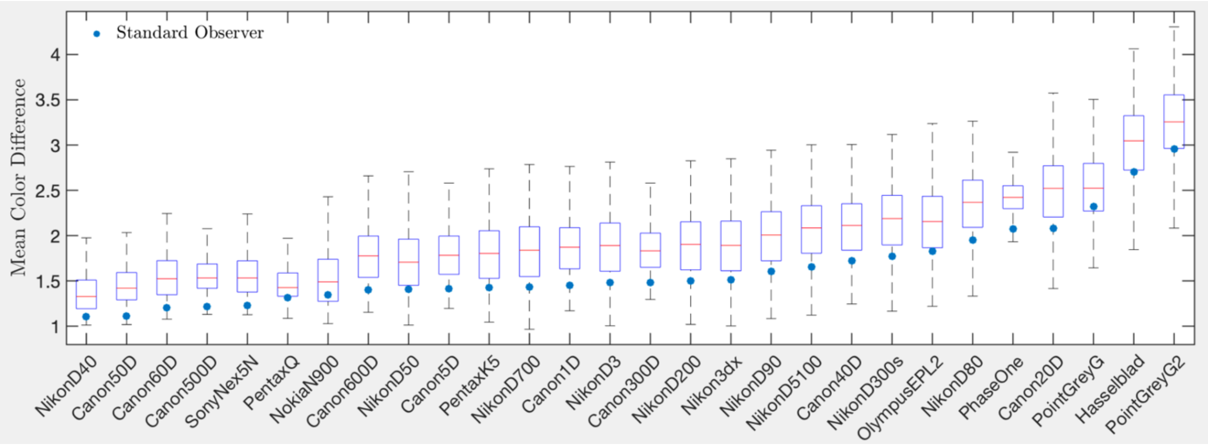

Figure 2. The mean CIELAB color difference distributions are similarly plotted as in Fig. 1.

Nikon D200 in Fig. 1, the former of which should be selected to maximize the larger population's satisfaction.

However, even though the average results confirm the utility of a standard observer, its predictive power might not hold for a given individual observer. Specifically, the lowest Pearson coefficient for the color difference was 0.156, and the worst Kendall's tau correlation for the Vora value was 0.196, meaning that the ranking by the standard observer would not be approved by such individuals, and a camera less colorimetric to the standard observer can be more colorimetric to an individual observer. Figure 3 presents the two extreme observers who can be best and worst predicted by the standard observer, respectively. This observer that has the lowest correlation also overall had lower Vora values, meaning those cameras tested might have higher observer-camera metamerism for them. While (Finlayson & Zhu 2020) have presented the optimized results for those 28 cameras, here we mainly focused on the evaluations, leaving further room for optimization for future work when necessary.

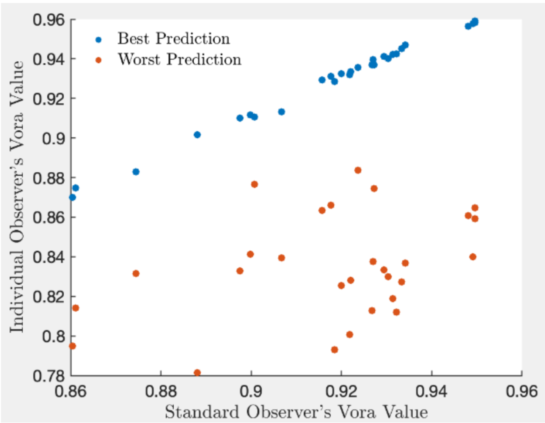

Figure 3. The observers with the highest and lowest Kendall's tau correlation relative to the standard observer in terms of Vora value. The orange points correspond to the observer whose camera ranking had the lowest correlation.

Results of a Fixed CCM

Between the two types of evaluation metrics, which are generally correlated, the Vora value is faster to compute and can generally predict the potential of observer-camera metamerism (Berns 2021); while the higher the better, a value of 0.95 is normally considered very good performance (Finlayson & Zhu 2020). The color difference statistics are probably more interpretable and practical since the calculation procedure can incorporate the steps implemented in the camera pipeline. The practical steps include white balance (estimating the illumination) and color correction. In particular, color correction that is done in camera characterization usually assumes the availability of the spectral information, including the sample targets such as a color-checker, the illumination, and the observer's CMFs. If the CCM is fixed using the standard observer's CMFs, the mean color difference, shown in Fig. 4, for each camera increased by 0.95-1.46 CIELAB units, which were averaged across the 1000 observers. Interestingly, for a given camera, the mean color differences for those 1000 observers did not correlate between a personalized CCM and a standard CCM, suggesting the fixed CCM impacted the results on a group level rather than on an individual level.

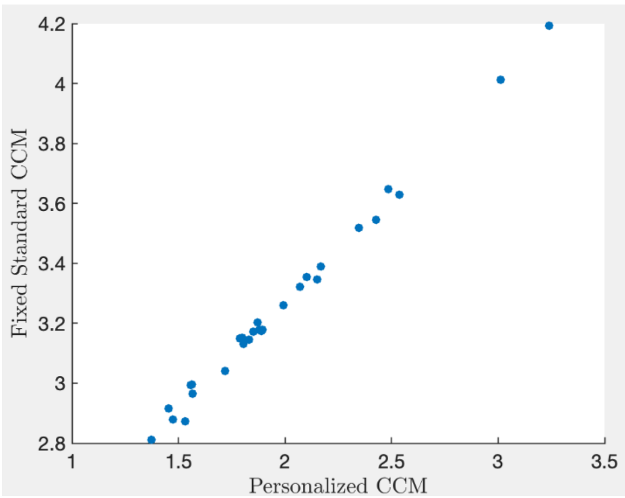

Figure 4. The mean color differences using a fixed CCM against a personalized CCM, each dot as one camera.

Recent work has also presented practical solutions for color correction with more interpolation anchors for different illuminants (Karaimer & Brown 2018) and has shown that the uncertainty of illuminant estimation can significantly impact the colorimetric performance (Tedla et al. 2022). Therefore, our results can be interpreted as upper bounds with ideal illuminant spectrum estimation.

Conclusion

In this paper, the general case of the Luther condition is investigated. Instead of considering only the standard observer, the colorimetric relations between any pair of cameras and individual observers were evaluated. Quantitatively, we show that a camera less colorimetric to the standard observer can be more colorimetric to an individual observer. And two cameras that are similarly colorimetric to the standard observer can have different levels of variation for the whole population. Furthermore, when the individual observer's CMFs are unknown, the typical color characterization using the standard observer, although a practically reasonable compromise, may likely cause higher mismatches between the camera and the individual observer.

This work inherits the essentially democratic nature of the Asano model, and with naïve optimism, we hope this approach can help the supply and demand find better matches and probably relax the single-observer dictated specs. By considering the camera as another metamerism source, this work, in addition to the previous work on observer metamerism, particularly in wide-gamut displays (Xie et al. 2017), provides further theoretical insights for personalized color imaging, where from camera to display color can be consistently captured and rendered for any individual observer.

Acknowledgements

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References

Asano Y. 2015. Individual Colorimetric Observers for Personalized Color Imaging. Ph.D. Dissertation. Rochester Institute of Technology.

Asano, Y., Fairchild, M. D., & Blondé, L. 2016. Individual colorimetric observer model. *PLoS ONE* 11(2): e0145671.

Barnard, K., Martin, L., Funt, B., & Coath, A. 2002. A data set for color research. *Color Research & Application* 27(3): 147-151.

Berns, R. S. 2021. Predicting Camera Color Quality. In: *Archiving Conference*, 61-64.

Finlayson, G. D., & Zhu, Y. 2020. Designing color filters that make cameras more colorimetric. *IEEE Transactions on Image Processing* 30: 853-867. [Code available on Github: https://github.com/zhedazhu1012/Filterdesign]

Jiang, J., Liu, D., Gu, J., & Süsstrunk, S. 2013. What is the space of spectral sensitivity functions for digital color cameras?. In: *IEEE Workshop on Applications of Computer Vision (WACV),* 168-179.

Karaimer, H. C., & Brown, M. S. 2018. Improving color reproduction accuracy on cameras. In: *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 6440-6449.

Luther R. 1927. Aus dem Gebiet der Farbreizmetrik. *Z. Tech. Phys*. 8: 540-558.

Roshan, E., & Funt, B. 2020. Color Sensor Accuracy Index Utilizing Metamer Mismatch Radii. *Sensors* 20(15): 4275.

Tedla, S., Wang, Y., Patel, M., & Brown, M. S. 2022. Analyzing color imaging failure on consumer-grade cameras. *JOSA A* 39(6): B21-B27.

Vora, P. L., & Trussell, H. J. 1993. Measure of goodness of a set of color scanning filters. *J. Opt. Soc. Am. A* 10(7): 1499-1508.

Xie, H., Rodríguez-Pardo, C. E., & Sharma, G. 2017. Multiobjective optimization for color display primary designs. *Journal of Electronic Imaging* 26(6): 063013.

Xie, H., Farnand, S. P., Murdoch, M. J., Park, J. S., & Min, B. 2019. Color Mismatches across Commercial Displays: Modeling the Effect of Observer Metamerism. In: *SID Symposium Digest of Technical Papers*, 1374-1377.

Psychophysical Colour

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Abstract

The CIE International Lighting Vocabulary (ILV) defines the word “colour” in two distinct senses, “perceived” colour and “psychophysical” (i.e., colorimetric) colour. Colorimetric specification of lights and objects can be a source of confusion in the broader colour community, and many find the concept of colorimetric or psychophysical “colour” to be suspect or even nonsensical. This paper reviews the connections between colour stimuli, colour perceptions, and colorimetric specifications, leading to consideration of the ontology of colour implicit in the two CIE definitions. In defining two senses of the word “colour” the CIE ILV expresses a pluralist ontology that acknowledges that we may wish to use the word “colour” either for our perceptions of colour or for the perceivable properties of lights and objects that these perceptions are based on. A colorimetric specification of a light identifies a class of spectral distributions that share a common overall balance at the level of their long-, middle-, and short-wavelength components as detected by the human visual system, resulting in a common disposition to evoke a perceived colour. A colorimetric specification of an object identifies for practical purposes a class of spectral reflectances having a common disposition to evoke a perceived object colour in daylight.

Keywords: *Colour education, perceived colour, psychophysical colour, colorimetry, colour ontology*

Introduction

The CIE *International Lighting Vocabulary* (ILV) defines the word “colour” in two distinct senses. “Colour” in the perceptual sense or “perceived colour” (CIE e-ILV 17-22-040) is defined as a “characteristic of visual perception” that can be described by six attributes, each of which is in turn defined as an “attribute of a visual perception”, either directly (*hue, brightness, and colourfulness*) or indirectly (*lightness, saturation, and chroma*).

“Colour” in the psychophysical sense is defined as a “specification of a colour stimulus in terms of operationally defined values, such as three tristimulus values” (CIE e-ILV 17-23-001). “Tristimulus values” (CIE e-ILV 17-23-038) are in turn defined as the “amounts of the reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered”, giving as examples the tristimulus values represented by the symbols R, G, and B, and X, Y, and Z in CIE colorimetry.

Colorimetric specification of lights and objects can be a source of confusion in the broader colour community. One often encounters the view that colorimetry is "all very well for technology but has nothing to do with human perception" and many find the concept of psychophysical or colorimetric "colour" to be suspect or even nonsensical. How can a numerical specification be considered to be a colour? This paper will outline a way to connect or reconnect the dots between colour stimuli, colour perceptions, and colorimetric specifications in a nontechnical way, and will conclude by considering the pluralist colour ontology implicit in the CIE definitions of *perceived colour* and *psychophysical colour*.

Colours of Lights

Newton showed that the colour of an isolated light could be predicted from the overall balance of its spectral components in relation to a two-dimensional circuit of directions of imbalance relative to daylight. The hue of a light could be predicted from the direction of imbalance or bias relative to daylight, and the saturation or "distance from whiteness" of the light could be predicted from the amount of imbalance. Another way of saying this is that the perceived colour of an isolated light is the way in which we perceive the overall balance of its spectral components. Thus, white as a colour of an isolated light is the way in which we perceive an overall spectral balance similar to that of daylight; whitish orange as a colour of an isolated light is the way in which we perceive a spectral distribution biased in a certain way towards the longer wavelengths of the spectrum, and so on.

Of course, colour perceptions are not based on instrumental measurements but on the responses of the human visual system and are therefore shaped in part by the characteristics of that system. We now know that Newton's directions of perceivable imbalance form a two-dimensional circuit because they arise from the responses of three cone cell types that divide the visible spectrum into long-, middle- and short-wavelength bands, in each of which one cone cell class responds more than the other two. Comparison of these responses by the process of cone opponency allows a colour-normal observer to detect a two-dimensional circuit of directions of spectral imbalance towards long, middle, short, or long *and* short wavelengths respectively.

Our dependence on the responses of three cone cell types means that physically different lights can evoke the same relative response of the three cone cell types, and therefore *match* in perceived colour when viewed under the same conditions. For example, very different spectral distributions can have an even overall balance, lacking any overall bias towards long, middle, or short wavelengths. Any number of physically different spectral distributions can share this same overall balance of components from the viewpoint of the human visual system, which is the *perceivable property* that these different spectral distributions, called metamers, have in common.

Finally, perceived colours can be influenced by a variety of factors in addition to CIE e-ILV 17-22-040.to the spectral properties of the stimulus, as acknowledged in Note 1 appended Nevertheless, despite the influence of these other factors, it is reasonable to say that in many ordinary circumstances we perceive variations in the spectral composition of light at the level of its long-, middle and short-wavelength components as different colours. This of course is why we're all looking at machines that work by emitting different mixtures of long-, middle- and short-wavelength light.

Colours of Objects

The CIE e-ILV defines an *object colour* as a "colour perceived as belonging to an object" (CIE e-ILV 17-22-042), where the word "colour" links to the entry for "perceived colour". So, an "object colour" as defined in the CIE ILV is a *visual perception* perceived as belonging to an object. In the image below we perceive the cube to have a uniform high-chroma orange object colour, as if it were painted all over with the same high-chroma orange paint, even though the image areas depicting its left, right and top planes send different amounts of light to the eye and evoke different responses at the level of the retina. Similarly, we perceive the lighter-coloured areas of the floor as being white things, even though the corresponding image areas send very different amounts of light to the eye. These object colour perceptions thus do not correlate directly with cone cell responses at the level of the retina, but instead seem to involve some form of rapid, automatic, and unconscious comparison of these responses by which we parse the visual field into a perception of illumination and perceptions of object colours that relate to the objects' *spectral reflectance*. Although they are perceptions, we perceive object colours to be located outside us in objects themselves, as in the white and high-chroma orange object colours we perceive to be located in the *physically non-existent* tiles and cube depicted here. In Newton's terms, object colours as defined by the CIE are not what he called "Colours in the Object", that is, an object's disposition to evoke a perception of colour by reflecting some wavelengths more than others. They are what he would call our "*Sensations*" of "Colours in the Object".

I should note that under some circumstances even freely examined objects can evoke perceived colours that are very poorly correlated with their spectral properties, notably when the object is an *image area* in a depiction of an illuminated scene, as in the wonderful colour constancy illusions of Purves and Lotto (2003). Purves and Lotto believed that their demonstrations show that visual perceptions do not stand for the actual properties of objects in the physical world, and this idea has gained some traction in the broader colour community.

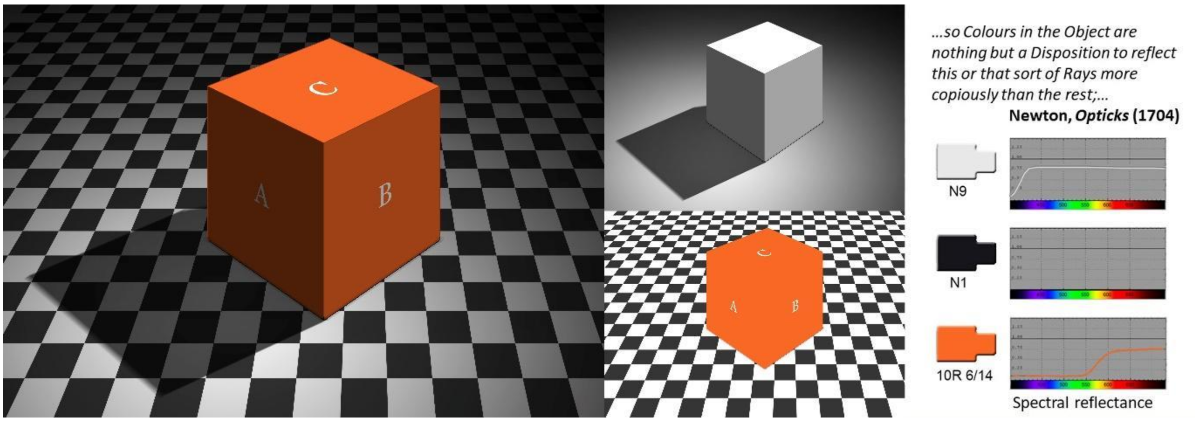

Figure 1. Illustration of object colour perception after Briggs (2021)

But we shouldn't lose sight of the overwhelming evidence that if we can freely examine an object in daylight, and the object is *not* an image area in a depiction of an illuminated scene, the colour we perceive as belonging to an object is generally a very good indication of the *spectral reflectance* at the level of its long, middle, and short wavelength components. Or to put this another way, under such conditions an object colour is the way in which we perceive the overall spectral reflectance of an object. Thus white as an object colour is the way in which we perceive a spectral reflectance that is very high and about equal in its long-, middle- and short-wavelength components, black as an object colour is the way in which we perceive a spectral reflectance that is very low and about equal in its long-, middle- and short-wavelength components, and a high-chroma object colour are the way in which we perceive a spectral reflectance that is strongly biased in towards certain wavelengths.

So why is our perception of the spectral reflectance of this specific class of objects so poor? I've argued elsewhere that in these illusions the perceived colours of the *virtual* objects depicted in the images are so visually insistent that it can be very difficult to attend to and compare colour perceptions relating to the physical image areas themselves (Briggs, 2018).

Our ability to perceive the overall spectral reflectance of an object as its colour is most effective in daylight or in similar lighting having a fairly even spectral distribution both on a broad scale, thus appearing "white" or achromatic, and on a small scale, thus having a high Colour Rendering Index (CRI). Under spectrally biased illumination our visual system has the capacity to *adapt*, to a degree, to the spectral bias, so that the illumination appears less strongly coloured than it would otherwise, and also, to a degree, to disentangle colours relating to the illumination from colours relating to the spectral reflectance of objects. Nevertheless, our capacity to distinguish objects based on their spectral reflectance diminishes as the imbalance of the spectral distribution of the illumination increases. Under monochromatic illumination we can perceive as object colour only variations in the object's reflectance of the single wavelength present.

Colorimetry of Lights

To give a simple, nonmathematical account of the rationale of colorimetry of lights, I begin by explaining that while it takes a three-dimensional, cubic colour space to represent the range of digital colour stimuli I can produce on my screen, if I ignore the total amount of light, as did Newton in his circle, I can represent the range of light stimuli emitted by the screen as a two-dimensional triangle showing the **ratio** of my long-, middle- and short-wavelength primaries, R, G and B. A two-dimensional diagram of this kind that shows the ratio of three primaries but not their intensity is called a *chromaticity diagram*. Many lights in my environment could be matched by a light on my screen and their chromaticity could be specified by the ratio of these primaries in the matching light. Whatever R, G and B lights I used, however, some lights I tested would be outside the range that I could match directly.

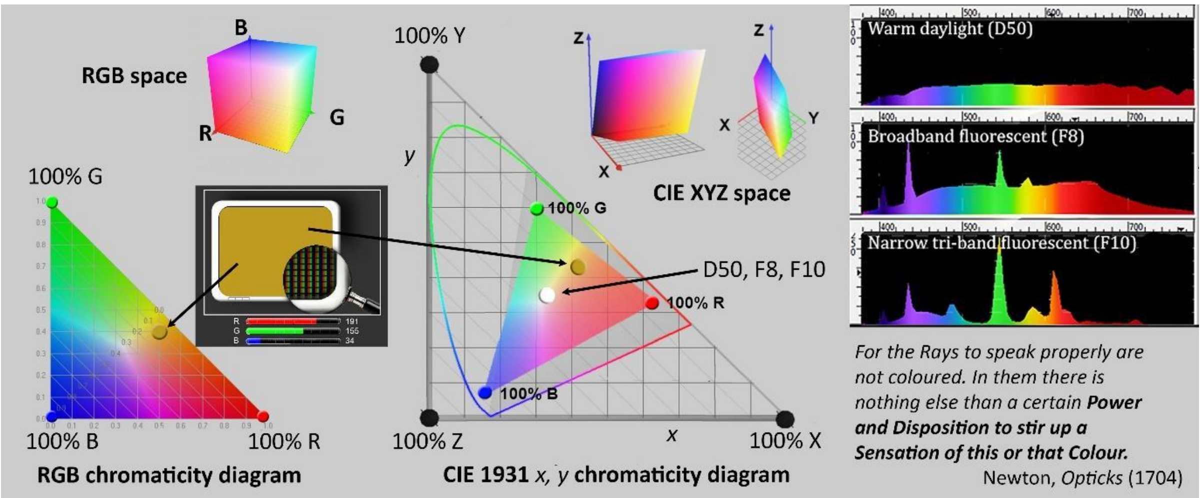

Figure 2: Explanation of the CIE 1931 chromaticity diagram (middle) by analogy with an RGB chromaticity diagram (left). Graphics exported from *ColorSpace* by Philippe Colantoni and *Maxwell Triangle* by efg2.com (now unavailable)

In 1931 the CIE devised a set of three purely theoretical primaries, CIE X, Y and Z, that lie outside the range of actual lights and thus can specify all actual lights mathematically with positive values. Just as the balance or ratio of R, G and B components of digital colours can be plotted in a two-dimensional RGB triangle, any actual light can be plotted according to the ratio of its theoretical X, Y and Z components in the two-dimensional CIE *x,y* chromaticity diagram. But what does this represent in plain language? Position in this triangle represents the overall *balance* of wavelengths in the light, at the level of the long-, middle- and short-wavelength components, as detected by the human visual system, given the necessary assumption of a "standard" human observer. The very different spectral distributions of daylight and of the two fluorescent lights shown above have the same nearly even overall balance, lacking any overall bias at the level of the long-, middle- and short-wavelength components. Proximity of lights to the lower right, upper or lower left extremes of this diagram signifies an overall imbalance towards long, middle or short wavelengths respectively, once again as detected by the visual system of a "standard" human observer.

Colorimetric specifications are designed to ignore physical differences that are not perceivable to a human observer, and to record just those differences that we perceive as colour differences. A colorimetric specification of a light represents a class of physically varied lights having a *common disposition* to evoke a perceived colour, in the sense that physically different lights having the same colorimetric specification *would be expected to match in perceived colour when viewed under the same conditions*. A colorimetric specification of a light may thus be said to quantify what Newton called colours "in the Rays"**,** meaning the light's "*Power and Disposition to stir up a Sensation of this or that Colour*". Note however that a colorimetric specification does not correspond to a single "inherent" perceived colour; our three "white" lights will match in colour when viewed under the same conditions, but viewed in different settings the perceived colour of these matching lights would vary accordingly.

Colorimetry of objects

We saw that *under favourable viewing conditions*, the colour we perceive as belonging to an object is normally a good indication of its *overall* spectral reflectance at the level of its long-, middle- and short wavelength components. Under such conditions the *hue* and *chroma* of the object colour indicate the *direction* and *amount* of overall imbalance in the object's spectral reflectance at this level, and the *lightness* indicates the overall proportion of light that the object reflects. Here again, though, our perceptions are shaped by the workings of the human visual system. Because the responses of our visual system tapers towards the red and violet extremes of the spectrum, wavelengths at these extremes have a relatively weak influence on our perception of the amount of light that an object reflects, which thus relates not directly to physical energy but to the physical energy weighted by the wavelength-by-wavelength response of the human visual system, called its relative *luminance*. With experience it's possible to form a reliable visual estimate of the *overall* spectral reflectance of any Munsell chip reflectance at the level of its long-, middle- and short-wavelength components. Indeed, *anyone* can form such an *overall* estimate for an object by looking up the spectral reflectance of the Munsell chip they judge to be most similar in colour. (This is not to suggest that all 5B 6/10 objects have exactly the same *wavelength-by-wavelength* spectral reflectance as a 5B 6/10 Munsell chip; they do not).

Colorimetric specification of objects is more complicated than for lights in that the light reflected by an object depends on the light falling on it. Each Munsell chip is manufactured to embody a colorimetric specification expressed as a CIE 1931 *xyY* value that specifies the chromaticity and relative luminance (Y) of the light that the chip would reflect under a daylight illuminant called *Illuminant C* (Newhall *et al.* 1943). Illuminant C was the standard daylight illuminant used at the time the Munsell notations were defined in 1943; its place is now taken by newer daylight illuminants such as D50, D55 and D65. Under these different daylight illuminants the spectral distribution of the reflected light varies somewhat but for practical purposes remains broadly correlated with the spectral reflectance of the chip. Granted these necessary assumptions of a standard observer and a specific daylight illuminant, CIE xyY values thus quantify for practical purposes the light reflected by each Munsell chip in daylight at the level of its overall balance of long- middle- and short-wavelength components, the *perceivable property* that we perceive as the colour of the chip in daylight.

Colour ontology

In philosophy of colour there are many theories of colour ontology, which concerns questions about the fundamental nature of colour. These theories differ among themselves in part over what the word "colour" is taken to apply to. In *eliminativism* the word "colour" is taken to apply exclusively to colour *perceptions* such as red, blue etc., leading to such statements as "colours do not exist", meaning that they do not exist outside the mind. In other theories the word "colour" is taken to apply to the power or *disposition* of lights and objects to cause a perception of red, blue etc., or to cause such a perception in a given perceiver and/or environment. Colour *physicalism* equates a colour with a specific spectral reflectance or "transmittance", in effect relegating perceptions like red and blue to being the *appearance* of this actual, physical colour. (See Maund, 2019, for a very clear and concise account of these and other positions).

In defining two senses of the word "colour" the CIE ILV expresses a pluralist ontology that acknowledges that we may wish to use the word "colour" either for our perceptions of colour (*perceived colour*) or for the perceivable properties of lights and objects that these perceptions are based on (*psychophysical colour*). When we speak of "colour measurement", "colour difference formulae", many "colour spaces" and the 16.7 million RGB "colours" on our screens, we are using the word "colour" in this second sense. It may help to point out that the *numbers* employed to record a psychophysical colour specification are not themselves considered to be a "colour", any more than the *numbers* employed in a Munsell specification such as 10R 6/14 are themselves considered to be a "colour". The numbers in a colorimetric specification of a light identify a *class of spectral distributions* that share a common balance at the level of the long-, middle-, and short-wavelength components as detected by the human visual system, resulting in *a common disposition to evoke a perceived colour*. A colorimetric specification of an object identifies for practical purposes a class of spectral reflectances having a common disposition to evoke a perceived object colour in daylight. In terms of Hardin's well-known quote – "Colored objects are illusions, but not unfounded illusions" - "psychophysical colour" specifies for practical purposes the properties of lights and objects that our "illusions" of object colour and other perceived colours are founded on.

Acknowledgements

I am very grateful to Robert Hirschler, Barry Maund, Mohan Matthen, and Derek Brown for generously providing comments on an earlier draft of this manuscript. All of their comments led to corrections or clarifications, but responsibility for any remaining errors is entirely my own.

References

Briggs, D. J. C. 2018. Colour Constancy Illusions and Painting. *Colour Society of Australia Melbourne 2018 Conference, Perception and Colour*, September, 2018. http://www.huevaluechroma.com/116.php

Briggs, D. J. C. 2021. More Than Three Dimensions: Communicating the Attributes of Colour Perception in Colour Education. *Proceedings of the 14th AIC Congress Milan*, September 1, 2021, pp. 1073-1078. https://www.aic-color.org/resources/Documents/Proceedings_AIC2021_r10.pdf

Hardin, C. L. 1993. *Color for Philosophers; Unweaving the Rainbow*, *Expanded Edition*. Hackett Publishing Co.

Maund, B. 2019. Color, in *The Stanford Encyclopedia of Philosophy* (Spring 2019 Edition), Edward N. Zalta (ed.), https://plato.stanford.edu/archives/spr2019/entries/color/

Newhall, S. M., Nickerson, D., & Judd, D. B. 1943, Final Report of the OSA Subcommittee on the Spacing of the Munsell Colors. *Journal of the Optical Society of America*, 33, 385–418.

Purves, D., & Lotto R. B. (2003). *Why we see what we do: An empirical theory of vision*. Sinauer Associates.

Session 13
Colour Science - IV

Preliminary Evidence for the Effect of Circadian Rhythms on Color Perception

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Abstract

Intrinsically photosensitive retinal ganglion cells (ipRGCs) affect the pupillary light reflex and regulation of circadian rhythms. ipRGCs have also recently been shown to affect visual perception, especially brightness perception, and reports are gradually accumulating to affect color perception. The purpose of this study was to verify the effects of ipRGCs on color perception through the repeated performance of color matching on the same display screen at different times of day. We performed color matching a total of 290 times over a period of nine months. The color matching results showed that central vision exhibited lower color discrimination ability than peripheral vision. Furthermore, significance tests revealed that the color perception characteristics between central and peripheral vision differed between day and night, indicating that M1 ipRGCs, which affect non-image-forming functions, and non-M1 ipRGCs, which affect image-forming functions, may interactively affect color perception.

Keywords: *ipRGC, color perception, circadian*

Introduction

At the beginning of this century, photoreceptors other than cones and rods were discovered in the mammalian retina and were named “intrinsically photosensitive retinal ganglion cells” (ipRGCs; Berson et al. 2002). ipRGCs are special ganglion cells containing the visual substance melanopsin, whose spectral sensitivity function was defined by the Commission Internationale de l'Eclairage (CIE 2018) with a peak at approximately 490 nm (Figure 1). There are six known subtypes of ipRGCs, M1–M6, which are primarily distinguished according to differences in their morphology and the brain regions to which they project. In earlier research, it was believed that ipRGCs influence non-image-forming functions, such as the regulation of circadian rhythms and pupillary light reflex (Hattar et al. 2002), which was classified as the first subtype M1. However, recent studies have increasingly revealed influences on visual perception, such as brightness perception and contrast perception (Brown et al. 2012) as image-forming functions, which were classified as non-M1 ipRGCs (M2–M6 ipRGCs). Since then, the contribution of ipRGCs to color perception has been reported, and the authors have also been working on experimental demonstrations. Through these experiments, we noticed that the results of visual perception differed depending on the time of the experiment. In other words, we found that circadian rhythms, through the action of M1 ipRGCs, may affect color perception. The purpose of this study is to provide preliminary evidence that circadian rhythms affect color perception.

In past experiments on the effects of ipRGCs on visual perception, great emphasis has been placed on the control of other sensory organs, as by knocking down the functions of cones and rods. In addition, individual calibration, which considers the differences in the sensitivity function of the individual eye, is also important. However, precise calibration is difficult , which constitutes a major barrier to these experiments. To solve this problem, the uniqueness of this study lies in the fact that we performed color matching on the same display screen. During the process of color matching on a display screen, for any visual characteristic, there is theoretically one, and only one, correct color with the same spectral distribution. Therefore, the null hypothesis is that if a sufficient number of experiments are conducted, the matching results will be distributed in the range of just noticeable differences centered on the correct color.

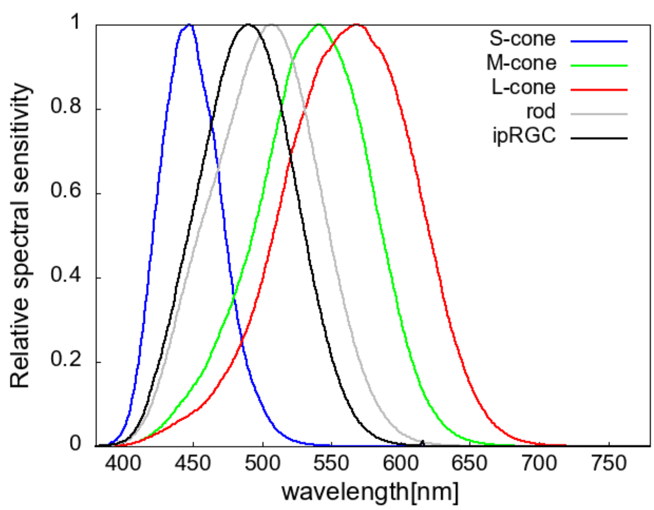


Figure 1. Spectral sensitivity of photoreceptor cells.

Experiment

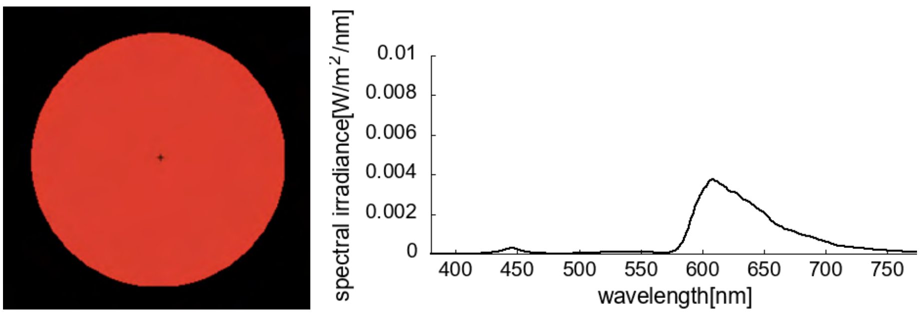
To verify the effects of ipRGCs on color perception, we repeatedly performed color matching on the same display screen. To examine both M1 ipRGCs, which affect non-image-forming functions, and non-M1 ipRGCs, which affect image-forming functions, experiments were conducted at different times of the day, taking into account circadian rhythms, and color matching was performed using different viewing angles.

Experimental Method

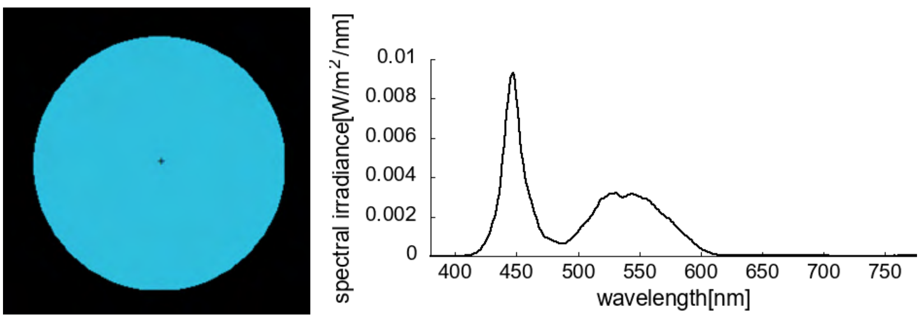
A large circle and small circle with the same center were displayed on the same display screen, and color matching was performed by using the color of the large circle as the target color and manipulating the color of the small circle. Color matching was performed by manipulating H (Hue), S (Saturation), and V (Value Brightness) using a keyboard.

The colors used in one session were three blue colors with high ipRGC absorption, i.e., [190, 200, 220], [210, 200, 220], and [230, 200, 220], and three red colors with low ipRGC absorption, i.e., [5, 200, 220], [325, 200, 220], and [345, 200, 220]. Figure 2 shows each color stimulus and its spectral distribution. Considering the possible influence of both M1 ipRGCs and non-M1 ipRGCs on color perception, we prepared two sets of stimuli: one for central vision with visual angles of 0°–1° and 1°–3° and the other for peripheral vision with visual angles of 0°–7° and 7°–10° (Figure 3), and performed color matching at different times of the day. The color of the small circle was randomly set within the range of H: ±15, S: ±35, and V: ±35 from the color of the target large circle.

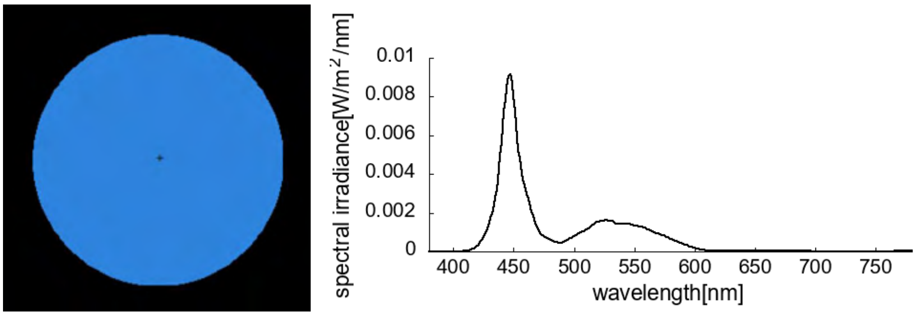
HSV operations were assigned to the keyboard so that they could be operated while viewing the display screen. H(Hue) took values from 0 to 359, and changes in the + direction were counterclockwise, while changes in the − direction were clockwise. S (Saturation) and V (Value Brightness) took values from 0 to 255. If it was required to go back to the initial value during color matching, "0" needed to be pressed. To finish color matching, "P" needed to be pressed in order to move on to the next color. A session ended when all six colors had been matched.



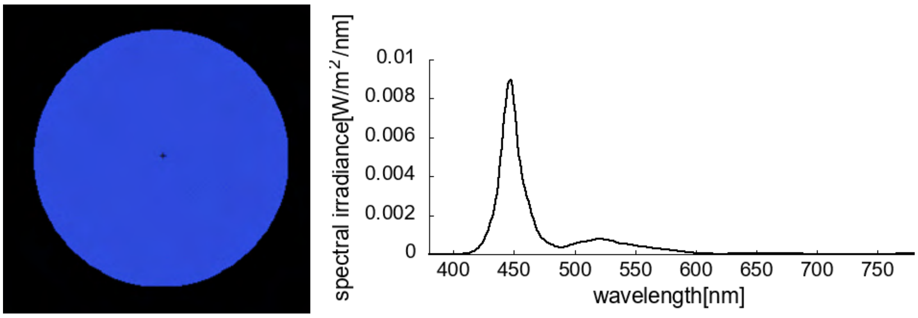
(a) [H, S, V] = [5, 200, 220]



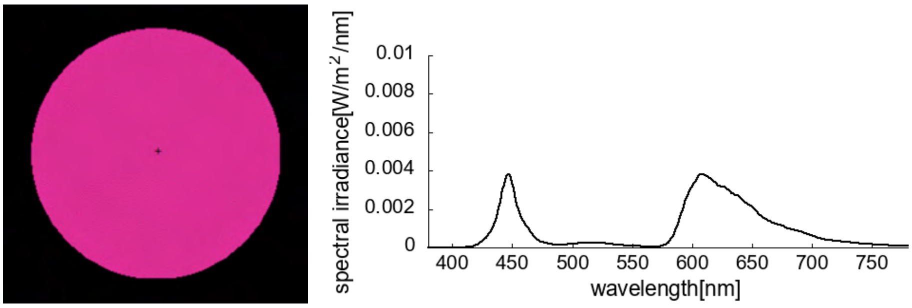
(b) [H, S, V] = [190, 200, 220]



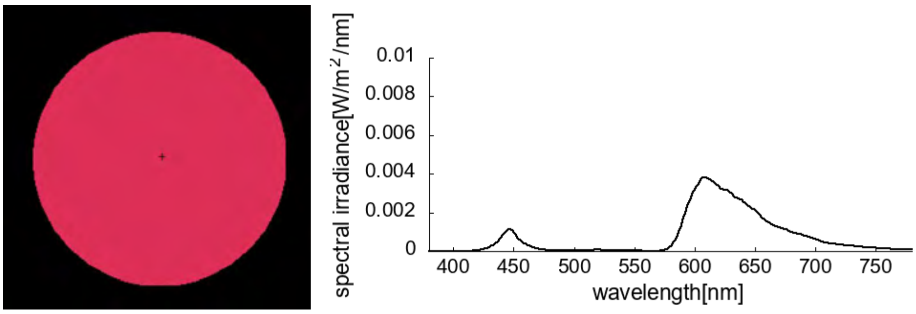
(c) [H, S, V] = [210, 200, 220]



(d) [H, S, V] = [230, 200, 220]



(e) [H, S, V] = [325, 200, 220]



(f) [H, S, V] = [345, 200, 220]

Figure 2. Stimuli used in experiments and their spectral distribution.

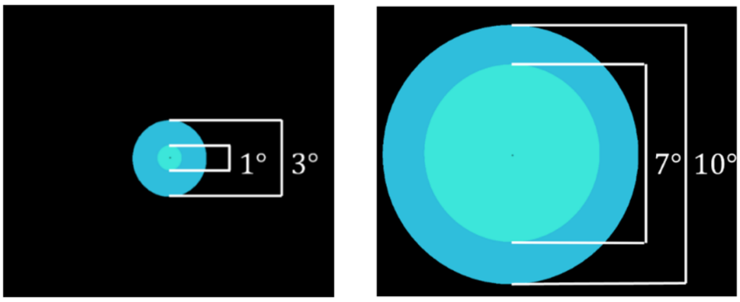


Figure 3. Stimulation of central (l) and peripheral vision (r).

Experimental Results

A total of 290 color matching runs were conducted from April to December 2021. The average color differences obtained between the large and small circles in ΔE2000 are shown in Table 1. This table shows that the average color difference for central vision is larger than that for peripheral vision when comparing the values for central and peripheral vision. This indicates that the ability to distinguish colors, or “color discrimination,” is lower for central vision than peripheral vision in the central vision and peripheral vision designs used in this study. Wilcoxon rank sum tests were performed on the obtained color differences to determine whether significant differences existed between the central and peripheral vision, and day and night results. In order to perform a significance test on color differences, which only take positive values, only the Wilcoxon rank sum test was performed without a normality test. The pairs for which significant differences were found as well as their hues are shown in Table 2. The table shows that there was a significant difference between central and peripheral vision during the day for all blue stimuli, but not for all blue stimuli during the night. This suggests that M1 ipRGCs and non-M1 ipRGCs may interact in color perception.

H	Central		Peripheral	
	Day	Night	Day	Night
5	0.292	0.298	0.124	0.255
190	1.113	1.218	0.787	1.047
210	1.855	1.693	1.395	1.648
230	1.470	1.206	0.841	0.846
325	1.081	0.956	1.025	0.951
345	1.196	1.124	1.113	0.872
average	1.168	1.083	0.881	0.936

Table 1. Average color difference between large and small circles after color matching at ΔE2000.

Combinations	Hue (H)
Central and peripheral vision in the day	5, 190, 210, 230
Central and peripheral vision in the night	5, 190, 345
Day and night in central vision	5
Day and night in peripheral vision	5

Table 2. Combinations and hues for which significant differences were identified.

Conclusions

In this study, we examined the effects of both M1 ipRGCs and non-M1 ipRGCs on color perception through the repeated performance of color matching between large and small circles on the same display screen. The color matching results showed that color matching accuracy was lower for central vision than peripheral vision in the central vision and peripheral vision designs in this study. This confirmed that the color discrimination ability of central vision was lower than that of peripheral vision. We also used the Wilcoxon rank sum test to confirm whether significant differences existed between central and peripheral vision and between day and night for the obtained color differences. The results showed that there was a significant difference between central and peripheral vision during the day for all blue stimuli, but not for all blue stimuli between central and peripheral vision during the night. This suggests that M1 ipRGCs and non-M1 ipRGCs may interact with each other. In the field of circadian typology (Adan et al. 2012), it has been suggested that differences in circadian typology affect the color confusion axis and its influence on color perception (Andrade et al. 2018). The involvement of M1 ipRGCs in color perception requires further study.

Since the findings of this study confirmed that both M1 ipRGCs and non-M1 ipRGCs can affect color perception, we intend to create a model that can reproduce colors, taking their effects into account, by changing in response to the amount of stimulation to ipRGCs.

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References

Adan, A., Archer, S.N., Hidalgo, M.P. Milia, L.D., Natale, V., Randler, C. 2012. Circadian Typology: A Comprehensive Review. *Chronobiology International*. vol.29(9). 1153-1175.

de Andrade, M. J. O., Cristino, E. D., Santos, L. G. B., de Oliveira, A. R., dos Santos, N. A. 2018. Daily variation of visual perception of colors: Preliminary studies. *Psychology & Neuroscience*. vol.11(3). 238–251.

Berson, D.M., Dunn, F.A., Takao, M. 2002. Phototransduction by Retinal Ganglion Cells That Set the Circadian Clock. *SCIENCE*. vol.295. 1070-1073.

Brown, T.M., Tsujimura, S., Allen, A.E., Wynne, J., Bedford, R., Vickery, G., Vugler, A., Lucas, R.J. 2012. Melanopsin-Based Brightness Discrimination in Mice and Humans. *Current Biology*. vol.22. 1134-1141.

CIE. 2018. CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light, *CIE S* 026/E:2018.

Hattar, S., Liao, H.W., Takao, M., Berson, D.M., Yau, K.W. 2002. Melanopsin-Containing Retinal Ganglion Cells: Architecture, Projections, and Intrinsic Photosensitivity. *SCIENCE*. vol.295. 1065-1070.

A Parametric Colour Difference Study on the Physical Size Effect for Sample Pairs to Have No Separation

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Abstract

It has been a long debate whether a colour difference or colour appearance model can only be used under either CIE 1931 2° or CIE 1964 10° standard colorimetric observer. The hypothesis is that the difference caused by the Field of View (FoV) or physical size to be small. This experiment was intended to provide scientific evidence on size effect. 280 sample pairs having CIELAB colour difference of 4 were selected around 5 CIE recommended colour centres, with no division line between two colours in a pair. Each pair was assessed at 4 FoVs, 2°, 4°, 10° and 20°. The results were also used to test the effects of different colour matching functions (CMFs) and 3 colour-difference formulae, CIELAB, CIEDE2000 and CAM16-UCS. It was found that CIE 1964, CIE 2006-10° outperformed CIE 1931, CIE 2006-2° and 2006-4° CMFs. However, the differences were so small that they can be ignored. Also, all combinations of formulae and CMFs gave better performance for visual data having larger than small FoV. Finally, CAM16-UCS and CIEDE2000 to perform better than CIELAB formula.

Keywords: *Physical Size, Colour Difference Formula, Parametric Effect, Colour Matching Function*

Introduction

According to the CIE (CIE 1995), colour-difference formulae should be used under a set of reference viewing conditions, i.e., object colours, having a hair line between two colours on a pair, subtended a viewing angle larger than 4°, against a uniform neutral grey background with L^* of 50, illuminated by a D65 simulator at 1000 *lx*, and having colour-difference less than 5 CIELAB units. The reference viewing conditions are difficult to achieve in the practice applications.

The CIE recommended CIE 1931 2° and 1964 10° standard colorimetric observers or colour matching functions (CMFs) to be used for field of view (FoV) less and larger than 4°, respectively. Taking into account individual's optical densities of lens, macular pigment and visual pigment, CIE 2006 CMF (CIE 2006b) has been proposed for different ages under FoV from 1° to 10°. To study the effect of field size on colour-difference evaluation and compare the performance of different CMFs (CIE 2006a, CIE 2006b) and colour-difference equations (CIE 2018, Luo et al. 2001, Li et al. 2017), the present experiment was conducted using square sample pairs in 4 different sizes.

Experiment

Display

The experiment was conducted in a darkened room using a 31-inch NEC PA311D liquid crystal display, with a resolution of 4096 x 2160 pixels. The correlated colour temperature of the display peak white was set to 6500 *K* with a luminance of 300 cd/m^2. The Gain-Offset-Gamma (GOG) model (Berns 1996) was used to characterize the display. The GOG model's predictive accuracy had an average of 0.35 CIEDE2000 (ΔE_{00}) (ISO/CIE 2014) units over 140 sample colours in the present experiment, with a standard deviation of 0.20 ΔE_{00} units. All the measurements were conducted using a Konica Minolta CS2000A tele-spectroradiometer in terms of spectral power distribution (SPD) for each stimulus. Their colorimetric values were calculated by multiplying SPD to CIE 1964 standard colorimetric observer (CIE, 2018), unless stated otherwise.

Stimuli

Five CIE recommended colour centres were studied, e.g., grey, red, yellow, green, and blue. 14 sample pairs were selected around each colour centre, including 7 pairs with lightness difference and 7 pairs without lightness difference. Sample colours were distributed uniformly from 0 to 180° in $\Delta a^*\Delta b^*$ plane, from 0 to 90° in $\Delta L^*\Delta a^*$ plane, and from 0 to 90° in $\Delta L^*\Delta b^*$ plane, respectively. All sample pairs had a colour-difference of about 4 CIELAB units. There was no hairline or gap between two colours on a pair. Sample pairs were shown on the display in 4 sizes, having 2°, 4°, 10°, and 20° field on view angle. Totally, 280 sample pairs (5 centres x 14 samples x 4 FoVs) were studied. 80 of them were repeated to evaluate intra-observer variation.

Visual Assessment

The grey-scale method (ISO 1993) was used to assess colour-differences of sample pairs. The grey-scale samples consisted of 9 ISO 105 A02 (ISO 1993) samples (GS-1 to GS-5 with an interval of 0.5) and 1 additional sample (GS-0.5). The grey-scale pairs were constructed between the standard (GS-5) and each of GS-0.5 to GS-5 samples. Equation (1) was used to scale the visual judgments in terms of grey-scale values (*GS*) to visual colour-difference values (ΔV).

$$\Delta V = 0.1172GS^4 - 1.7394GS^3 + 9.6987GS^2 - 26.0010GS + 31.8068 \qquad (1)$$

Forty-six normal colour vision observers participated in the experiment, including 21 males and 25 females, with ages from 19 to 30 years (mean 24 years, standard deviation 2.9). The experiment consisted of 4 parts, FoV of 2°, 4°, 10° and 20°. Each observer was involved in 1 to 4 parts of the experiment. Each part was assessed by 20 observers.

The experiment was carried out in a darkened room. Observers seated 60 cm in front of the display. After the 1-minute adaptation, observers were asked to assess the colour-difference of sample pairs using a grey-scale with one decimal. Sample pairs were shown in a random order.

Results and Discussion

Observer Variation

The standard residual sum of squares (STRESS) metric (CIE 2016) (see Equation 2) was used to evaluate the intra- observer and inter-observer variation.

$$STRESS = 100\sqrt{\frac{\sum(F\Delta E_i - \Delta V_i)^2}{\sum \Delta V_i^2}} \quad (2)$$

where $F = \frac{\sum \Delta E_i \Delta V_i}{\sum \Delta E_i^2}$, a scaling factor to adjust ΔV and ΔE to be on the same scale.

For the inter-observer variation, the STRESS values were 41 (2°), 39 (4°), 44 (10°) and 39 (20°), with an average of 41. For the intra-observer variation, the STRESS values were 25 (2°), 22 (4°), 21 (10°) and 18 (20°), with an average of 21. The results indicate that the observers performed more consistently for larger field size. Also, the inter-observer variation was larger than the intra-observer variation by about 200%.

Physical Size Effect

The STRESS values between all possible combinations of ΔV values between two FoVs were calculated. Figure 1 shows the scattering diagrams between ΔV values from 2° FoV and the others. Table 1 lists the STRESS values between ΔV values from different FoVs and the average ΔV. Comparing the average ΔV, the STRESS values were 14 (2°), 12 (4°), 14 (10°) and 11 (20°) respectively. Also, the largest discrepancy was found between 2° and 10° FoVs to have 24 STRESS units. However, comparing the inter-observer variation of about 40 units, this difference is considered to be small.

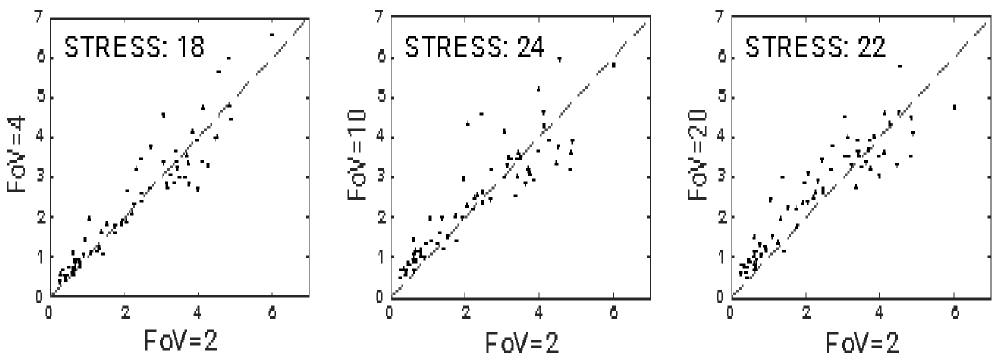

Figure 1. The scattering diagrams between *ΔV* values from 2° FoV and the others.

Comparison of CMFs

The spectral power distribution (SPD) of each sample was used to calculate tristimulus values XYZ using 5 sets of CMFs, named CIE 1931, CIE 1964, 2006-4°, CIE 2006-2°, CIE 2006-10°, for which the latter two were acquired from the website of Colour & Vision Research Laboratory (http://www.cvrl.org) and 2006-4° CMF was calculated based on CIE publication (CIE 2006b) for the 24 years old observer, the average age of the present observers. And then, colour-differences values of sample pairs from CIELAB, CIEDE2000 and CAM16-UCS were obtained. And their values were inter-compared between all 10 combinations of CMFs. It was found the results in terms of the STRESS value were very similar between the three colour models. The results from CIELAB were taken as an example. They can be divided into three groups: 1) 2° observers (CIE 1931 and CIE 2006-2°), 2) 10° observers (CIE1964, and CIE 2006-10°), and 3) CIE 2006-4° respectively. The STRESS values were 3.0 and 1.0 for the two CMFs in Groups 1 and 2 respectively. This means the two 10° CMFs agreed better than the two 2° CMFs. Compared to CIE 2006-4° CMF, the closest was CIE 2006-2°, followed by CIE 1931, CIE 1964, CIE 2006-10° with 1.2, 3.5, 4.3, 4.4 and 4.8 STRESS units respectively. The largest difference was found between CIE 1931 and 1964 CMFs (5.0 units). This STRESS value is still considered to be extremely small compared to the inter-observer variation (41 units) and physical size effect (22 units), respectively.

Model Performance

The visual data were used to test the performance of three colour models, CIELAB (CIE 2018), CIEDE2000 (Luo et al. 2001) and CAM16-UCS (Li et al. 2017). Again, the performance is reported using the STRESS value calculated between the visual differences ΔV and the predicted differences ΔE. Figures 2 and 3 show models' performance using each CMF under individual FoVs and mean FoV, respectively. All CMFs gave quite similar results. CAM16-UCS and CIEDE2000 outperformed CIELAB by a large margin as previously reported by many researchers. The former two gave quite good performance, i.e., much smaller STRESS values than that of inter-observer variation. Close examination can find that regardless of which FoV subdata, 10° CMFs outperformed 4° CMF and 2° CMFs. In addition, all combinations of formulae and CMFs gave more accurate predictions to the larger FoVs than those of smaller FoVs.

Most importantly, the CAM16-UCS developed using mainly 2° FoV data on the colour appearance model (CAM16) (Li et al. 2017) and 10° FoV colour difference data on uniform colour space can give accurate prediction of visual colour differences from both FoVs.

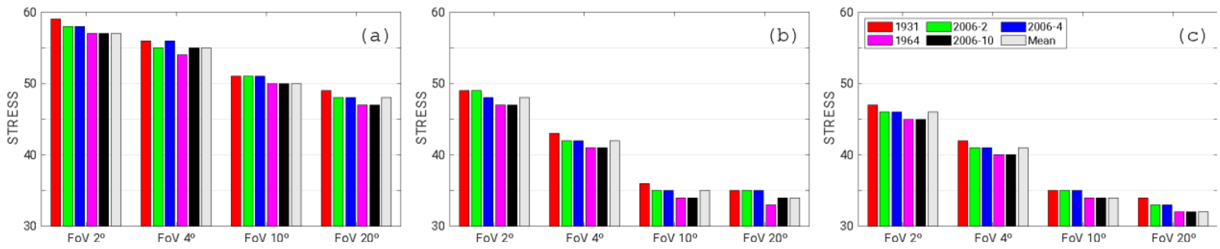

Figure 2. The models' performance in STRESS unit under each FoV and CMF: (a) CIELAB; (b) CIEDE2000; (c) CAM16-UCS.

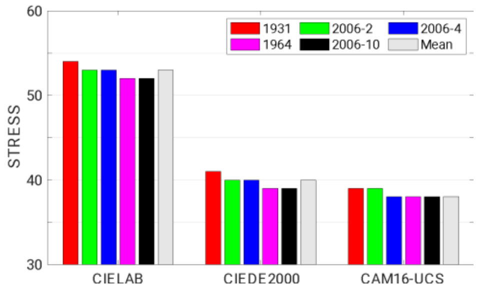

Figure 3. The models' performance in STRESS unit under mean FoV and each CMF.

Conclusion

The experiment was conducted to reveal the FoVs of test stimulus (2°, 4°, 10° and 20°) affected by physical sizes. The results clearly showed that different FoVs had little impact on colour differences. In addition, different CMF used in the colour difference formulae had little difference. We can conclude the parametric effect due to stimulus sizes to be small.

Acknowledgement

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Reference

Berns, R. S., 1996. Methods for characterizing CRT displays. *Displays* 16, 173-182.

CIE, 1995. Industrial Colour-Difference Evaluation. *Commission Internationale de l'E´clairage*, Vienna, Austria.

CIE 014-1E:2006, 2006a. Colorimetry – Part 1: CIE standard colorimetric observer. *Commission Internationale de l'E´clairage,* Vienna, Austria.

CIE 015:2018, 2018. Colorimetry. *Commission Internationale de l'E´clairage,* Vienna, Austria.

CIE 170-1:2006, 2006b. Fundamental chromaticity diagram with physiological axes - Part 1. *Commission Internationale de l'E´clairage,* Vienna, Austria.

CIE 217:2016, 2016. Recommended Method for Evaluating the Performance of Colour-Difference Formulae. *Commission Internationale de l'E´clairage,* Vienna, Austria.

Colour & Vision Research Laboratory. http://www.cvrl.org.

ISO 105-A02, 1993. Textiles - Tests for colour fastness - Part A02: Grey scale for assessing change in colour. *The International Organization for Standardization*.
ISO/CIE, 2014. Colorimetry -- Part 6: CIEDE2000 colour-difference formula. ISO/CIE 11664-6:2014(E) (ISO/CIE, 2014), pp. 11664--11666. *Commission Internationale de l'E´clairage*, Vienna, Austria.
Li, C., Z. Li, Z. Wang, Y. Xu, M. R. Luo, G. Cui, M. Melgosa, M. H. Brill, and M. Pointer, 2017. Comprehensive color solutions: CAM16, CAT16, and CAM16-UCS. *Color Res Appl* 42, 703-718.
Luo, M. R., G. Cui, and B. Rigg, 2001. The development of the CIE 2000 colour-difference formula: CIEDE2000. *Color Res Appl* 26, 340-350.

3D printed human skin appearance with a multilayered spatial distribution of pigment components

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Abstract

In this paper, we propose a pipeline that reproduces human skin using an inkjet 3D printer by obtaining the spatial concentration distribution of pigments from an image of human skin taken by an RGB camera. The pigment concentration distributions were obtained from the skin image using a method for separating skin pigment components with independent component analysis. This method can extract the melanin and hemoglobin components, which are the main pigments that make up skin tone. We used inkjet 3D printers to fabricate the skin model because these printers are suitable for creating multilayered structures. In our proposed method, the melanin and hemoglobin layers are created as separate layers and arranged in a multilayered structure to reproduce human skin, which has a multilayered structure consisting of an epidermis with melanin pigment and a dermis with hemoglobin pigment. Subjective evaluation showed that the skin reproduced by our method was superior to that produced using conventional printing.

Keywords: *3D printings, multilayer spatial distribution, human skin, pigment component*

Introduction

In recent years, the usage of 3D printers has increased in a wide range of fields, such as medicine and dentistry, Lee (2014) and Dawood et al. (2015), for prototyping of automobile parts Wang et al. (2014), and for manufacturing of consumer products; they are also now used in general households. For these applications, inkjet 3D printers are often used because they enable full-color modeling. In these applications, it is important to reproduce not only the color, but also the material appearance, such as the surface properties and transparency.

Many studies have focused on the material appearance, particularly the control of translucency. For example, one study proposed a method to reproduce complex scattering properties by Hašan et al. (2010), whereby the scattering properties of several materials are measured and radial reflection and scattering profiles are generated. This allows for the proper arrangement of the material in the depth direction and reproduces the complex scattering properties well. In another study, complex light scattering was reproduced using BSSRDF, which is a function that represents surface subsurface scattering, Dong et al. (2010). In this study, materials with different scattering effects were stacked with varying spatial thicknesses to represent inhomogeneous scattering. However, when modeling with translucent materials, it is difficult to have a texture that contains detailed information. This is because of the lateral light scattering in highly translucent materials, which causes blurring of the surface texture. This problem was overcome using an inverse Monte Carlo simulation-based method to optimize the material arrangement under the surface problem, Elek et al. (2017). An alternative approach to fabricate a translucent object is to use mixtures of translucent materials, Papas et al. (2013). In this approach, the concentration of the mixture of several translucent materials is estimated such that it reproduces the desired appearance and scattering properties. Furthermore, a method to perform full-color modeling with spatially varying translucency was recently proposed by Brunton et al. (2018) using RGBA signals instead of BSSRDF, which has high measurement and processing costs (the 'A' in RGBA is the signal for translucency). The accuracy of this method was subsequently enhanced, Urban et al. (2019) by optimizing the signal to link to both optical material properties and human perceptual uniformity, independent of hardware and software.

Attempts have also been made to reproduce human skin using 3D printers. Human skin has a layered structure consisting of an epidermal layer containing melanin pigment and a dermal layer containing hemoglobin pigment. Therefore, it is important to imitate this layer structure to reproduce real human skin. One study used multilayered skin modeling performed with a neural network-based method to estimate the optimal layer structure layout for reproducing human skin with arbitrary skin color and transparency, Nagasawa et al. (2021). However, this study assumed that the skin is a uniform surface, whereas in reality, its color varies spatially. To solve this problem, it is necessary to reproduce the spatial variation of skin color.

In the present study, we propose a pipeline for 3D modeling of human skin with multilayered spatial distribution of pigments, using skin images taken by an RGB camera. The coloring layer consisted of two layers — the epidermal layer with melanin pigment and the dermal layer with hemoglobin pigment — using a technique called pigment component separation, Tsumura et al. (2003), which extracts the pigment distribution from the skin image. In addition, the thickness and order of these coloring layers were fixed. The melanin and hemoglobin layers were fabricated using the CMYK values calculated from the spatial distribution of these pigments. The method of calculating CMYK values is based on color patches. Furthermore, the translucent texture was improved using clear ink, which can be used in an inkjet 3D printer.

Methodology

In this paper, we introduce a workflow for creating realistic human skin with a 3D printer. This involves reproducing the spatial concentration distribution of pigments obtained from an image of human skin taken by an RGB camera. The method is shown in Figure 1. The spatial concentration distributions of melanin and hemoglobin pigments were obtained by applying a pigment component separation method to the target skin image taken by an RGB camera. The method is robust to changes in illumination intensity because shading is removed at this time. For printing on an inkjet 3D printer, each pigment concentration was converted to a CMYK value. We obtained the transformation equation using a method with color patches. We used three methods: lookup tables, multiple regression analysis, and neural networks. Then, a halftone process was applied to create a skin-like object consisting of a melanin layer as the epidermis and a hemoglobin layer as the dermis. Clear ink was inserted above and below these colored layers to improve the translucency. Furthermore, the thickness of this clear ink was adjusted and the thickness most suitable for the skin texture could was determined by subjective evaluation.

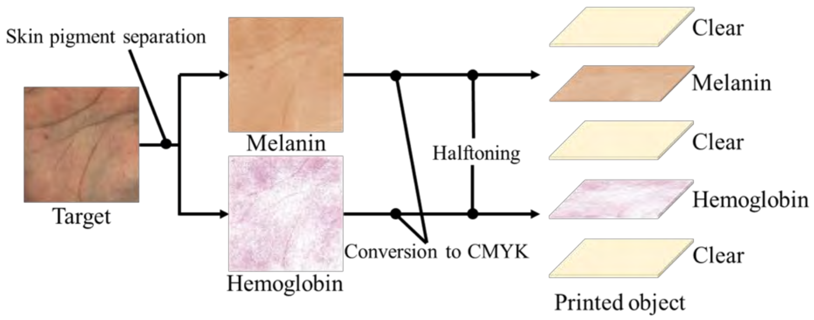

Figure 1: Our workflow for human skin reproduction with multilayer spatial distribution of pigment components.

Color patches for human skin

To create a human skin color patch with a melanin and hemoglobin layer, we first determined the correct specification. The colors of melanin and hemoglobin were obtained from their vectors, which were estimated by pigment component separation. 30 different concentrations of each pigment were extracted. By combining these concentrations, it is possible to create patches with 900 different concentration combinations. The melanin and hemoglobin layers were used as the colored layers, and a white layer was placed at the bottom as a reflective layer. In addition, a clear layer was placed at three locations: at the top, between the hemoglobin and melanin layers, and between the hemoglobin and reflective layers.

Because the color patches were made using an inkjet 3D printer, CMYK values are required to fabricate the color layer. The 30 dye concentrations can be expressed as RGB values. Therefore, we transformed the color space with the ICC profile (Japan Color 2011, coated). In addition, we performed halftoning for the inkjet printing. The largest dot size was used to prevent unevenness in the stacking process. The error diffusion method (Floyd–Steinberg) was used for dithering to reduce the quantization error due to halftoning. The coefficients of error diffusion were 7/16, 3/16, 5/16, and 1/16 for the right neighbor, left bottom, true bottom, and right bottom, respectively. Through these processes, 900 color patches with two pigment layers, as shown in Figure 2, were created.

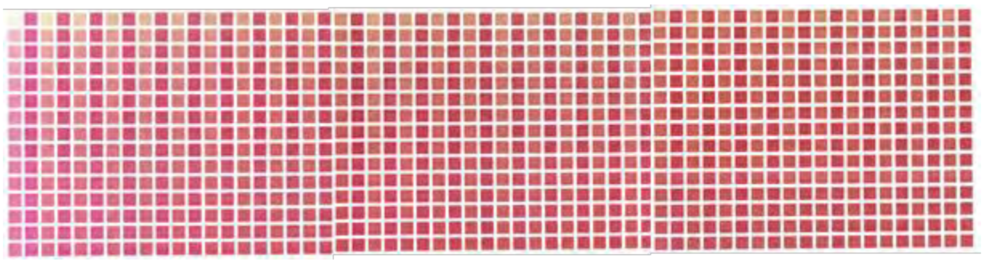

Figure 2: Color patches with two pigment layers and clear layers.

Conversion of pigment concentration to CMYK

The color patches were used to correlate pigment concentrations with CMYK values. Melanin and hemoglobin concentrations were obtained by applying pigment component separation to images taken of the 900 color patches. A polarizer was placed in front of the camera and lighting when taking photos because surface reflections need to be removed during pigment component separation. We constructed a transformation method using pigment concentration of each patch and the CMYK values calculated as described above. We used a lookup table (LUT), multiple regression analysis, and neural networks, and compared the accuracy of the printed results for these methods.

Lookup table

The LUT is the simplest method that we used. The system recorded 900 associations between melanin and hemoglobin concentrations and the CMYK values obtained from color patches in a dictionary. To convert pigment concentrations to CMYK values, we searched for the closest value to the target pigment concentration in the LUT and obtained the corresponding CMYK value as an output.

Multiple regression analysis

Multiple regression analysis is a method of predicting a single objective variable by multiple explanatory variables. The objective variables are the CMYK values of the melanin and hemoglobin layers. The explanatory variables are the RGB value of the pigment concentration obtained by the separation of the pigment components. We used the RGB values for pigment concentration to provide redundancy and improve estimation accuracy. The accuracy of the CMYK value prediction was verified by the cross-validation method. We used leave-one-out cross-validation, in which one data point was extracted from the dataset, and regression equations were trained with the other data and then verified with the extracted data. The error was evaluated as the root mean square error (RMSE), which was 0.03116 or 3.1%

Neural network

Here, we present the results of the estimation of CMYK values using the neural network. The inputs were RGB values derived from the pigment concentration, and the outputs were CMYK values for printing. The middle layer was the fully connected layer, which had 20, 30, and 20 neurons from the input side to the output side. ReLU was used for the activation function and Adam was used for the optimization algorithm. The accuracy of this method was verified by leave-one-out cross-validation, and the RMSE was 0.03546.

Experiment

Comparison of methods

We describe the comparison of three types of CMYK transformation method described in the previous section. Subjectively, the method using multiple regression analysis yielded the most favorable results. The objects using LUTs lost their overall smoothness, which may be because of the lack of interpolation between the data. In the neural network-based method, the overall concentration was averaged and contrast was reduced. The fabricated object using multiple regression analysis is shown in Figure 3.

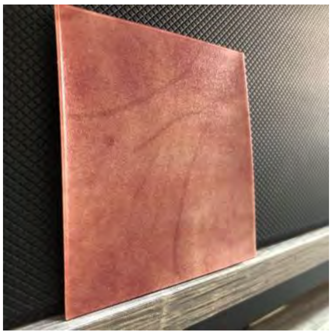

Figure 3: The fabrication result using multiple regression analysis.

Number of clear layers

As mentioned earlier, in addition to the melanin and hemoglobin layers, which are coloring layers, a clear layer was inserted at three locations: the top layer, between the melanin and hemoglobin layers, and between the hemoglobin and reflective layers. These clear layers are referred to as the first, second, and third clear layer from the top. The first clear layer was used to protect the colored layer. The second and third clear layers were provided under the assumption that they improve translucency. We varied the number of layers (and thus the thickness) of the second and third clear layers to observe how they affect the skin-like appearance. Second and third clear layers with two, four, or six constituent layers were prepared, and nine samples were created with different combinations of these thicknesses, as shown in Table 1.

Sample No.	1	2	3	4	5	6	7	8	9
2nd clear layer	2	2	2	4	4	4	6	6	6
3rd clear layer	2	4	6	2	4	6	2	4	6

Table 1: Number of layers of each clear layer in the different samples.

Subjective evaluation

For subjective evaluation of the human skin samples fabricated with our method, we used the semantic differential method (SD method). This is a method proposed by the American psychologist Osgood to measure the impression of a target concept. The SD method uses pairs of adjectives that have opposite meanings (e.g., ‘rough’ and ‘smooth’ in our case). The evaluation was conducted using a slide bar with a scale of −5 to +5. The 13 pairs of adjectives are used in this experiment. The subjects were nine men and women in their twenties. The nine models shown in Table 1 were evaluated. In addition, to show the effectiveness of our method, we compared models with one and with two colored layers (all clear layers are a single layer). Experiments were conducted under daylight illumination using Macbeth's Spectralight2 as a lighting booth. The factors that contribute to the evaluation of skin appearance were extracted through factor analysis of the experimental data. The number of factors was set to three.

Based on the factor analysis, the first factor was defined as the skin-ness factor. Evaluation of this factor was obtained by taking the weighted average of the evaluation values using the factor loadings. For a conventional one-layer model and our two-layer model, this factor was −2,37 and 0.06, respectively. Thus, our proposed method is able to realistically reproduce skin. The results of the evaluation of the thickness of the clear layers (defined in Table 1) are presented in Table 2. The highest values were obtained when the second clear layer comprised two layers and the third clear layer comprised four layers. As an overall tendency, the higher the number of the second and third clear layers, the higher the evaluation value.

Sample No.	Number of 2nd clear layers	Number of 3rd clear layers	Evaluation value
1	2	2	0.9428
2	2	4	1.5186
3	2	6	0.6254
4	4	2	-0.5796
5	4	4	0.9439
6	4	6	1.3705
7	6	2	-0.0477
8	6	4	1.3850
9	6	6	1.4106

Table 2: Evaluation results for the thickness of clear layers

Conclusions

In this paper, we proposed a pipeline for 3D modeling of human skin with multilayered spatial distributions of melanin and hemoglobin components based on images taken by an RGB camera. To obtain pigment concentration distributions from the RGB skin images, pigment component separation was used. Each pigment concentration was then converted to a CMYK value using a color patch-based method. Halftoning was applied, and a clear layer was inserted to realistically reproduce human skin. Subjective evaluation experiments showed that our method could reproduce a more skin-like texture than the conventional printing method.

The reproduction in this study is based on the assumption that the skin is flat, which has the limitation that it cannot be applied to shapes with unevenness. To remove this limitation, more complex methods need to be considered, such as acquiring the shape of the skin and applying a layer structure according to the shape.

References

Lee, Ventola C. 2014. Medical applications for 3D printing: current and projected uses. *Pharmacy and Therapeutics* 39(10) (2014): 704.

Dawood, A., B. M. Marti, V. Sauret-Jackson, and A. Darwood. 2015. 3D printing in dentistry. *British Dental Journal* 219(11) (2015), 521.

Wang, X., Q. Guo, X. Cai, S. Zhou, B. Kobe, and J. Yang. 2014. Initiator-integrated 3D printing enables the formation of complex metallic architectures. *ACS Applied Materials & Interfaces* 6(4) (2014), 2583-2587.

Hašan, M., M. Fuchs, W. Matusik, H. Pfister and S. Rusinkiewicz. 2010. Physical reproduction of materials with specified subsurface scattering. *ACM SIGGRAPH 2010* (2010), 1-10.

Dong, Y., J. Wang, F. Pellacini, X. Tong and B. Guo. 2010. Fabricating spatially-varying subsurface scattering. *ACM SIGGRAPH 2010* (2010), 1-10.

Elek, O., D. Sumin, R. Zhang, T. Weyrich, K. Myszkowski, B. Bickel, A. Wilkie, and J. Křivánek. 2017. Scattering-aware texture reproduction for 3D printing. *ACM Transactions on Graphics (TOG)* 36(6) (2017), 241.

Papas, M., C. Regg, W. Jarosz, B. Bickel, P. Jackson, W. Matusik, S. Marschner and M. Gross. 2013. Fabricating translucent materials using continuous pigment mixtures. *ACM Transactions on Graphics (TOG)* 32(4) (2013), 1-12.

Brunton, A., C. A. Arikan, T. M. Tanksale, and P. Urban. 2018. 3D printing spatially varying color and translucency. *ACM Transactions on Graphics (TOG*) 37(4) (2018), 1-13.

Urban, P., T. M. Tanksale, A. Brunton, B. M. Vu, and S. Nakauchi. 2019. Redefining a in rgba: Towards a standard for graphical 3d printing. *ACM Transactions on Graphics (TOG)* 38(3) (2019), 1-14.

Nagasawa, K., J. Yoshii, S. Yamamoto, W. Arai, S. Kaneko, K. Hirai, and N. Tsumura. 2021. Prediction of the layered ink layout for 3D printers considering a desired skin color and line spread function. *Optical Review*, 28(4), 449-461.

Nagasawa, K., K. Fukumoto, W. Arai, K. Hakkaku, S. Kaneko, K. Hirai, and N. Tsumura. 2021. Layout Estimation for Layered Ink of 3D Printer to Reproduce the Desired Line Spread Function of Skin using Simulated Data. *Journal of Imaging Science and Technology*, 65(5), 50501-1.

Tsumura, N., N. Ojima, K. Sato, M. Shiraishi, H. Shimizu, H. Nabeshima, S. Akazaki, K. Hori and Y. Miyake. 2003. Image-based skin color and texture analysis/synthesis by extracting hemoglobin and melanin information in the skin. *ACM SIGGRAPH 2003* (2003), 770-779.

Cross-cultural influence of preferred memory colours on mobile display devices

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Keywords: *Memory colours, Threshold method, 50% acceptability ellipsoid, colour appearance ratings*

Abstract

An experiment was carried out to study memory colours across 106 observers from 5 ethnic groups on mobile displays. The threshold psychophysical method was used and each observer was asked to make a forced choice decision between like and dislike for the image assessed. Twenty-four familiar objects were investigated and each memory colour was defined by their colour centre and 50% preference acceptance ellipsoid in CIELAB space. The results were analysed in terms of observer variations, inter-comparison of individual objects and observer groups between different objects. Some systematic variations are reported.

Introduction

The term 'memory colour' is defined as those colours that are recalled in association with familiar objects with which we have a frequent visual experience. Memory colour has generated a sustained interest in the colour world. Previous studies mainly focused on the colour chips [1] under lighting cabinets or colour samples on real scenes [2-4]. Observers judged a range of colours in terms of degree to match their memory colours. More recently, the experiment was done on displays [5-9]. Observers can either judge the closeness to their memory colours [10,11] or adjust the display colour to match their short-term and long-term memory colours [12,13].

Less attention was paid to study the ethnic group difference and the preference of memory colour on the most widely used mobile devices. The goal is to study a comprehensive set of memory colours across different ethnic groups on mobile phones.

Experimental Display

Five Huawei displays were used in the experiment. Each one was characterized using the 3D Look-up-table (3D-LUT) model from a 9×9×9 database measured by a JETI-Specbos 1211 tele-spectroradiometer (TSR). Its accuracy was tested using the 24 colours on the XRite Macbeth ColorCheck Chart (MCCC). Their performances ranged from 1.24 to 1.79 with a mean of 1.53 CIELAB units. The inter-device agreement was found to be 1.90, which is about the same as the 3D-LUT's performance. Judging by the similar magnitude of colour differences, it was decided to process the images using one model and apply the image to all five displays.

Memory colour selection

Initially, a range of 42 common memory objects were collected from the markets. These were measured using a XRite SpectroEye portable 45°/0° spectrophotometer. The results were recorded in terms of CIELAB values [14] under D65/10° condition. In addition, their images were captured using a Nikon Z6 camera (polynomial model) in the viewing cabinet. The memory object in each image was cropped and the measured colour was introduced to form the 'original' image. Six memory targets (blue sky, summer grass, rose pine, smurf and lavender) were also collected from the images on the website due to the unavailability for collection. Finally, these colours were plotted in CIELAB a^*b^* plane for colour selection. Finally, 24 colours were selected to cover a large colour gamut and lightness range.

Each image was consisted of 'original' image against a uniform grey background (L^*=50). For each image, these were rendered in a^*b^*, a^*L^*, and b^*L^* planes according to rules, i.e. to have two distances against the colour centres according to the earlier findings, and to be able to adjust the distance to make the outer layer to be sufficiently large. Note that the ideal stimuli distribution for the threshold method is to have images to be judged as 50% as 'liked' and the other half to be 'disliked'.

Observers

As mentioned earlier, the goal of the project is to cross different ethnic groups. In total, 106 normal colour vision observers, who passed the Ishihara colour vision test, participated in the experiment. They were divided into 5 groups: 20 native Chinese (CHZ), 31 South Asians (SA), 23 Chinese living in the UK (CHL), 21 native British Caucasians (CA) and 11 Africans living in the UK (AF). Their mean ages were 23, 31, 31, 29, 34 years old respectively. They were all the students or staff from Zhejiang University or Leeds University.

Experimental procedure

The experiment was conducted in a dark room. Each observer first adapts in the experiment for 1 minute. S/he was shown the screen as used in the real experiment. They were then trained to judge a few images to be liked or disliked according to their memory colours. A user-friendly interface was designed by

touching the screen technology. Observers controlled the buttons in terms of liked, disliked and redo.
Each observer did one object at a time. Each experiment in one session took about 1 hour to complete all 28 memory objects, for which 4 objects were repeated to examine the repeatability performance.

Results

The threshold method was used to scale each image. The raw data (liked or disliked) were processed to form a percentage of the liked (P_v in percentage).

Observer variation

The observer variation was analysed in terms of the mean colour difference from the mean (MCDM) [15]. E.g. for each object image, the $L^*a^*b^*$ values for each observer's rendered images were first averaged (M1). These were then averaged for all the observers' average (M2). The difference between M1 and M2 was calculated for each individual observer. The mean of these differences are called MCDM, which represent the typical colour difference between observers in each group.
The results showed that the inter-observer variations were ranged from 1.07 (AF) to 1.57 (CA) DE^*_{ab} units with a mean of 1.32. and intra-observer variations were ranged from 0.72 (SA) to 1.19 (CHZ) DE^*_{ab} units with a mean of 1.00. It was found that each ethnic group had inconsistency for different objects. For example, the CA observers assessed Pork and Pine most inconsistent. But the other groups did assess these objects consistently.

50% preference ellipsoids

The result for each memory object was defined in terms of colour centre and 50% boundary. These were determined by an ellipsoid equation in CIELAB space as given in Eq. (1) and (2).

$$P_p = \frac{1}{1+e^{(\Delta E' - \alpha)}} \quad (1)$$

$$\Delta E' = \sqrt{\begin{array}{c} k_1(L^* - L_0^*)^2 + k_2(a^* - a_0^*)^2 + k_3(b^* - b_0^*)^2 \\ +k_4(a^* - a_0^*)(b^* - b_0^*) + k_5(L^* - L_0^*)(a^* - a_0^*) + k_6(L^* - L_0^*)(b^* - b_0^*) \end{array}} \quad (2)$$

where $[L^*_0, a^*_0, b^*_0]$ are the memory colour centre and are used to represent the present study; the k_1 to k_6 are the coefficients for the ellipsoid equation; the a is the colour difference from eq. (1) corresponding to 50% acceptance of preference. All 10 coefficients were optimised by maximizing the correlation coefficient between the visual data (P_v) and the calculated value from Eq. (2) (P_p). A MATLAB routine, lsqcurvefit, to perform least square optimization was used.
Figs. 1 and 2 show the ellipses plotted in a^*b^* and $L^*C^*_{ab}$ planes, respectively. It can be seen in Fig. 1 almost all ellipses except Smurf to point towards neutral point, indicating observers are more rigorous along hue than chroma direction. Also, smaller ellipses are closer to the neutral region. Note that Smurf may not be a

familiar object across all ethnic groups, i.e. its ellipse is large and does not point in a huge direction. Fig. 2 shows all ellipses were orientated towards following the vividness direction [16], i.e. a more vivid colour would have a higher lightness and chroma values than a less vivid colour. Furthermore, the size of the ellipses is increased along the vividness direction.

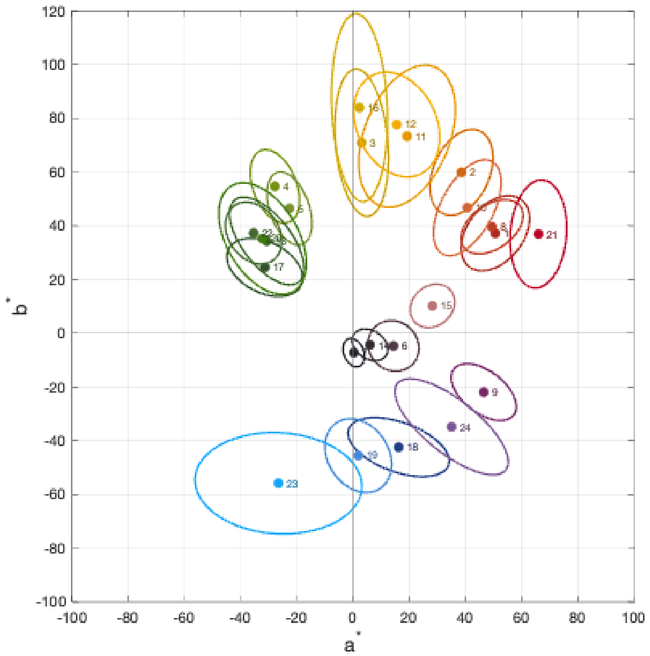

Figure 1. Preference ellipsoids in a*b* plane of global observers

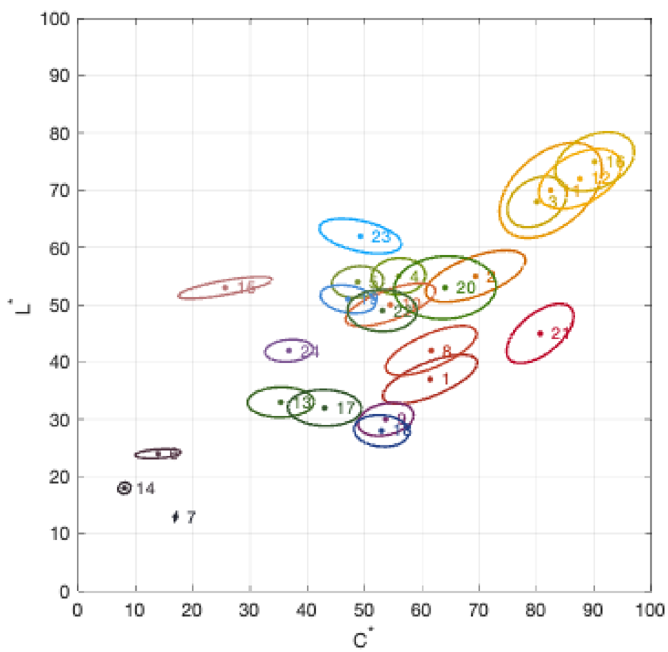

Figure 2. Preference ellipsoids in $L^*C^*_{ab}$ plane of global observers

Cross ethnic group comparison

The MCDM measure was again used to identify the ethnic group difference for each object. Fig. 3 shows the mean colour difference between each group and the overall mean for each object. The 'mean' results showed that the CHZ and AF groups gave the least agreement to the other groups, and CHL the best agreement. Regarding to individual memory objects, green pepper, Broccoli, Blue sky, Summer grass, Smurf had the largest ethnic group differences (MCDM>4.0 DE^*_{ab} units). Conversely, Strawberry, Orange, Purple grape and Pine had the best agreement (MCDM<1.5 DE^*_{ab} units).
Statistical t-test was also performed. A significant difference ($p<0.05$) was found in preferred memory colours between different ethnic groups except between CHZ and CHL.

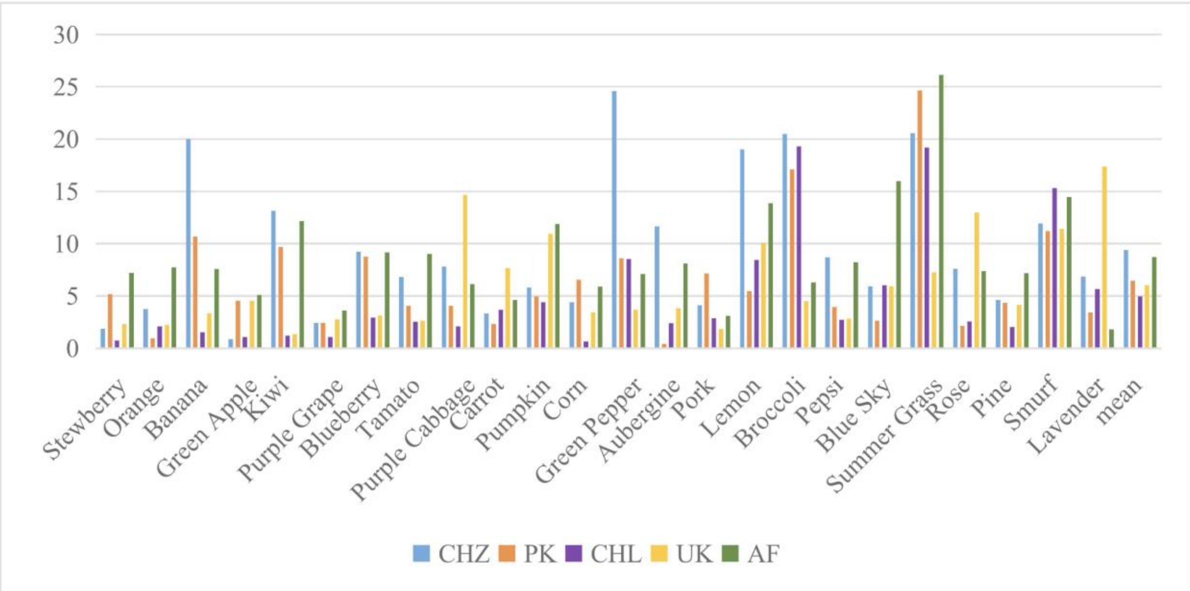

Figure 3. The DE^*_{ab} colour difference of preference ellipsoids centres between each ethnic group and global observers.

Statistical test was also performed based on each CIELAB L^*, C^*_{ab} and hue angle attributes across different ethnic groups. It was found that 'pork' had obvious ethnic differences in the L^*. Banana, green pepper, lemon and summer grass colours had significant ethnic differences in the C^*_{ab}; Memory colour of blueberry and aubergine had obvious ethnic differences in h_{ab}.

Conclusion

An experiment was carried out to study memory colours across 106 observers from 5 ethnic groups on mobile displays. The threshold psychophysical method was used and each observer was asked to make a forced choice decision between like and dislike for the image assessed. Twenty-four familiar objects were investigated and each memory colour was defined by their colour centre and 50% preference acceptance ellipsoid in CIELAB space. The ellipses were plotted in CIELAB space to show systematic patterns.

The intra- and inter- observer variations were quite small, 1.0 and 1.32 DE^*_{ab} units, respectively. The CA group and AF group observers performed the least and the most consistent, respectively.

The results from the CHL observers agreed the best to those of the others. The CHZ and AF observers were more different from the other groups. Amongst the objects, green pepper, Broccoli, Summer grass, Smurf had the largest ethnic group differences.

References

C.J. Bartleson, "On the preferred reproduction of flesh, blue-sky, and green-grass." *Photographic Sci. and Eng*. 6(1), 19-25(1961).

C. L. Sanders, "Assessment of colour rendition under an iIlluminant using colour tolerances for natural objects," *Illum. Eng*. 54, 640–646 (1959).

K. A. G. Smet, W. R. Ryckaert, M. R. Pointer, G. Deconinck, and P. Hanselaer, "Colour appearance rating of familiar real objects," *Colour Res. Appl*. 36(3), 192–200 (2011).

M. Vurro, Y. Z. Ling, and A. C. Hurlbert, "Memory colour of natural familiar objects: Effects of surface texture and 3-D shape*," J. Vis*. 13(7), 20 (2013).

S. M. Newhall, R. W. Burnham, and J. R. Clark, "Comparison of successive with simultaneous colour matching," *J. Opt. Soc. Am*. 47(1), 43–54 (1957).

P. Siple and R. M. Springer, "Memory and preference for the colours of objects," *Percept. Psychophysics*. 34(4), 363–370 (1983).

J. Pérez-Carpinell, M. D. de Fez, R. Baldoví, and J. C. Soriano, "Familiar objects and memory colour," *Colour Res. Appl*. 23, 416–427 (1998).

S. N. Endrikhovskaya, F. J. J. Blommaert, and H. de Ridder, "Representation of memory prototype for an object colour," *Colour Res. Appl*. 24(6), 393–410 (1999).

S. N. Endrikhovskaya, F. J. J. Blommaert, and H. Ridder, "Colour reproduction and the naturalness constraint," *Colour Res. Appl*. 24(1), 52–67 (1999).

P. Bodrogi and T. Tarczali, "Colour memory for various sky, skin, and plant colours: Effect of the image context," *Colour Res. Appl*. 26(4), 278–289 (2001).

P. Bodrogi and T. Tarczali*, Investigation of colour memory in colour image science: exploiting digital media*. John Wiley & Sons Limited. 23–48(2002).

K. A. G. Smet, W. R. Ryckaert, M. R. Pointer, G. Deconinck, and P. Hanselaer, "A memory colour quality metric for white light sources," Energy Build. 49, 216–225 (2012).

Y. Zhu, M. R. Luo, B. Sebastian, P. Bodrogi, T. Khanh. "Long-term memory colour investigation: Culture effect and experimental setting factors," *Journal of the Optical Society of America A*. 34. 1757. 10.1364 (2017).

M. Melgosn, "Testing CIELAB-based colour-difference formulas," *Colour Res. Appl*. 25(1): 49-55 (2000).

R. S. Berns, *Billmeyer and Saltzman's Principles of Colour Technology*. Wiley; 2000.

R. S. Berns, "Extending CIELAB: Vividness, depth, and clarity," *Colour Res. Appl*. 39(4): 322-330 (2014).

Comparison of brightness perception of facial skin with differences of skin color

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Abstract

Reddish skin appeared brighter than yellowish skin when both had the same lightness for Japanese observers (Yoshikawa et al., 2012). Nevertheless, Thai, Korean, Chinese, or European observers showed opposite or inconsistent tendencies (He et al., 2021). There are some possible reasons for this difference, such as the observer's ethnicity and living environment as well as the judgment criterion or the definition of brightness. Here, we investigate how the definition of brightness and judgment criteria influence facial brightness evaluation. We conducted experiments with two criteria, "appearance match" and "brightness match." We also tested two types of scale images for judgments: face and uniform patch. The results of the two criteria showed a similar trend, suggesting the little influence of brightness definition. The results for the face scale image showed a similar tendency as the previous studies, but not for the uniform color scale. This may imply that the observer matched different areas on the face when using the uniform scale (i.e., Japanese observers tended to gaze at the eyes and cheeks). We need further investigation on the fixation area of observers in different regions or countries. Our results suggest the influence of stimuli and evaluation criteria on facial brightness judgment.

Keywords: *Facial color, Brightness perception*

Introduction

Human skin color is one of the most common colors we see in everyday life. Skin color varies among different ethnic groups, and it can range from dark to light and yellowish to reddish. Differences in the color appearance of skin could arise from many factors. It has not been verified whether the color perception of groups with similar cultural backgrounds and living environments are similar and different from other groups.

The skin color distribution of young Japanese women shows a trend that yellowish skin has higher lightness than reddish skin. In contrast, reddish skin appeared brighter than yellowish skin when both had the same lightness

(Yoshikawa et al., 2012). This suggests that the color perception of facial skin is special. We further investigated how the brightness perception of facial skin was influenced by the diversity of skin colors and observers. As a result, Japanese observers showed that reddish skin appeared brighter than yellowish skin, consistent with the previous research. Conversely, Thai, Korean, Chinese, or European results showed opposite or inconsistent tendencies (He et al., 2021). It is unclear why only the Japanese perceived reddish skin as brighter and what factors affected the judgment of skin brightness by people from different cultural backgrounds. The observer's task was brightness matching. Because the observers' mother tongue is divergent, the possibility of differences in the understanding of "brightness" cannot be ruled out. The understanding of three color attributes could be different even for experienced observers (Melgosa et al., 2000). It is necessary to verify whether brightness's definition and judgment criteria affect the results.

This study investigates whether the influence of judgment criteria, the definition of brightness, and complexity of the scale image for evaluation on facial brightness judgment.

Experiment 1: Influence of judgment criteria and definition

We used uniform color patches as scale stimulus. Because the uniform color patch has the same hue and changes only in the brightness direction, we hoped to eliminate the influence caused by the different understanding of "brightness matching" by observers. Also, by setting up "brightness matching" and "appearance matching" evaluation experiments, we tested whether Japanese observers' brightness judgment of the facial skin was affected by those definitions.

Stimulus

First, we prepared several original male and female faces of Asians, Caucasians, and Africans corresponding to intermediate, light, and brown skin color. As shown in Figure 1, six average faces (three male faces and three female faces) were made by morphing the original faces in the same group (Yin et al. 2006). The noise, such as freckles and spots on the face, was removed. We added a hairband at the hairline and an N5 gray bar on the eyes to avoid effects other than face colors, such as hairstyles and expressions. The average skin color of each face image corresponds to the average CIELAB value of each skin color types; intermediate (L^* = 60.93, h_{ab} = 55.91, C^* = 20.48), light (L^* = 59.6, h_{ab} = 51.05, C^* = 19.07), brown (L^* = 46.50, h_{ab} = 63.95, C^* = 20.52). These values were obtained from previous studies (Everett et al., 2012, Yoshikawa et al., 2012, Xiao et al., 2017). Here, we refer to ITA colorimetric classification to indicate three skin color types, intermediate, light, and brown (Bino et al., 2013).

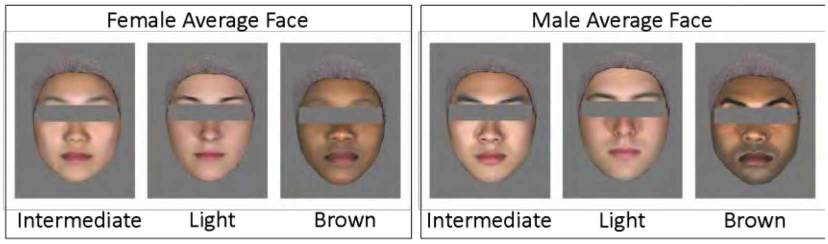

Figure 1. The six average faces.

Figure 2 shows the example of test stimuli and the scale stimuli with the light skin color. The six average faces are used to generate a test stimulus image set with constant lightness and different hue angles. There were five hue levels in total; the scale of the hue angle was in 4-degree steps. We modified the skin tone by changing the ratio of ***L*, a*, b****, and the entire distribution of the face area shifted along the ***a*, b*,*** and ***L**** dimensions. In other words, the color of each pixel in the face area was shifted the same distance as the shift of average color while keeping the color distribution of the face the same. To eliminate the uncertainty caused by the language during task description, we prepared a uniform color patch with the hue of each original face varying lightness for scale stimuli.

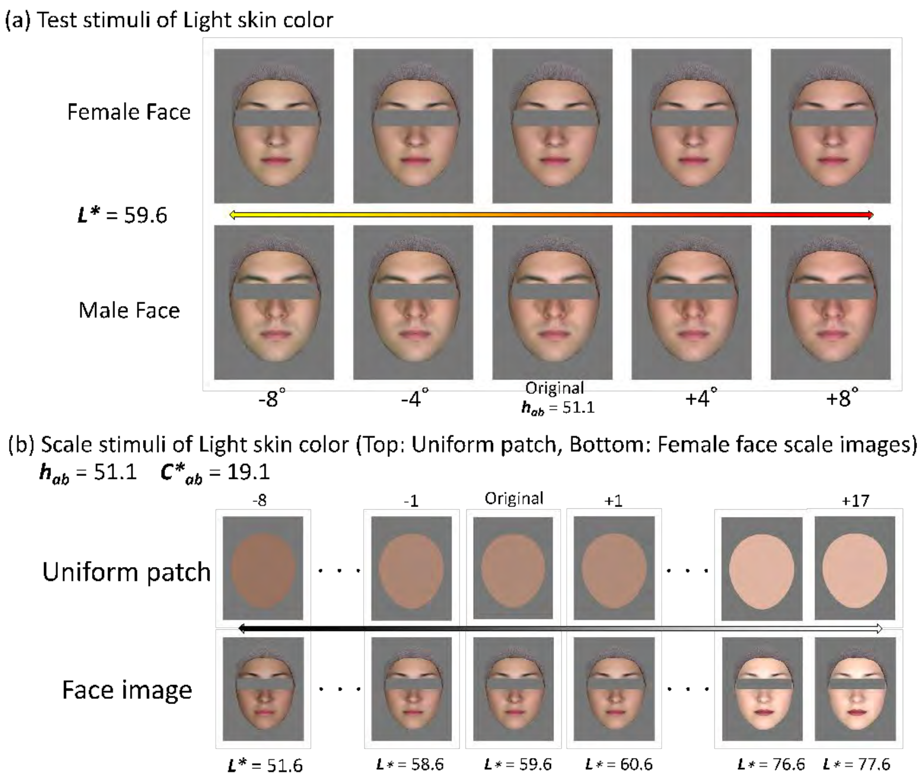

Figure 2. Examples of the test stimuli and the scale stimuli with the light skin color.

Experimental environment and Observers

The experiment was carried out in a dark room with a viewing distance of 60 cm. The observers were 10 Japanese university students with normal color vision. Figure 3 shows the experimental display.

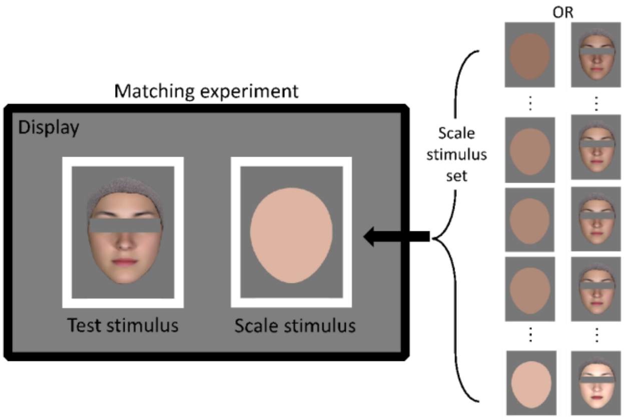

Figure 3. The experimental display.

Procedure

The test and scale stimuli were presented on a display. Observers adjusted the lightness of the scale stimulus by operating the keyboard until its appearance matched that of the test stimulus. Some observers were instructed to "adjust the appearance of the left and right images to be consistent," while others were instructed to "adjust the brightness of the left and right images." In each session, 30 stimuli for the six faces were evaluated once. Each observer ran five sessions.

Results

Figure 4 shows the results of Experiment 1. The horizontal axis is the hue angle change, representing the five hue levels of the test stimulus. The positive direction indicates that the skin color of the image is more yellowish. The vertical axis is the difference between the perceived lightness and the measured lightness value of the test image. The three symbols represent three different skin colors. The average result of 8 observers when the task is "brightness matching" and that of 2 observers when the task is "appearance matching" is shown. Observers evaluated higher lightness for the yellowish face, contrary to the previous research where face images were used as scale images. In addition, although the descriptions of experimental tasks are different, there is no significant difference between the results of the two tasks ($p_{Intermediate}$ = 0.79, p_{Light} = 0.34, p_{Brown} = 0.59). The judgment criteria of brightness and appearance seem to have no significant impact on the results, suggesting that it is not the reason for differences in the brightness judgment of facial skin. However, we obtained different tendencies due to the change of scale image. We further investigated the reason in Experiment 2 and other additional experiments.

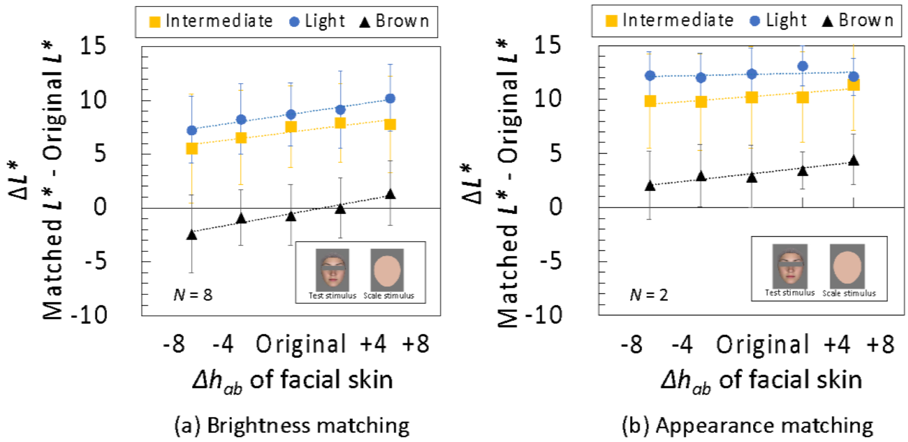

Figure 4. The results of Experiment 1.

Experiment 2: Using face image as a scale stimulus

The results for the uniform color scale were contrary to previous studies. We experimented using face images as scale images to compare the impact of scale stimuli directly since the observers in Experiment 1 were a different group from previous studies. Moreover, we considered that the amount of information in the scale image seems to impact judging the color appearance of the skin. In Experiment 2, the face image corresponding to the test image with an unchanged hue and only changed lightness was taken as the scale image.

Stimulus, Experimental environment, Procedure, and Observers

The test stimuli were the same as in Experiment 1. We also used face images for scale stimuli (See Figure 2(b) bottom). The Experimental environment and procedure were also the same as in Experiment 1. The experimental task was "brightness matching." The observers were 6 Japanese university students with normal color vision. Each observer ran three sessions.

Results

Figure 5 shows the average results of six observers. Results in the session of light skin color type, the observer showed the same trend as the previous study, which was significantly different from that for
the uniform patch scale stimulus ($p < 0.05$).

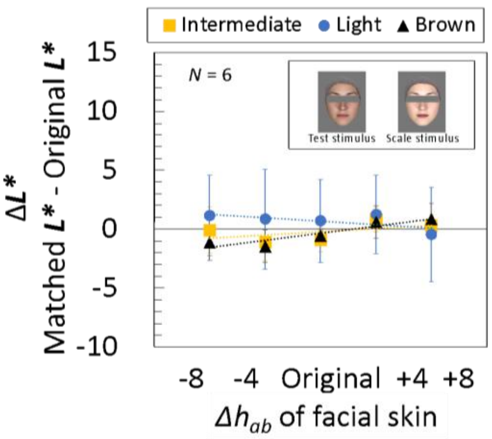

Figure 5 The results of Experiment 2.

Discussion

When using the face scale image, the results of the light skin stimulus set showed the same tendency as the previous studies (reddish skin appeared brighter than yellowish skin when both had the same lightness). This could be because the uniform stimulus image set lacked the information necessary for the judgment or caused different judgment criteria since they did not have any intense highlight and texture like face stimulus images.

Therefore, we conducted a supplementary experiment. Ten observers evaluated 30 test images on a 7 points scale, once for each. The evaluation items include health, preference, brightness, whiteness, tone (yellow to reddish), and transparency. The results showed that the reddish direction was positively correlated with all other evaluation items; when observers rated the stimulus image as more reddish, they also rated it as having higher whiteness and brightness values. Brightness and whiteness also showed a strong positive correlation. This may prove that the observer could distinguish whether the face was reddish or yellowish and evaluated the reddish image as brighter, consistent with previous studies.

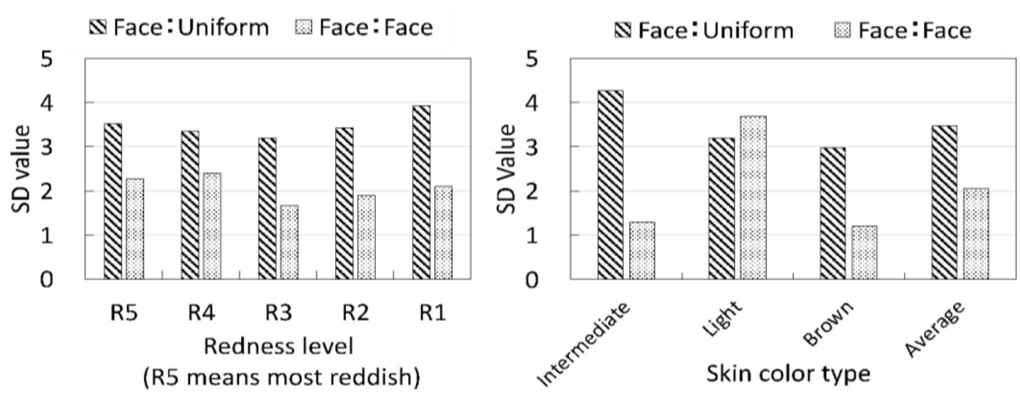

Figure 6. The standard deviation values of Experiment 1 and Experiment 2.

Although the reason for the opposite result when the scale image becomes a uniform patch is unknown, observers reported that the evaluation became more difficult for the uniform scale patches. We compared the standard deviation of Experiments 1 and 2, as shown in Figure 6. The vertical axis is the value of the standard deviation. The horizontal axis of the left and right figure shows the redness level of the test image, and the three skin color types and their average value, respectively. The standard deviation is larger in most of the uniform patch conditions. This may be because each observer focused on different areas of a face, which is an uneven three-dimensional surface, and matched the color or brightness of different areas. Therefore, in part of the experiment, we used an eye tracker to collect the gaze position of the observer synchronously. The main fixation areas of Japanese observers were the eyes and cheeks in general. Although the measurement accuracy needs improvement, the gaze area may also be an important factor in facial perception differences due to different cultural backgrounds.

We investigated how the definition of brightness and judgment criteria influence facial brightness evaluation. When using the face scale image, the results showed the same tendency as the previous studies (reddish skin appeared brighter than yellowish skin when both had the same lightness). However, the definition of brightness did not significantly affect the results. In the impression evaluation experiment, most observers also rated the reddish face as brighter. However, the opposite trend was shown in the uniform color patch scale. The factors affecting the perception of facial lightness would not be single but multiple and comprehensive. Our results suggest the influence of stimuli, the evaluation method, and the focused area on facial brightness judgment. We also need further investigation on the fixation area of observers in different regions or countries and the criterion of judgment. Investigating the perceived differences in skin color and appearance under different cultural backgrounds to contribute to cross-cultural communication, makeup, and medical treatment.

Acknowledgements

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References

Bino, D. S., and F. Bernerd. 2013. Variations in skin colour and the biological consequences of ultraviolet radiation exposure. *British Journal of Dermatology*, 169: 33-40.

Everett, J. S., M. Budescu, and M.S Sommers. 2012. Making sense of skin color in clinical care. *Clinical Nursing Research*, 21(4):1-22.

He, Y., M. Taiga, T. Suguru, K. Kumiko, and Y. Mizokami. 2021. Comparisons in perception of facial skin brightness, as influenced by differences in skin color: Asian observers. *Color Research & Application*, 46: 808-820.

Melgosa, M., M. J. Rivas, E. Hita, and F. Viénot, 2000. Are we able to distinguish color attributes? *Color Research & Application*, 25, 356-367.

Xiao, K. Database of colorimetric measurements of human skin. Available at: http://www.color.org/groups/medical/skin/ skin_colour.xalter.
Xiao, K., J. M. Yates, and F. Zardawi. 2017. Characterizing the variations in ethnic skin colours: a new calibrated data base for human skin. *Skin Research and Technology*, 23: 21-29.
Yoshikawa, H., K. Kikuchi, H. Yaguchi, Y. Mizokami, and S. Takata. 2012. Effect of chromatic components on facial skin whiteness. *Color Research & Application*, 37: 281-291.
Yin, L., X. Wei, Y. Sun, J. Wang, and J. R. Matthew, 2006. A 3D facial expression database for facial behavior research. *7th International Conference on Automatic Face and Gesture Recognition*, 211 - 216.

Session 14

Colour in Health and Design

Colour and Care in Space

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Abstract

This research paper allows us to look into the actions of our relationship with space in the particular environment of the hospital. Beyond the creation of space, our focus is on colour and the way it sets space in motion, both physical and imaginary. As an architecture student, I had the opportunity to do two internships. The first one was with the architect Emmanuelle Moureaux in Japan, where I understood how colour can transform and interact with space. This experience led me to a second internship, this one in research of architecture. I worked with Laure Mayoud in the "Femme Mère Enfant" hospital. The particularity of this psychologist is that she treats with "cultural prescriptions". My project for this internship therefore aimed to create a tool that children could handle and that would make them play and interact with space and colour. As such, my hypothesis poses questions regarding the effects of colour on healing and care.

Keywords : *colour, space, care, mouvement*

Introduction

The following communication presents the means by which a workshop with artist and architect Emmanuelle Moureaux in Japan led me to a research internship with Lyon's hospitals.

Boudreaux's workshop provided insight into the ways that colour can transform and interact with space. Given my interest in colour and my architecture studies, I therefore wished to explore the potential of colour in a healthcare setting. Working with the "Femme Mère Enfant"[1] The hospital gave me the opportunity to create an interactive tool that would transform the well-established relationship between colour and space. My architectural studies have allowed me to realise that, despite the intangible effects of colour on built space, colour is not used as a primary conceptual tool. The aim of this experiment was to understand the potential of colour on the built environment and, in particular, the way it interacts

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[1] The Woman Mother Child Hospital is entirely dedicated to the couple, the mother, and the child. It is the only permanent reception centre for pediatric emergencies in the Lyon area (82,000 visits per year) and also has a gynaecological emergency service.

with patients and caregivers in a healthcare setting. As such, my hypothesis poses questions regarding the effects of colour on healing and care.

Emmanuelle Moureaux colour spaces

My approach to this project was strongly influenced by the knowledge of colour in space I developed during my internship with Emmanuelle Moureaux in Tokyo. Her work as an architect is based on the notion of "shikiri"[2]. She uses colour as a three-dimensional element – as layers – in order to create spaces. For Moureaux, colour is not only as a finishing touch applied to surfaces. Throughout this internship I came to realise how much her projects focus on the feelings and emotions created by colour: "I want the visitors to feel something, emotions through colour, I would say this is my main goal," "theses emotions can be different for everyone"[3]. Emmanuelle Moureaux pursues the creation of wonder, surprise, and bursts of colour in space. This comes from her own amazement when she discovered the colours of Japan for the first time: the traditional blue tiles, the light panels in the streets, the traditional outfits, the temples...

During the creation process of the installation *Universe of Words* in which I participated, I came to realise that working with layers and overlays of porous materials (paper, thread...) can make the walls and ceilings of a space disappear and create a limitless universe of colours. Indeed, some ten years ago, Emmanuelle Moureaux also developed a "100 colours" guideline that allows her to follow a specific order of shades in her work. Each installation will use different quantities and proportions of these 100 colours. Furthermore, the enormous quantity of *hiraganas*[4] and lines in the installation managed to build a deconstructed space.

In order to grasp the magnitude of the installation, one must note that Universe of Words took place over 200m^2; it required the work of about three-hundred-and-fifty people and consisted of 140,000 hiraganas. I believe it is only when participating in the set-up of the installation that one can comprehend the immensity of work, effort, and organization that such a project requires.

Surprising to me in this experience was that, despite having participated in the setting-up, when I entered the finished installation for the first time, I felt transported. It was as if there was a radiant force coming from inside the installation. I was overwhelmed and in awe by this world of colour. The organization of Universe of Words permitted visitors access to smaller areas and corners, allowing them to live the submersion of colour on different scales. It is

[2] Inspired by traditional Japanese sliding screens, Emmanuelle Moureaux created the concept of "shikiri", which translates "to divide space with colours".
[3] Translation of an interview I had with Emmanuelle Moureaux during my internship in Tokyo, 2019
[4] Characters of one of the Japanese alphabet.

submersion in these worlds that takes away the temporality and our knowledge of space. In such contexts, we are therefore forced to rely and focus on our feelings and emotions, or as Kandinsky would call it, “the material states of the soul”5.

Figure 1. Universe of words, exhibition, Chiyoda, Tokyo 2019, source : https://www.emmanuellemoureaux.com/#/universe-of-words

Colour and care theory

Throughout my research on the relationship between colour and space I had the opportunity to complete a research internship with Chantal Dugave, an artist-architect and teacher at the school of architecture in Lyon, as well as Laure Mayoud, a psychologist. Through this internship I wished to question the interactions between colour and the theory of care[6]. As Laure Mayoud works in partnership with Lyon’s hospital, the project I developed focused on the children’s department at the Femme Mère Enfant Hospital in Lyon. Moreover, her approach is to treat her patients with “cultural prescriptions”[7]. The intention of the project was to develop an interactive tool that could, in some way, generate care through the effects of colour. Throughout my research and related experiments, I leveraged my position as an architectural student in order to interact with the notion of space.

The particularity of care theories is that they allow social and political issues to be presented beyond the field of care and health. They also allow us to question the place and role of vulnerability and care in our own lives, and then to question its place in society. Apart from the home and, perhaps, healthcare spaces, we do not define the spaces that we occupy in everyday life as places where we can express our vulnerability. It is therefore interesting to question spaces and architecture in

[5] Kandinsky, W., 1988, Du spirituel dans l’art et dans la peinture en particulier, translation : RICOME L.
[6] Girault, E., 2010, « Joan Tronto, Hervé Maury, Un monde vulnérable. Pour une politique du "care" ».
[7] She uses poems, perfumes, paintings and music to cure her patients.

terms of how they can become conducive to this encounter. Consequently, this raises the question: what role does colour play in humans' awareness of our own vulnerability?

The ethic of care is an active process that can be broken down into four "analytically distinct but intimately related" [8] phases: "caring about, taking care of, caregiving and care receiving"[9]. In my internship experience, I did not position myself as a caregiver but as an architecture student seeking to question how colour and space could "care about" the quality of the hospital environment. It was during my visits to the the Femme Mère Enfant hospital that I became not only aware of some of the children's needs, but also those of their caregivers. Indeed, a child in hospital is alone, without their family, in a room that is not their own and that they cannot really make their own. They therefore express a lack of attachment, comfort, and familiarity in their environment, but also a lack of lightness, imagination, and playfulness. It is therefore important "to take care of" the quality of the architectural space in such medical settings.

In order to develop a "care-giving" approach, I took Emmanuelle Moureaux's work and process as a reference. Indeed, I wished to develop an object that could use layers in order to generate space through the intangible material of colour. Moreover, the work of the artist-architect gave me the keys to generate space from two-dimensional porous elements such as paper. Unfortunately, the last phase, "care receiving," did not take place because of the COVID-19 pandemic. The nature of this crisis made it impossible for me to bring the object to the hospital and to see its uses and effects on children. I therefore did not get any feedback from the patients and care-givers. However, working with Laure Mayoud, founder of the association *L'invitation à la beauté* (The Invitation to Beauty)[10]I was able to test my proposal with members of the association.

How to manipulate colour and space ? .

At the beginning of this research internship I had the opportunity to meet with professionals (care-givers, doctors, artists, illustrators, authors, etc.) but also patients. A conversation with a children's illustrator and author made me realise the importance of interaction, appropriation, surprise, and amazement between object and child. One of the main objectives of the project was to stimulate the children's imagination. My first step in developing a prototype was to define its content and materials. Indeed, these two factors were critical to creating a world of colour and wonder. The content would need to stimulate the interest and action of its reader: games, cutouts, drawings, stickers, fill-in-the-blank texts, etc. were used to achieve this end. Textured sheets served as the medium through

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[8] C TRONTO J., 2008, « Du care », Revue du MAUSS, 2008/2 (n° 32), p. 243-265
[9] Ibid.,
[10] http://www.linvitationalabeaute.org/

which colour was communicated. Maintaining children's interest, however, also necessitated the stimulation of the senses (touch, sight, etc.). Therefore, transparent, glitter, cardboard, mirror sheets could be implemented to play with readers' senses. Their use also offered the possibility of encounters or overlap between different materials and colours in order to create depth and perspective within the object. Transparent coloured papers were also used to give the possibility to project oneself – in a way not dissimilar to glasses – in space.

Figure 2. Organization of the *Leporello*, source : © RICOME L.
Figure 3. Working draft of the *Leporello*, source : © RICOME L

Finally, the colours used had to be bright and lively, as they are the ones that have the strongest surprise and amazement effect. Moreover, the fact that this project was set in the particular environment of a hospital set certain constraints. Indeed, it was more welcomed to work with colour that initiated active energy and good humour, rather than melancholy with bleak colours such as black. After having determined the stakeholders and relevant tools, I was able to define the format of this object. As the aim was to find a way to set space in motion through the use of coloured sheets, I chose to work on a *Leporello*. This object is a book that unfolds like an accordion due to the particular folding and gluing techniques. This format allowed me to work with a two-dimensional element that unfolds and opens us. It is not a fixed and passive object; its shape interacts and takes place in space. The *Leporello* also offers different readings through non-linear approaches. Moreover, I found interesting the way this object can become an immersive experience through its changes of scales.

The format, the content and the materials allowed me to focus afterwards on the way I could create depth and space through this object. The layers of the *Leporello* could be played with by cutting out some parts of a page in order to overlay sheets and materials. I also had to spend time on the colour scheme to ensure positive interactions between the colours used, the space, and those interpreting the project. Similarly crucial was the need to account for potentially disparate readings of the installation. The choice and ordering of the colours also needed to stimulate the amazement and harmony that colour schemes have the potential to imbue in onlookers.

Colour and movement

Through this approach I was therefore looking to create depth, width, and thickness in the interpretation and the movements created. The colour pattern and the colours themselves allowed me to open up vibrations and emotions in the "receiver". In order to develop this approach, we need to seize the ways that colours produce movements. First of all, the movements created are physical. From Wassily Kandinsky's approach, colour has a double effect. The first one is purely physical and short-term, an effect which Kandinsky compares to the touch of ice or fire, and which can generate ephemeral feelings of happiness. Then follows a second, deeper effect: deeper that brings out an emotion of the soul. This duality allows colour to have different time scales and to stimulate our bodies and mind in different ways. Kandinsky's other approach involves "letting the colour alone act on you"[11]. This means that even as a passive spectator we interact and live the effects of colour. In order to understand the place colour holds in space, we have to separate colour in two main contrasts. The first one is warmth/coldness which is perceived as horizontal movement, coming towards us for warmth and moving away for coldness. The second contrast can be generalised as the difference between black and white, therefore the tendency for a colour to be bright or dark.

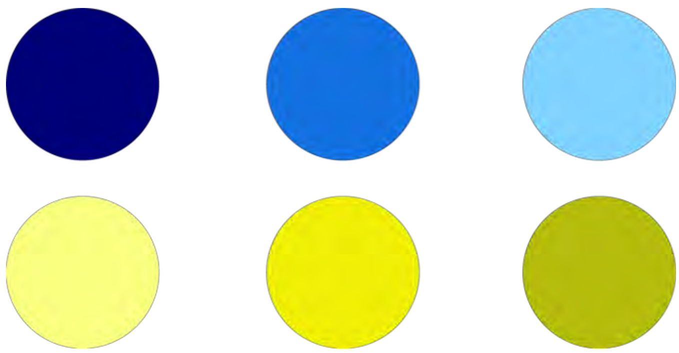

Figure 4. Light and dark effects on blue and yellow

The shades of one colour keep the same horizontal movement but the speed changes (from dynamic to static). A warm colour with a bright shade will see its

[11] KANDINSKY W., 1988, Du spirituel dans l'art et dans la peinture en particulier, translation : Lou RICOME

effect increase with a dynamic movement, just like a cold dark colour will. However, a cold warm colour or a bright cold colour will tend to become motionless. Another type of movement that we have to take into account is the concentric or eccentric movement of a colour. This can be observed with the example of a yellow and blue circle. Indeed, the yellow circle overflows from its outline whereas the blue one withdraws in its centre and moves away from us. If we come back to the movement previously established, we can observe that the effect of the yellow circle increases when brightened and the effect of the blue once increases when darkened.

Figure 5. Your uncertain shadow installation, Olafur Eliasson, 2015, London, source: https://olafureliasson.net

Moreover, from a scientific approach we know that colour does not stay the same over time. Many micro-transformations make it constantly evolve. These constant changes question the interactions of colours and their environment. They also unconsciously stimulate our vision/perception and attention because even though we have an impression of continuity: "Objects always shift or mutate over time, and, if we become aware of this constant movement, we may be able to understand the world as a much more open, negotiable space"[12]. This quote from Olafur Eliasson, artist, makes us question the rigidity of space when it encounters the element of colour. To be aware of this approach enables us to have an active relationship to a coloured environment: "Its instability, its evanescence and its mobile identity"[13]. Olafur Eliasson even speaks of an "open-ended process, rather than a discrete or ponctuel act of looking"[14] in our interaction with colour. These processes allow Eliasson to work on projects that will generate movement and that can not be observed from a distance or with a passive contemplation.

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[12] Eliasson, O., 2006, « Some Ideas about Colour », Olafur Eliasson: Your Colour Memory, p. 77
[13] Crary, J., 2004, « Your Colour Memory: Illuminations of the Unforeseen » In Olafur Eliasson: Minding the world, Edited by Olafur Eliasson and Gitte Ørskou, Exhibition catalogue, Aarhus: ARoS Aarhus Kunstmuseum, p.220
[14] *Id.*, p.221

Opening up uncertainties and instabilities through the use of colour stimulates a constant consciousness towards our bodies and minds. Eliasson's main goal is to give the visitors the opportunity to relearn to be open and attentive to our bodies, with all its senses. He manages to do so by using colour in its unexpected and imbalanced capacities. An example of his approach is the installation *Your Uncertain Shadow* that aimed to activate the visitor's body by putting their physical movement at the center of the production: the body itself generates light and colour. This approach to colour, according to the philosophers James, Nietzsche, John Dewey, and Henri Bergson, gives us the opportunity to "escape the numbing claims of habits and routine"[15]. The imbalance or discontinuity of coloured experiences generate a disruption of habits[16] through our bodies and senses. By these sensitive stimuli, we remain alive, anchored in our body, in our feelings, and in the lived moment. We are awakened against habit, boredom, and stability, which enriches our bodily experience and the way we take our place in the world.

Setting the psychic back in motion

Second of all, movements generated by colours are also psychological. As we have started to understand that colour is one of the elements that stimulates the relationship with ourselves, our way of being, our imagination and our ability to open up to the world. By activating space, by creating movement and by generating emotions and sensations, colour activates the imagination that we develop for ourselves of our experiences. We can therefore perceive colour as an element allowing us to "explore the imagination as a living mediation structuring the experience of the world"[17]. This act of setting in motion, both physically and psychologically, allows us to anchor ourselves in space and in the exchanges that we encounter: "this trans-position of the subject can only be explained by the action of an imagination creating the impression of living inside beings and things as if they lived in us"[18]. Therefore, colour stimulates the imagination through its sensory and emotional capacities. The sociologist, Phillipe Descola, emphasizes this characteristic, explaining that "detached from feeling, colour has no existence"[19].

Our relationship with colour is consequently rooted in the temporality of our self, our feelings, and our subjectivity. We are in perpetual evolution and transformation through the events of life, which implies the impossibility of repeating a sensitive phenomenon. The active nature of colour stimulates us and seeks to set our body and our imagination in motion within space. These

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[15] *Id.*, p.223
[16] Olafur Eliasson's description to the use and effect of colour on ourselves and our lives
[17] Crary, J., 2004, « Your Colour Memory: Illuminations of the Unforeseen » In Olafur Eliasson: Minding the world, Edited by Olafur Eliasson and Gitte Ørskou, Exhibition catalogue, Aarhus: ARoS Aarhus Kunstmuseum, p.223
[18] Ibid.
[19] Ibid.

movements and feelings allow us to "experience ourselves" by focusing our attention on our body and mind. According to Philipe Descola, experiencing ourselves/feeling ourselves is the very essence of life, since one lives the experience and existence of oneself without distance, without hindsight. It is precisely when we experience ourselves that we can gain awareness of our vitality, of our existence as unique living beings. Taking time to feel this phenomenon is part of our encounter with ourselves and therefore of the development of our personhood, of our identity, and of our wellbeing. According to Kandinsky, intangible elements open up the world to the unexpected, mysterious, and indescribable, allowing us to experience what he describes as "the essence of our invisible life"[20]. These invisible phenomena stimulate what is strongest, deepest, and most indescribable in our experience of the world and of ourselves.

The hypothesis I developed through my research asks, therefore, not how colour can bring physical treatment or care to certain needs. Rather, I seek to question how colour can generate psychological well-being through the vitality it stimulates in the human experience of space. This movement that is induced by colour, both physically and psychologically, brings us knowledge and awareness of ourselves and the ways we feel. I therefore developed the *Leporello* with the idea that its uses and interactions with colour and space would generate psychological well-being in patients of Lyon's hospital. Furthermore, we must keep in mind that this project is set in a very specific environment: the patients under observation cannot necessarily move out of their beds. I therefore chose to question and work on the ways that movement could be brought to the often-stagnate hospital rooms of these patients. This is how I believe the experience and use of the coloured *Leporello* could generate movement in the patients' limited spatiality. As was mentioned previously, I did not have the opportunity to test the *Leporello* in its intended environment as a result of the healthcare-related constraints imposed on the COVID-19 pandemic. However, during my time in the hospital and in my work with Laure Mayoud, I was able to grasp the profound impact artistic works can have. Her encounters and discussions with the patients made me realise how much a painting, a picture, or simply a colour has the ability to open up windows to the outside and imaginary world of the patient. By paying attention to these productions, patients are transported and are given the opportunity to escape from the difficult reality of the hospital.

These observations allowed me to develop the hypothesis on which I based my research and allowed me to define the ways the *Leporello* would generate psychological well-being for the patients through the movements created by colours.

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[20] TABET P., 2013, Peindre la vie. Phénoménologie de l'invisible In : La Vie et les vivants : (Re-)lire Michel Henry

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References

Crary J., 2004. Your Colour Memory: Illuminations of the Unforeseen *In Olafur Eliasson: Minding the world*, Eds, Olafur Eliasson and Gitte Ørskou, Exhibition catalogue, Aarhus: ARoS Aarhus Kunstmuseum, 209-225. http://olafureliasson.net.s3.amazonaws.com/texts/Your_Colour_Memory_Illuminations_of_the_Unforeseen_by_Jonathan_Crary_111191.pdf

Eliasson, O., 2006. Some Ideas about Colour. *Olafur Eliasson: Your Colour Memory*, Glenside p. 75–83. https://s3-eu-west-1.amazonaws.com/olafureliasson.net/texts/Some_Ideas_About_Colour_109981.pdf

Girault, E., 2010, Joan *Tronto, Hervé Maury, Un monde vulnérable. Pour une politique du "care" »*, Lectures [En ligne], Les comptes rendus, http://journals.openedition.org/lectures/929

Kandinsky, W., 1988, *Du spirituel dans l'art et dans la peinture en particulier*, Paris, Gallimard.

Tabet, P., 2013, *Peindre la vie. Phénoménologie de l'invisible In : La Vie et les vivants : (Re-)lire Michel Henry* [en ligne]. Louvain-la-Neuve : Presses universitaires de Louvain. http://books.openedition.org/pucl/2736

Tronto, C.J., 2008, Du care*, Revue du MAUSS*, 2008, 2 32), p. 243-265. https://www.cairn.info/revue-du-mauss-2008-2-page-243.htm

Color-design applied to the elderly's nutrition: a public health issue

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Abstract

In a general context of population aging, we question the therapeutic scope of the concept of "gourmet color". The color then becomes a major health ally when taking meals for elderly. Indeed, taste comes first by sight. A multisensory search for gourmet colors helped identify appetizing and stimulating chromatic combinations, summoning the sensory memory attached to tastes. We associate a research on the textures and more precisely the use of the modified textures, adapted to the swallowing disorder. The color makes possible a restitution and a rediscovery of the flavors, often denatured by the aspect of these textures. This new chromatic composition makes it possible to question in particular the codes of the gastronomy and the collective catering in favor of an innovative, stimulating and gourmet culinary experience which can be declined for the daily meals. Thanks to this meeting, combining color research and textures, we seek to promote a therapeutic diet that awakens the senses, restores the desire and experience of taste in elderly. Thus, this concept of "gourmet color" becomes a key element for a harmonious aging and factor of good health.

Keywords: *Aging, Appetence, Sensory Perceptions, Undernutrition*

Introduction

Aging is naturally accompanied by changes, particularly physiological changes. Changes in body composition, hormonal function, or digestive system, chemosensitive senses, etc., are all changes that affect the eating habits and practices of elderly (Kergoat (2001)). And advancement to old age, 80 years and older, is conducive to an increase in these changes and to the proven appearance of sarcopenia and/or significant iatrogenesis (Coutaz and Morisod (2001)). These clinical manifestations, little symptomatic or misdiagnosed, can lead to a state of malnutrition in the person (Ferry et al. (2005)). The consequences of this undernutrition are many, ranging from increased risk of falling (Alonso et al. (2010)), cognitive disorders to depressive states.

For good reason, the meal is the primary source of pleasure for the elderly, especially in institutions because it represents a moment of sharing and enjoyment (Seshadri (2008/09)). But when the state of undernutrition is diagnosed, it’s a question of restoring the nutritional state of the person, to improve and to favor quality and pleasant eating habits for the user. Nutritional management is therefore part of a complex therapeutic context, including both the nutritional value of the foods on offer and their presentation (Lecerf and Schlienger (2016)). But undernutrition isn’t the only consequence of our physiological evolution. Diet also plays an important role. An undernourishment will accentuate the consequences of natural evolution and may even trigger other pathologies then nonexistent in the person and thus engender an increased fragility. This undernourishment can be caused by a change in eating habits and habits. For example, when a person with a cognitive impairment no longer knows how to use cutlery, or when someone else has motor problems and can no longer use them, there is a decrease in food intake, whether it’s unconscious or conscious. It can also be voluntary, especially in institutions when a resident refuses to eat (Cottet et al. (2010)). This refusal may be the manifestation of a malaise, or simply to indicate a non-adequacy with one's tastes and/or needs (Cardon and Gojard (2008)). This is why it’s important to adapt the diet to the needs and desires of the person, to promote an oral diet, which is psychologically beneficial. An adapted diet is then translated by the combination between a nutritional balance and the use of modified textures to allow seniors to feed autonomously while giving them the desire to eat (Lesourd et al. (2001)).

Experimentation

Considering the importance of this combination between nutritional balance and food textures, we focused on a work of modified textures, which could be transposable to all food families. The appropriate choice of textures according to the needs of the person thus contributes to facilitating their nutritional balance (Pouyet et al. (2013)). Research on modified textures now promotes the empowerment of dietary practices and oral nutrition by adapting to people's needs, but sometimes to the detriment of presentation (INRA (2012)). The change in appearance of the food leads to a change in sensory perceptions and can lead to loss of identity, which may lead to undernutrition (Howes (2010)). Indeed, despite the fact that the modified textures meet the physical and physiological needs, they participate in the modification of sensory perceptions, their loss of appetite. This is why the research we have conducted concerns directly the feeling of palatability, feeling conveyed by the colors and more specifically by the colors described as gourmet (Blin-Barrois et al. (2003)). Associated modified textures adapted to the needs, correlated with colors arousing gluttony, one makes possible the composition of an adapted and appetent food. For this, we sought to qualify the characters of a greedy color and identify families of colors that can arouse gluttony, and so the appetite once transposed to different textures.

Results

In order to convey this feeling of greed, it’s first necessary to define its qualities. Relative to "the art of preparing a good meal" (Rey (2016)), it’s characterized in occidental society by the use of quality foods, generous quantities, etc., above all the pleasure of eating rather than the need to feed. Color plays a major role in this pleasure, present when the color of the food is consistent with the image that is made (Blin-Barrois et al. (2003)). Trusting this premise, a gourmet color would be a color consistent with the color image that is made of the food. It's then necessary to define the colors relating to the different families of foods that we consume. We then define a chromatic panel, presenting the food color families (Figure 1), a definition based on collective representations.

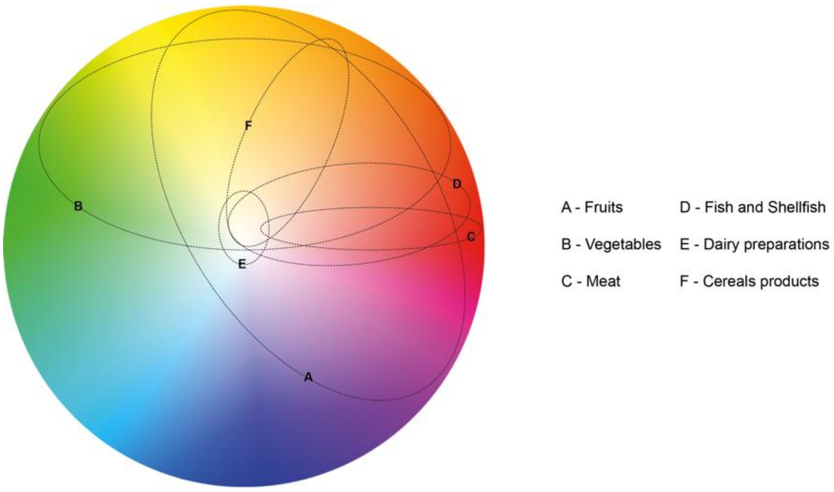

Figure 1. Simplified identification on chromatic circles of the families of colors called food, according to the collective representations and the images which one makes of food.

The development of these different families makes it possible subsequently to produce color charts relating to each of them, subdivided into different categories (Figure 2).

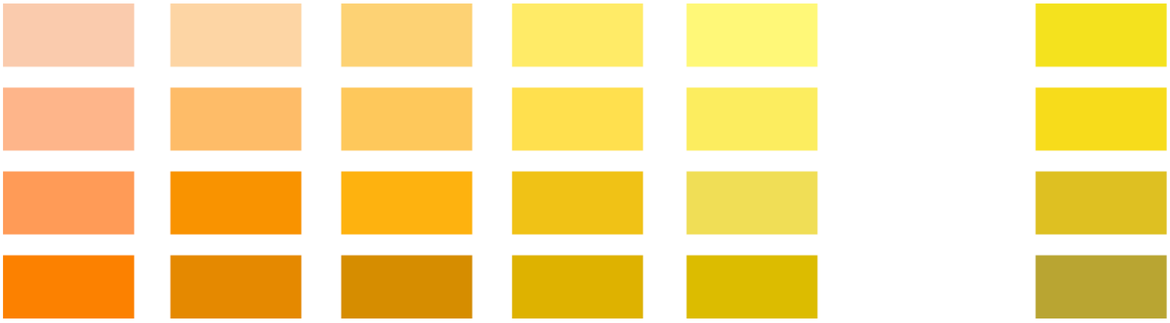

Figure 2. Example of a fruit chromatic range: a sample from the *Yellow Fruits* category, extracted from the *Fruit* color chart.

They allow one to visualize their respective chromatic richness. Above all, they make it possible to identify chromatic recurrences between families and subcategories. They reflect the tunes of families, making it possible to move from one to another, or on the contrary to create structuring boundaries. These swatches offer a rich chromatic pool, allowing the sampling from one color chart to another in order to design chromatic ranges presenting entities specific to each family. Considering the different foods necessary for the nutritional balance, we can create color combinations that are visually greedy, thus arousing the appetite of the user (Jacquot et al. (2012)). The use of these color charts makes it possible to multiply the combinations, both chromatic and tasteful, and to propose new and original sensory experiences or contraries respecting the memories of a cuisine of yesteryear and authentic (Figure 3).

Figure 3. Examples of chromatic ranges, preceding the preparation of the dishes. They present the proportions and chromatic characters of the foods in the recipes, whether new, old, or even exotic. Respectively from left to right (revisited dishes in modified textures): Chili Con Carne, Meringue Lemon Pie, Japanese Mochi, Panna Cotta Yellow Fruits, Indian Dahl.

Discussion

Defining the characters and families of food colors allows us to observe rich chromatic ranges that are representative of the food spectrum. Thanks to the consideration of the different categories of foods, we can conceive a multitude of chromatic combinations, reflecting the common use of the different foods constituting our diet. Emphasizing their chromatic character makes it possible to compensate for their destructuring if necessary. This allows sensory perception to be meaningful (Sagot, 2003) by creating visual cues through sometimes-colored families. By synesthesia principle, they allow an accentuation of the tastes thanks to the visual suggestion (Maille, 2007). Thus, we bring a new sensory dimension to food through color/texture ranges, in the form of modified textures. The color suggests gluttony thanks to its identity register and the chromatic combinations. The color, thus arousing the feeling of palatability, is part of the complex system of therapeutic feeding. It's then a question of considering color in its materiality and no longer as a conceptual object. The natural colors of the foods and their impermanence according to the cooking and the preparations become creation's materials. The combinations and choices of foods then make it possible to create new sensory universes by reconciling chromatic, taste and nutritional characters. Moreover, if the use of the concept of gourmet colors makes it possible to check a state of undernourishment, they can also take on a preventive dimension (Jaeger (2008)). Maintaining the appetite of people through the use of palatable textures contributes to their nutritional balance and an oral diet, thus contributing to the feeling of autonomy and the enhancement of the person (Patry and Raynaud-Simon, 2010).

Conclusion

The nutrition of seniors is becoming an important issue in care protocols, particularly because of their fragility, which can be associated with a state of undernutrition, becoming critical for their health. Food becomes an important ally to stop this state of undernutrition. It's a question of adapting it to their deficiencies and their needs, but also to their desire (Escalon and Beck (2010)).

The palatability of food is then a major lever of a therapeutic diet, palatability sometimes forgotten in favor of technical answers to needs. Transforming food into various modified textures, sensory perceptions are altered at the expense of gluttony. The color then makes it possible to palliate the loss of palatability thanks to the synesthesia principle. Supporting the chromatic character of a food will then accentuate its taste. The consideration of food colors thus contributes to the greed of foods despite their destructuring and the consequent loss of their identity. The definition and development of the concept of "gourmet color" makes it possible to anchor the use of color in treatment courses in favor of a therapeutic -chromatic-therapeutic diet. These color/texture ranges make possible a diversified diet. By taking into account the singularity of each, they stimulate the appetite gluttony and awakens the senses.

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References

Alonso, E., S. Krypciak, and E. Paillaud. Rôle de la nutrition dans les chutes et les fractures des sujets âgés. *Gérontologie et société* 33, no. 134 (20 October 2010): 171–87.

Blin-Barrois, B., M. Barrois, and S. Lejeune. Couleurs à boire, couleurs à manger. *Les livrets du Conservatoire Conservatoire des ocres et pigments appliqués, Roussillon - Provence livret 2*. Aix-en-Provence: Edisud, 2003.

Cardon, P., and S. Gojard. Les personnes âgées face à la dépendance culinaire : entre délégation et remplacement. *Retraite et société* 4, no. 56 (2008): 169–93.

Clesse, C., I. Dumand, E. Nassau, C. Prudent, M. Decker, C. Savini, J. Lighezzolo-Alnot, and M. Batt. Représentations Sociales Du Vieillissement Des Sujets Porteurs de Troubles Psychiques :

Impacts et Conséquences d'une Double Stigmatisation. *NPG Neurologie - Psychiatrie - Gériatrie* 16, no. 95 (1 Octobre 2016): 291–99.
Cottet, I., G. Marion, and P. Dreyer. Plaisir de manger et refus d'alimentation en établissement d'hébergement pour personnes âgées dépendantes. *Gérontologie et société* 33, no. 134 (20 October 2010): 207–15.
Coutaz, M., and J. Morisod. Nutrition et vieillissement. *Revue Médicale Suisse* 3, no. 2353 (2001): 21500.
Escalon, H., and F. Beck. Perceptions, connaissances et comportements en matière d'alimentation' *Gérontologie et société* 33, no. 134 (20 October 2010): 13–29.
Ferry, M., P. Daveau, and A. Rozenkier. Nutrition et vieillissement. *Retraite et société* 2, no. 45 (2005): 188–92.
Howes, D. L'esprit multisensoriel, ou la modulation de la perception. *Communications* 86, no. 1 (2010): 37–46.
INRA. Les liens entre les comportements alimentaires et la santé. In *Comportements alimentaires*, 27–45. Matière à débattre et décider. Versailles: Éditions Quæ, 2012.
Jacquot, M., P. Fagot, and A. Voilley. La Couleur Des Aliments : De La Théorie à La Pratique. TEC&DOC. *Sciences et Techniques Agroalimentaires*. Paris (France), France: Lavoisier, 2012.
Jaeger, C. De. Conseils pour une meilleure prévention. *Que sais-je? 3e éd*., no. 2696 (2008): 107–24.
Kergoat, H. Les Sens Chimiosensibles : Modification Du Goût et de l'odorat Au Cours Du Vieillissement et Son Impact Sur l'état Nutritionnel. *Le Gérontophile, Fondation Nationale de Gérontologie*, 23, no. 2 (2001): 8–14.
Lacau St. G., J., S. Périé, M. Bruel, B. Rousseau, B. Susini, and C. Gaillard. Troubles de La Déglutition de l'adulte. Prise en charge diagnostique et thérapeutique. *EMC - Oto-Rhino-Laryngologie* 2, no. 1 (1 February 2005): 1–25.
Lecerf, JM., and JL. Schlienger. *Nutrition préventive et thérapeutique*. Elsevier Masson, 2016.
Lesourd, B., A. Raynaud-Simon, and MF. Mathey. Comment favoriser la prise alimentaire des sujets âgés. *Nutrition Clinique et Métabolisme* 15, no. 3 (2001): 177–88.
Maille, V. *L'intensité Du Goût et de La Couleur de Produits Alimentaires : L'influence de l'incongruence Perçue Sur l'acceptabilité*. Aix-les-Bains, 2007.
Martineau, C. Terminologie standardisée des textures modifiées pour la dysphagie : prise de position des experts de l'IDDRI. *Médecine Des Maladies Métaboliques* 13, no. 1 (1 February 2019): 101–2.
Patry, C., and A. Raynaud-Simon. La dénutrition : quelles stratégies de prévention ? *Gérontologie et société 33*, no. 134 (20 October 2010): 157–70.
Pouyet, V., A. Giboreau, G. Cuvelier, and L. Benattar. Perception, préférences et consommation alimentaires chez les personnes âgées atteintes de la maladie d'Alzheimer. *Cliniques* 6, no. 2 (2013): 217.
Rey, A.. Dictionnaire Historique de la langue française.In *Le Robert*, 6 mars 2019.
Sagot, S. Couleurs, textures et matériaux d'un design gourmand. SEPPIA 1 (2003): 27–33.
Seshadri, S. *Le Repas, Source de Plaisir* 15, no. 148 (2008): 424–27.

Development of a Questionnaire to Assess the Impact of Congenital Colour Vision Deficiencies on Education.

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Abstract

Technological advances over recent decades have heralded a new era for education in which colour is omnipresent in the classroom: in textbooks, worksheets, smartboards, laptops, tablets and learning applications. Despite this, little research has been conducted on the impact of this change on the educational experiences and outcomes of colour vision deficient (CVD) students. Here, following a qualitative study of childhood impacts of CVD, we develop and validate a questionnaire measuring the impacts of CVD, focusing on education. CVD participants reported significantly more difficulties than control participants in total and across all impact subscales: Education (15 items), Social (5 items), Emotions (13 items) and Day-to-Day (9 Items), demonstrating construct validity and providing evidence that CVD has a substantial adverse effect on affected individuals. This calls into question the status quo of CVD, characterized by a lack of universal screening and guidance on how to make educational materials accessible to the CVD learner. The questionnaire can be used alongside robust diagnostic tools for CVD, allowing investigation of the effect of CVD type and severity, and to understand the impacts of the increasing reliance on colour on CVD students across a range of educational contexts.

Keywords: *Colour Vision Deficiency, Education, Perception, Colour Blindness*

Introduction

For most people, colour vision arises from the responses of three colour-sensitive cells in the eye: one sensitive to short-wavelength light (appearing blue), one sensitive to medium-wavelength light (appearing green) and one sensitive to long-wavelength light (appearing red). Red-green colour-vision deficiency (CVD) is an hereditary condition affecting 8% of males and 0.4% of females involving one of the latter two cell types. The milder form is anomalous trichromacy, where either the medium-sensitive cell (m-cone; deuteranomaly) or the long-sensitive cell (l-cone; protanomaly) are shifted in the wavelengths of light they respond to.

The more severe form is dichromacy, where either the m-cone (deuteranopia) or l-cone (protanopia) is missing. Depending on type and severity, CVD individuals' ability to discriminate between colours can be significantly compromised.

The impacts of CVD include issues at work, problems watching and participating in sports, difficulties interpreting colour-coded information and learning at school (Cole, 2004). Barry et al. (2014) developed a questionnaire to measure quality of life in those with CVD (the CBQOL), with sections on health and lifestyle, emotions, and work, reporting CVD individuals exhibit significantly worse quality of life overall and in each section. However, the CBQOL does not measure the pertinent impact of CVD on education, and as such is primarily focused on adults. Others have found a significant impact of CVD on school achievement in general (Grassivaro Gallo et al., 2003) and specific subjects including languages, mathematics, science and geography (Grassivaro Gallo et al., 1998), as well as CVD children reporting significantly more difficulties with colour-related tasks at school than their counterparts with normal colour vision (NCV; Ugalahi et al., 2016; Mashige, 2019).

Despite its prevalence and the evidence that the condition has a significant impact on education, CVD is not routinely screened for, meaning those affected, particularly anomalous trichromats, may remain undiagnosed, unable to develop educational coping strategies and plan careers accordingly. Formal screening only occurs in seven states in the USA (Collins, 2013), and there is no formal screening in India (Jadhav et al., 2017), or, as of 2009, the UK (Department of Health, 2009). Furthermore, in the UK CVD is not classed as a disability or special educational need (SEN), meaning there is no legislation preventing discrimination based on CVD, or requiring reasonable adjustments in educational settings.

There is a need to provide further evidence of the impacts of CVD on education and the outcomes of understanding these impacts may have important real-world impacts on the lives of CVD children in school. We have previously carried out a qualitative study of the impacts of CVD in childhood (Pattie et al., 2021; Dlay et al., 2021). The present study builds on this to develop and validate a questionnaire measuring the impacts of CVD, with a focus on education, to gather more robust, quantitative data on the impacts of CVD in a wider range of affected individuals.

Method

Participants

Participants were recruited through an online link posted on social media websites e.g., Facebook and Twitter. There were 497 responses, however 125 were removed due to incomplete questionnaires. Six CVD participants were removed for self-reporting total colour-blindness or blue-yellow colour-blindness. One control participant was removed for entering the same answer (“4: daily”) for every question, including distractor items. Of the remaining 366 participants there were 153 self-reported NCV controls (mean age=35.47; SD=19.71; 91 females) and 213 self-reported CVD participants (mean age=31.49; SD=19.30; 13 females). CVD participants were asked to report their subtype: 64 self-reported anomalous trichromats (41 deuteranomalous and 23 protanomalous); 64 self-reported dichromats (33 deuteranopes and 31 protanopes) and 85 participants could not specify their subtype.

Questionnaire development

The questionnaire was developed using the results of a thematic analysis of interviews and focus groups with CVD adults, CVD children and parents of CVD children, focusing on the experience of growing up with CVD (Pattie et al., 2021; Daly et al., 2021). Specifically, it was developed from the themes/subthemes which addressed the negative impact of CVD: barriers to learning within education, negative reactions of others, negative impacts on emotions and self-view and a day-to-day subtheme.

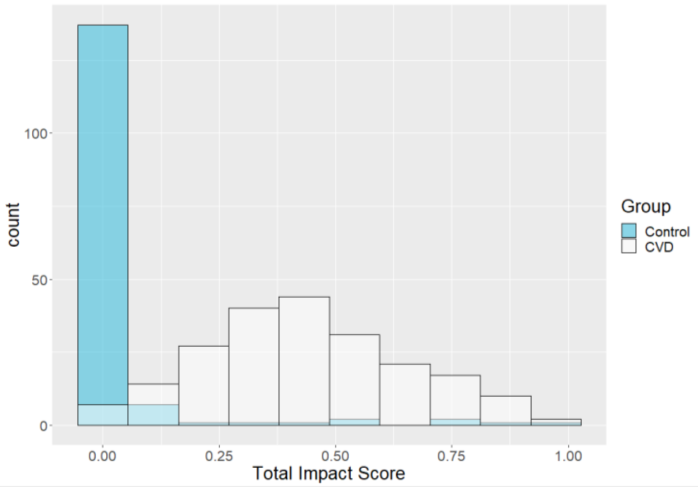
The questionnaire had 42 items: 15 on Education (e.g. “Maths”), 5 on Social impacts (e.g. “People laughing at you for making mistakes about colour”) 13 on Emotions (e.g. “Frustrated”; including 4 distractor positive emotions), and 9 on Day-to-day impacts (e.g. “Doing arts and crafts”). Participants were asked to indicate how often they experienced specific difficulties (e.g. “Think about your experiences at school in the past. How often have you had problems in the lessons or tasks below because of your colour vision?”) on a Likert scale ranging from “0: Never” to “4: Daily”. For the education and day-to-day items there was also a “Not relevant to me” response option, for example if they had not studied the subject or encountered the day-to-day task in question.

The questionnaire can be obtained from the authors upon request.

Data analysis

The four distracting positive emotion items (“Special/unique”, “Happy”, “Excited” and “Proud") were removed, so that impact score reflected the negative impact of CVD.

As participants were able to answer “Not relevant to me” for some questions, the impact score needed to reflect how many questions were answered. Thus, actual impact score was expressed as a proportion of total possible impact (ranging from 0 to 1). The highest impact score per item was 4, therefore impact score was calculated using the following formula:



$$Impact\ score = \frac{\Sigma\ Given\ answers}{Number\ of\ questions\ answered \times 4}$$

Figure 1. Distribution of Total impact scores for control and CVD participants.

When examining Education and Day-to-day subscales, any participants who answered “Not relevant to me” to over 50% of subscale questions were removed.

Shapiro-Wilk tests revealed that only Total impact score for CVDs was normally distributed (see Figure 1), while all other subscales for CVDs and total impact score and all subscales were not normally distributed for controls (see Table 1). Therefore, Wilcoxon Signed Ranks tests were carried out to determine whether CVDs scored significantly higher on the questionnaire than controls.
All data analysis was conducted in R-Studio.

	Control		CVD	
	W	p	W	p
Total	0.310	<0.001	0.987	0.053
Education	0.362	<0.001	0.975	0.002
Social	0.294	<0.001	0.969	<0.001
Emotion	0.248	<0.001	0.935	<0.001
Day-to-day	0.262	<0.001	0.979	0.003

Table 1. Results of Shapiro-Wilk tests for normality for control and CVD groups on total impact score and subscale impact scores.

Results

A Wilcoxon Signed Ranks test revealed that CVD participants had significantly higher Total impact scores than control participants (W=31048, p>0.001; see Table

2). This significant difference is illustrated in Figure 2, which also displays potential outliers in the control group. The InterQuartile Range (IQR) criterion identified 38 potential outliers within the control group i.e. those with an impact score larger than the 75th percentile + 1.5(IQR). See Discussion for consideration of why these outliers may have occurred.

Subscale	Statistic	Control	CVD
Total	Median	0.000	0.428
	IQR	0.000	0.276
Education	Median	0.000	0.400
	IQR	0.000	0.366
Social	Median	0.000	0.400
	IQR	0.000	0.350
Emotions	Median	0.000	0.306
	IQR	0.000	0.417
Day-to-day	Median	0.000	0.530
	IQR	0.000	0.388

Table 2. Median and interquartile range (IQR) for Total and subscale impact scores for control and CVD participants.

Further Wilcoxon Signed-Ranks tests determined whether this difference was present across all subscales. Impact scores for the subscales were calculated in the same way as total impact score (see Data Analysis section). CVD participants scored significantly higher on all subscales than controls (see Table 3). Figure 2 illustrates these significant differences, as well as potential outliers present in the control group for each subscale.

	W	p	Control		CVD	
			n	Median	n	Median
Education	19649	<0.001	109	0.000	194	0.400
Social	30573	<0.001	153	0.000	213	0.400
Emotion	30612	<0.001	153	0.000	213	0.306
Day-to-day	26127	<0.001	131	0.000	210	0.530

Table 3. Results of Wilcoxon Signed Rank Tests comparing subscale impact scores for control and CVD participants. Of the control participants, the IQR criterion identified potential outliers in each of the subscales: 21 in Education, 21 in Social, 17 in Emotions and 11 in Day-to-day.

Discussion

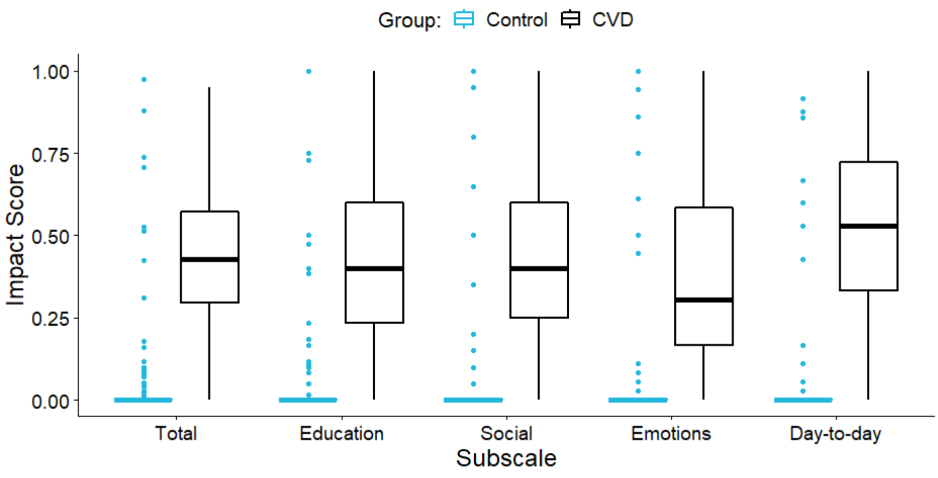


Figure 2. Comparison of Total and subscale impact scores of control and CVD participants.

Here, we demonstrate the construct validity of a questionnaire to measure the impact of CVD, with a focus on education. CVD participants scored significantly higher than controls on the overall questionnaire and on each subscale. This demonstrates a significant impact of CVD on education, social situations, emotions, and day-to-day tasks.

The findings regarding education support previous studies reporting a significant negative impact of CVD on education (Grassivario Gallo et al., 2003; Grassivario Gallo et al., 1998; Ugalahi et al., 2016; Mashige, 2019), as we find CVD participants report more frequent issues in school due to their colour vision. This questions CVDs lack of status as a disability or SEN in the UK. A child has a SEN if they have "a disability that prevents or hinders him or her from making use of facilities of a kind generally provided for others of the same age in mainstream schools or mainstream post-16 institutions" (the Children and Family Act, UK, Section 20 (2b), 2014); and a person is defined as having a disability if they have an impairment resulting in a "*substantial* and *long-term* adverse effect" on their "ability to do normal daily activities" (the Equality Act, UK, Section 6 (1), 2010). We demonstrate here that CVD individuals report significantly higher impacts on every subscale, demonstrating this substantial adverse effect and suggesting they are unable to make use of the facilities available to their NCV counterparts. As CVD is congenital and untreatable, these impacts are lifelong.

One limitation of this validation study was the use of self-report of CVD. While this was necessary to allow the questionnaire to be disseminated online, it means the grouping of participants into CVD and control groups is uncertain. Use of the questionnaire alongside detailed categorization of participants, for example using Rayleigh matches, would improve on this, and would allow more in-depth analysis, such as investigating the impacts of different types and severities of

CVD. Related to this limitation are the several outliers in the control group. It is possible these outliers may have undiagnosed CVD. Albany-Ward and Sobande (2015) report 80% of UK CVD schoolchildren arrive in Year 7 without a diagnosis, meaning that, unless a diagnosis is sought out after this point, their CVD will remain undiagnosed. Furthermore, it is possible that other underlying vision problems were present within these outliers as there was no question in the demographics section asking about other vision problems. This should be included in the future.

Whilst the present questionnaire was developed to be independent from the CBQOL (Barry et al., 2017), and to have a primary focus on childhood impacts and education, there are similarities between the two questionnaires. For example, both investigate the impacts on emotions, and the CBQOL examines lifestyle, which is comparable to the present questionnaire's Day-to-day subscale. It would be beneficial to administer both questionnaires to investigate concurrent validity. However, despite its similarities to the CBQOL, the present questionnaire has merit as an independent measure, due to the inclusion of the Education subscale and utilization of children, as well as adults, with CVD.

The present questionnaire can not only be used to determine the impact of an individual's CVD (e.g. for use by a teacher to provide reasonable adjustment to CVD students), but also to investigate other factors involved in CVD impact. For example, it is probable that the educational impacts of CVD are higher for today's children than they were in the past, due to the increase in reliance on colour teaching materials. For instance, it is now common practice in UK schools to mark books with coloured bands to denote reading age or level, ask children to indicate task difficulty using traffic light colours and use coloured educational tools like Unifix or Numicon (Colour Blind Awareness, n.d.). Despite this recent increase in use of colour, the cessation of routine testing in UK schools was likely linked to the publication of a cohort study of individuals born in 1958, attending school in the 1960s-70s (Cumberland et al., 2004). The study reported no impact of CVD on educational outcomes and concluded that CVD confers no functional disadvantage in an educational context. The present questionnaire can be used to investigate whether this remains a valid conclusion in today's educational environment; with the data reported here and elsewhere (Grassivario Gallo et al., 1998; Grassivario Gallo et al., 2003) indicating that this may not be the case.

In conclusion, the present study demonstrated construct validity for a novel measure of the impacts of CVD. CVD individuals report significant impacts of the condition overall, and on all subscales. The measure can be used in the future to provide further evidence that CVD can present as a significant barrier to learning, and therefore, should be screened for in schools, and when present, appropriately accommodated for.

Acknowledgements

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References

Albany-Ward, K., & Sobande, M. 2015. What do you really know about colour blindness? *British Journal of School Nursing 10*, no. 4: 197-199.

Barry, J. A., Mollan, S., Burdon, M. A., Jenkins, M., & Denniston, A. K. 2017. Development and validation of a questionnaire assessing the quality of life impact of Colour Blindness (CBQoL). *BMC Ophthalmology 17*, no. 1: 1-7.

Collins, K. B. 2013. Addressing the Needs of Students with Colour Vision Deficiencies in the Elementary School Library. PhD diss., Old Dominion University.

Cumberland, P., Rahi, J. S., & Peckham, C. S. 2004. Impact of congenital colour vision deficiency on education and unintentional injuries: findings from the 1958 British birth cohort. *BMJ 329*, no. 7474: 1074-1075.

Dlay, H. K., Pattie, C., Mullally, S., & Jordan, G. 2021. “Considerations of socio-emotional impacts of X-linked colour-vision deficiencies: A thematic analysis.” In *43rd European Conference On Visual Perception* (ECVP) 2021 Online. Perception. 50: no. 1_suppl: 185-186.

Grassivaro Gallo, P., Panza, M., Lantieri, P.B., Risso, D., Conforti, G., Lagonia, P., Piro, A., Tagarelli, G. and Tagarelli, A. 2003. Some psychological aspects of colour blindness at school: A field study in Calabria and Basilicata (Southern Italy). *Colour Res. Appl. 28*: 216-220. https://doi.org/10.1002/col.10148

Grassivaro Gallo, P., Panza, M., Viviani, F., & Lantieri, P. B. 1998. Congenital dyschromatopsia and school achievement. *Perceptual and Motor Skills 86*, no. 2: 563-569.

Jadhav, A., Sg, P. K. & Kundu, S. 2017. Importance of colour vision testing in school based eye health examination. *Community Eye Health 30*, no. 98: S24-S25.

Mashige, K. P. 2019. "Impact of congenital color vision defect on color-related tasks among schoolchildren in Durban, South Africa." *Clinical Optometry 11*: 97-102.

Pattie, C., Dlay, H., Mullally, S., & Jordan, G. 2021. "Living With Colour-Vision Deficiency At School: A Thematic Analysis Of Accounts Of Colour-Deficient Adults, Children, And Their Parents". In *43rd European Conference On Visual Perception* (ECVP) 2021 Online. Perception 50: no. 1_suppl: 52.

“Pre-School & Primary School”, Colour Blind Awareness, accessed May 16, 2022, https://www.colourblindawareness.org/teachers/pre-school-primary-school

Ugalahi, M. O., Fasina, O., & Ogun, O. A. 2016. "Impact of congenital color vision defect on color-related tasks among Secondary School Students in Ibadan, Southwest Nigeria." *Nigerian Journal of Ophthalmology 24*, no. 1: 20-24.

The Colours of Diabetes: Colorimetry, Chemical Indicators, and Colour Standardization in Diabetic Sugar Measurement in the First Half of the Twentieth Century

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Abstract

For most of the 20th century, the diagnosis and management of diabetes were inseparably tied to colour. This paper discusses colour as a tool of measurement in diabetic glucose analysis in the late 19th and early 20th centuries, in the period before polarimetry and automatic monitoring became routine. With the development of chemical indicators for glucose analysis, colours became central for diabetes diagnosis. From the 1920s onward, insulin therapy required frequent and precise sugar monitoring, with testing responsibility shifting from physician to patient. Colour scales of various kinds allowed non-specialists to interpret test results, but materializing colour in these standards posed further challenges, including accessibility, colour accuracy, representativeness, and how to assess the effects of substrate. These difficulties were shared with other fields that used colorimetric methods and colour comparisons for measurement, analysis, and communication. Taking diabetic glucose analysis as a case study provides insights into historical discussions on the uses, limits, and challenges of colour as a measurement tool.

***Keywords**: diabetes history, glucose tests, color scales, colorimetry, material culture*

Introduction

Most scholarship on diabetes history discusses the discovery of insulin and diabetes therapeutics. The development of urine and blood sugar testing has received comparatively little attention, and surveys of the subject focus mainly on developments in the later 20th century, with contemporary automatic blood glucose monitoring as their horizon [1][2]. This paper, in contrast, looks at the early history of diabetic sugar testing. In the 19th and into the 20th century, a number of means existed for determining the presence of urine sugar for diabetes diagnostics, including polarimetry, fermentation tests, and specific density tests [3]. The first tests based on chemical indicators were developed in the 1840s, but chemical tests did not become the standard method of analysis until after the development of Benedict's test in the first decade of the 20th century. These chemical tests used reagents to make the invisible sugar in diabetic urine, and later blood, visible. Colour changes with these chemical indicators formed the basis for colour scales that would enable medical professionals and lay users to quickly and conveniently assess test results, as monitoring responsibility shifted increasingly from diabetes specialists to diabetic individuals after the introduction of insulin. Until the spread of automatic monitoring in the 1980s, diagnosis and management of diabetes was inseparably tied to colours [4].

Turning colour into a tool of measurement was not straightforward since it depended on accurate colour standards. These difficulties were not unique to diabetic glucose testing. Developments within this specialist field connect to broader contemporary developments and discussions on application-oriented colour standards and draw attention to the way that knowledge and expertise circulated.

Chemical Indicators

Following the emergence of organic chemistry in the early decades of the 19th century, a variety of methods were developed to chemically identify sugar in solution, many of them using colour indicators such as picric acid and indigo-carmine [5], with some authors recognizing the potential for the analysis of diabetic urine [6]. In 1841 Carl August Trommer, a pharmacist and veterinary surgeon, developed the first widely used test for glucose analysis. At the time Trommer was assistant to Eilhard Mitscherlich, who had been studying sugar since the mid-1830s and working on analysis methods and apparatus for the German sugar beet industry. The method that Mitscherlich and Trommer developed, and that carried Trommer's name, differentiated sucrose and glucose for product quality assessment and was based on the use of copper sulphate as a reagent. Heated with an alkali such as potash, its blue colour turned bright red in the presence of glucose and precipitated red cuprous oxide. This method was modified by the German chemist Hermann von Fehling a few years later to become Fehling's solution and then in 1908 and again in 1911 by the American biochemist Stanley Benedict. While copper reduction tests continued to be used in the sugar and beverage industries, with Fehling's and especially Benedict's solution and its further modifications, their utility for the analysis of glucose in urine was established.

Benedict's 1908 solution and his 1911 modification provided two means for sugar determination [7-8]. The first was called the qualitative test. The solution was combined with urine in a test tube, heated, boiled, and cooled. If sugar was present, the test tube filled with red cuprous oxide precipitates and the solution turns red, yellow, or green. This was a simple yes/no test determined on the presence of precipitate. Quantitative measurement was done with the modified solution. Potassium sulphocyanide and ferricyanide gave it a blue colour. Urine was slowly titrated into the boiling solution until the blue colour disappeared. The user could then read off the amount of urine used and calculate its sugar concentration. This test required practice and visual skill, as well as the appropriate lighting and background since it was not easy to ascertain the moment when the last of the blue colour disappeared. While some diabetes specialists recommended their patients do the simple qualitative precipitation test, the more difficult quantitative titration test was not considered appropriate for nonprofessionals.

Blood sugar analysis was less common and fraught with difficulties due to the many substances in the blood that could affect analysis. In 1919 biochemist Otto Folin and his assistant, Hsien Wu, developed a method for making protein-free blood filtrates, so that it was possible to use colorimetric methods to analyse blood serum components [9-10]. In 1928 Folin introduced a new colorimetric method for blood sugar analysis using ferricyanide as a reagent [11]. Mixed with an alkali in a sugar solution, it oxidized to produce ferrocyanide, which, Folin noted, "is measured colorimetrically as Prussian blue." (Folin, 1928: 421). Conceptualized as a colorimetric method, blood sugar analysis was more complex than urine sugar analysis and conducted mainly in medical, pharmaceutical, and biochemical laboratories.

Colour as a Tool of Measurement

In 1921/22 Frederick Banting, Charles Best, John McLeod, and James Collip isolated and purified insulin and tested it on a severely diabetic patient. Their success led to the swift expansion of insulin therapy in the following years. The introduction of insulin led to numerous changes in the function and role of diabetic sugar testing. Previously, testing was used primarily to diagnose diabetes and occasionally check the progression of the disease. Some diabetes specialists recommended their patients test their urine every so often with Benedict's precipitation test, but since there were few therapeutic interventions, there was no advantage to frequent and precise testing. Effective insulin therapy, in contrast, required both more frequent testing and more precise monitoring to dose insulin and prevent complications. Patients became responsible for the bulk of routine sugar testing. It thus needed to be accessible to a wider group of users, including non-specialized general practitioners and diabetic individuals with no medical training, as diabetes became a chronic but manageable disease and the lifespan of diabetic individuals dramatically increased.

The colour changes shown by these chemical indicators provided a means for both practitioners and individuals unfamiliar with biochemical analysis procedures to interpret the results of glucose tests. Although rough visual estimation could be trained, for more accurate assessment a reference standard was needed. Colour scales and colour standards were designed to meet this need.

The use of colour as a tool of measurement raised a number of issues for designers, biochemists, medical professionals, and diabetic users. These can be roughly divided into two core sets of problems, although in practice they were interrelated. The first set of issues attempted to confront the problem of subjectivity in colour perception and interpretation. The second wrestled with the problem that colour needed to be the colour of something, and that this materialization has its own challenges. Connecting both was the need for standardization both of the relationship between the sugar concentration and the colour it turned with the reagents and of the relationship between the colour of the analysed solution and its representation in the colour measurement tool.

Biochemists and medical practitioners were well aware of the first set of issues. As insulin therapy expanded and the variety of test options grew, more responsibility shifted to an increasing number of diabetic patients and diverse healthcare practitioners. Questions about colour perception abilities and accuracy were the subject of several studies [12-13]. The situation looks quite different in regard to questions of materialization and standardization. Material artifacts and discussions of material practices reveal the extent to which these questions affected measurement practices, but they were rarely subject of extended discussion. Instead, information must be gathered from brief references and comments on the periphery of other discussions. In this situation, it can be helpful to look at colour scale discussions in other areas, much as test designers could look to these fields for guidance as well.

A number of different types of measurement scales were developed, some for certain kinds of users or situations. Most frequently used were 1) permanent liquid standards, which replicated the color of known amounts of the substance under investigation, sometimes with dilutions of the same substance, sometimes with other substances; 2) color scales, which provided a close color approximation in another medium, usually in the form of a printed paper standard.

Permanent standards

While early biochemists occasionally used permanent standards for colorimetric work when suitable, for example in hemoglobinometry, they more commonly made their reference standards fresh or replaced them frequently to avoid deterioration. This added labour and time and required more chemical skills in addition to skills in the use of the colorimeter. A faster method that required fewer skills and was more suitable for working physicians was a comparator made of a series of graduated permanent standards that could be compared with the sample.

Water quality assessment offered a model for this type of standard. Since at least the 1870s civil engineers and water sanitation experts had been looking for ways to communicate the colours of waters between laboratories. In 1892 Allen Hazen proposed using a platinum-based solution that could be diluted to shades of yellow [14]. This could be used to create a graduated system of liquid standards to represent the colour of the water under investigation as well as to communicate this colour to another laboratory not in vague descriptive terms but in degrees of dilution of the platinum solution. This comparator was a communication tool, in that any lab could use the platinum standard to replicate the color of another lab's water sample without seeing it, but it had no connection to water composition.

In the 1920s, LaMotte Chemical Products, a new company specializing in chemical water analysis, began marketing ready-made graduated liquid colour standards. Lamotte's standards were based on a series of Pyrex ampoules filled with the same substance and indicator that were being analysed, in different degrees of concentration The user then placed the unknown sample in a block comparator between two of the ampoules until they found the best match. Less than a year after Folin introduced his ferrocyanide method, Lamotte introduced a blood sugar analysis kit containing all equipment needed to conduct blood sugar analysis, along with a series of ampoules filled with different concentrations of Prussian blue (Figure 1).

Figure 1: Lamotte blood sugar outfit. Held by the Mutter Museum. Photograph by the author.

Although these standards were easier to use and less expensive than a colorimeter, there were disadvantages to this method. Blood sugar analysis still required some skill, so this method was designed for professionals. The standards were also quite fragile, and few have survived intact. In addition, as Figure 1 shows, the owner of this set of standards modified his set. Presumably he created his own set of standards to test whether these were accurate, found them lacking, and adjusted their labels to reflect the difference.

Paper standards

Colorimeters and permanent standards were designed and marketed to laboratories and medical professionals due to their expense. Some physicians continued to use the titration method, which the Eli Lilly Company began marketing in the 1930s as Urine Test Kit #1. It included pre prepared reagents, a spiritus burner, and the necessary glassware. In 1929 Abraham Sheftel proposed a new method of assessment using Benedict's solution but based on the phenomenon of colour change [15]. Although this change had long been recognized, the red precipitate affected perception of the solution colour, rendering it a very inexact tool for quantification. Sheftel's method removed this precipitate with a colloid, so that the colours were clear, and used a paper colour scale to measure sugar concentration.

The idea of using a paper colour scale for measurement purposes in a medical setting had been introduced in 1902 by Theodor Tallqvist as an alternative to the liquid standards used for hemoglobinometry [16]. It is likely that Sheftel, a physician interested in colorimetry for medical purposes, was familiar with Tallqvist's paper standard hemoglobinometer. Sheftel's modified test used a narrower range of colours than the standard Benedict's test by diluting urine at higher concentrations for increased measurement accuracy (see Figure 2).

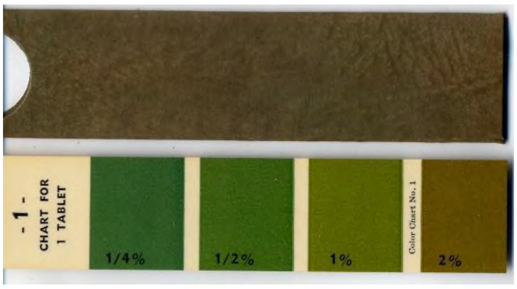

Figure 2: Urine sugar colour scale. Lilly Sugar Test Kit #6 (Sheftel). NMAH (permission pending)

As urine sugar testing became more widespread and regular, especially for diabetic patients, and chemical aspects of the tests became easier to handle, paper standards like this one became the most widely used tool for sugar concentration measurements in routine analysis.
Once the paper scale was intended to serve as a measurement tool, rather than simply a colour guideline, its materiality became significant. This was an issue more broadly discussed in regard to paper standards. As water analyst W. M.

Clark pointed out, “aside from the inherent difficulty in freeing a printed colour from the effect of the vehicle, there remains the utter impossibility of reproducing upon paper the exact virage observed in a liquid solution.” (Clark, 1920: 40) [17]. Paper standards required careful interpretation, since they did not actually look like the sample.

Paper standards reacted differently to light than liquid standards. The material they were printed on affected how the colour was perceived, and the ink could never fully reproduce the colour of the liquid urine sample or how it was affected by light. To standardize the colours for these scales, biochemists and test designers depended on printers and ink mixers and their expertise. This need for accurate color reproduction connected biochemists working on diabetic sugar tests, if only peripherally, to broader attempts to standardize colour in the first half of the 20th century [18]. Although not involved in these colour standardization attempts themselves, they could use the fruits of these discussions, the structured colour swatch books of the Munsell Color System and, later, the Color Harmony Manual to communicate their colour needs to their printers [19-20].

Conclusion

Colour indicators rendered the invisible sugar of diabetic urine and blood visible but turning colour into a tool of measurement meant capturing and taming its elusive and subjective nature. It needed to be standardized, matched to quantities, and made material. The challenges posed by these needs, along with differing user abilities, skills, and capacities led to the development of numerous kinds of colour scales for diabetic sugar assessment, many of them emulating colour measurement tools used in other fields. The case study of diabetic glucose measurement sheds light on the historical context of colour scale discussions in the later 19th and early 20th century and on both how a particular kind of measurement tool is adopted and adapted in different areas of study, and how knowledge, skills, and apparatus circulate between them.

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References

1. Clarke, S. F., and J. R Foster. 2012. A history of blood glucose meters and their role in self-monitoring of diabetes mellitus. *British Journal of Biomedical Science* 69 (2): 83-93.
2. Moodley, N., U Ngxamngxa, M. J. Turzyniecka and T. S. Pillay. 2015. Historical perspectives in clinical pathology: a history of glucose measurement. *Journal of Clinical Pathology, 68*: 258-264.
3. Martin, M. und H. Fangerau. 2009. Technisierung der Sinne – von der Harnschau zur Urinanalyse. Das Beispiel der Harnzuckerbestimmung. *Der Urologe* 5: 535-541.
4. Whitehouse, F. W. 2006. The color blue: musings after 68 years in the diabetes wars. *Diabetes Spectrum* 19(3): 130-131.
5. Prideaux, E. B. R. 1916. *The theory and use of color indicators*. New York: Van Nostrand.
6. Braun, C. D. 1865. Über die Umwandlung der Pikrinsäure in Pikraminsäure und über die Nachweisung des Traubenzuckers. *Zeitschrift für analytische Chemie* 4: 185-188.
7. Benedict, S. 1909. A reagent for the detection of reducing sugars. *J. Biol. Chem*. 5: 485-487.
8. Benedict, S. 1911. The detection and estimation of glucose in urine. *J. Am. Med. Assoc.* 57(15): 1193-1194.
9. Folin. O. and H. Wu. 1919. A system of blood analysis. *J. Biol. Chem.* 38: 81-110.
10. Meites, S, 1989. *Otto Folin. America's first clinical biochemist*. Washington, DC: American Association for Clinical Chemistry.
11. Folin, O. 1928. A new blood sugar method. *J. Biol. Chem.* 77: 421-430.
12. Liefson. J. 1969. Glycosuria tests performed by diabetics at home. *Public Health Reports 81* (1): 28-32.
13. Dobson, H. L., R. Shaffer, and R. Burns. 1968. Accuracy of urine testing for sugar and acetone by hospital ward personnel. *Diabetes* 17(5): 281-285.
14. Hazen, A. 1892. A new color-standard for natural waters. *American Chemical Journal* 14(4): 300-310.
15. Sheftel, A. G. 1930. Sugar testing. US Patent 1,769,862, filed August 15, 1929, and issued July 1, 1930.
16. Tallqvist, T. W. 1902. Hemoglobinometer. US Patent 703,319, filed Jan 16, 1902, and issued June 24, 1902.
17. Clark, W. G. 1920. *The determination of hydrogen ions.* Baltimore: Williams and Wilkins.
18. Rosse, M. 2019. *The republic of color. Science, perception and the making of modern America*. Chicago: University of Chicago Press (chp. 6).
19. Jacobson, E. 1942. *The colour harmony manual and how to use it. Chicago*: Color Laboratories Division, Container Corporation of America.
20. Free, H. M., interview by J. J. Bohning, 14 December 1998, Oral History Collection, Science History Institute, https://digital.sciencehistory.org/works/ksyktpa

Colour Naming of Post-COVID Participants Hints to “Darkening” of Perceived Colour

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Abstract

We investigated colour naming in individuals who have recovered from COVID-19. Data was collected from native Russian speakers in an online experiment (http://colournaming.com). An unconstrained colour-naming method was employed. The dataset included responses of 201 participants (147 women) aged between 19–65 years (M = 33.4 ± 13.2), who had had coronavirus infection and the confirmed medical diagnosis. The data was compared with data collected pre-pandemic (2018–2019) from 2,457 respondents (1,402 women) aged between 16–98 years (henceforth termed “healthy”). For intergroup comparisons, we estimated frequency of Russian basic colour terms (N=12), frequent non-basic colour terms, and achromatic modifiers, as well as the number of words in colour descriptors and colour-naming patterns. In post-COVID respondents, we found an increase in ‘brown’-naming, along with an increase of frequency of achromatic modifiers. These naming pattern changes provide indirect evidence that colour vision of these respondents has been affected by coronavirus. If confirmed in a psychophysical examination of colour vision, the two phenomena might be indicative of an affected processing of spatial luminance contrast in post-COVID individuals.

Keywords: *Colour Naming, COVID-19, Colour Perception*

Introduction

There is increasing evidence that patients who have recovered from COVID-19 exhibit various symptoms of vision impairment, such as photophobia, blurry vision, and decreased visual acuity. Clinically these are associated with raised intraocular pressure (IOP), eye muscle spasms, and dilated retinal veins, the sign of retinopathy (e.g. Costa et al., 2021; Invernizzi et al., 2020). By now it is not known whether COVID-19 infection affects colour vision. However, post-COVID ocular changes, such as IOP and retinopathy, are likely to manifest as an impairment of blue-yellow discrimination, according to previous non-COVID studies (e.g. Castelo-Branco et al., 2004).

Based on the available data, we hypothesised that, compared to respondents who have not been affected by coronavirus, the affected colour perception in post-COVID respondents will manifest as an altered pattern of colour naming. To test this hypothesis, we compared colour naming in individuals who have recovered from COVID-19 and in those whose responses had been obtained before the pandemic.

Materials and Methods

Participants

Data was collected from native Russian speakers in an online experiment (http://colournaming.com). The 2022 dataset included responses of 201 participants (147 women) aged between 19–65 years ($M = 33.4 \pm 13.2$), who had had various forms of coronavirus infection and the confirmed medical diagnosis. The 2022 data was compared with pre-pandemic data collected in 2018–2019 from 2,457 respondents (1,402 women) aged between 16–98 years (henceforth termed "healthy").

Web-based psycholinguistic experiment

Participants were randomly presented with virtual colour cards selected by a computer program from 606 stimuli. Colour was described by coordinates in CIELAB colour space (for further details, see Griber et al., 2021). Respondents were asked to name each colour using the most appropriate colour descriptor – either a simple word, a modified or a compound term.

Analysis

For intergroup comparisons, we used several linguistic measures:

(1) frequency of Russian basic colour terms (N=12) and recurring non-basic colour terms;

(2) frequency of achromatic modifiers;

(3) number of words in colour descriptors;

(4) colour-naming patterns.

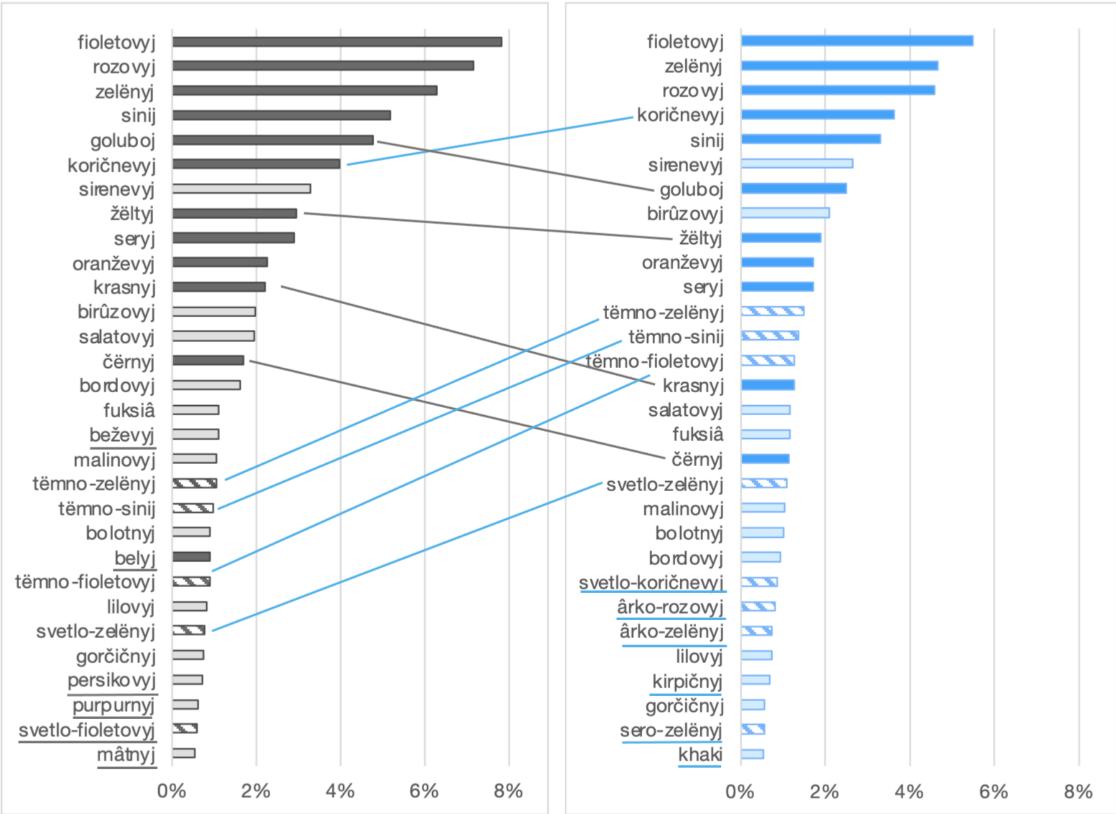

Figure 1. Most frequent colour names in non-COVID (left) and post-COVID (right) respondents. BCTs are indicated by solid bars, frequent non-BCTs by transparent bars, and modified or compounded terms are thatched. Colour names offered frequently by one group but not by the other are underlined.

Results and Discussion

Comparison of ranking of the most frequent colour names (Figure 1) showed that participants from both groups used basic colour terms (BCTs) more frequently than non-BCTs. Compared to the "healthy" respondents, post-COVID participants offered koričnevyj 'brown' more frequently; conversely, percentage of the terms *oranževyj* 'orange' and *krasnyi* 'red' was lower; also, the terms for "light" colours – *želtyj* 'yellow', *rozovyj* 'pink' or *goluboj* 'light blue' – were offered less frequently.

Notably, CTs with achromatic modifiers were much more prevalent in the post-COVID participants' descriptors compared to "healthy" respondents (Figure 2): *tëmnyj* 'dark' (10.0% vs. 5.0% respectively), *svetlyj* 'light' (6.7% vs. 4.0%), *ârkij* 'bright' (4.1% vs. 1.7%), *blednyj* 'pale' (2.7% vs. 1.5%), *grâznyj* 'dirty' (2.4% vs. 0.9%), and *pastel'nyj* 'pastel' (1.1% vs. 0.2%). The 'dark'-modifier was used particularly frequently in combination with *zelënyj* 'green', *sinij* 'dark blue', and *fioletovyj* 'purple', i.e. BCTs that in colour space denote colour categories of relatively low lightness, thus, prompting that this modifier conveyed further perceived dimming of the corresponding colours.

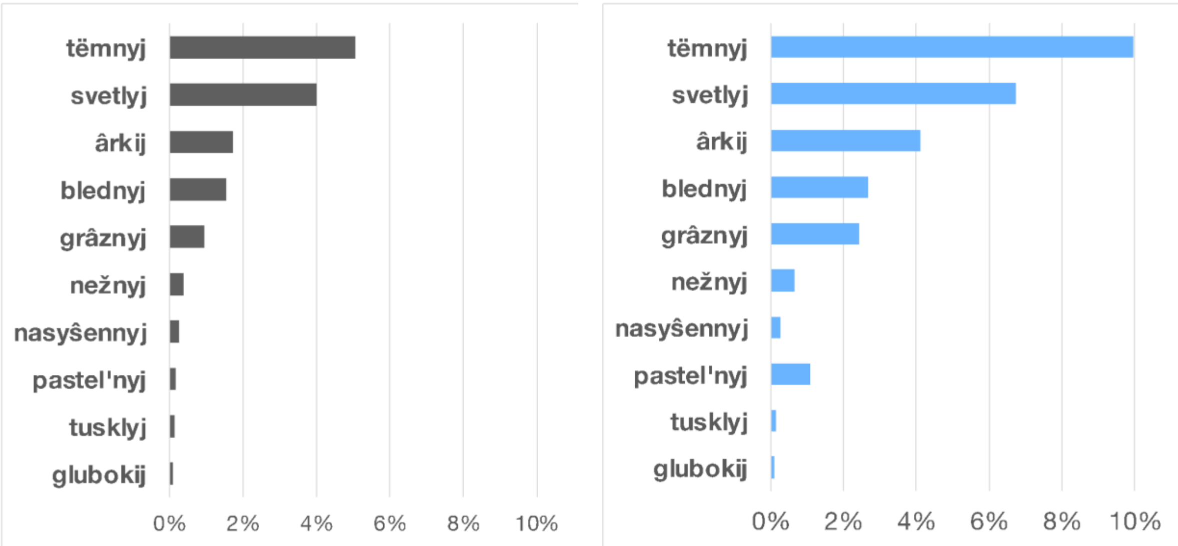

Figure 2. Frequency of achromatic modifiers in compounded colour names in non-COVID (left) and post-COVID (right) respondents

Colour-naming patterns differed significantly between the two groups, too (Figure 3): whereas the vast majority of "healthy" respondents' colour descriptors were monolexemic (BCTs: 49%; non-BCTs: 30%), for post-COVID respondents the corresponding numbers were lower (BCTs: 32%; non-BCTs: 25%). Moreover, they frequently offered more elaborated, polylexemic descriptors, e.g. *tusklyj tёmno-krasnyj* 'dull dark red' or *blednyj rozovyj s fioletovym otlivom* 'pale pink with a purple opalescence'.

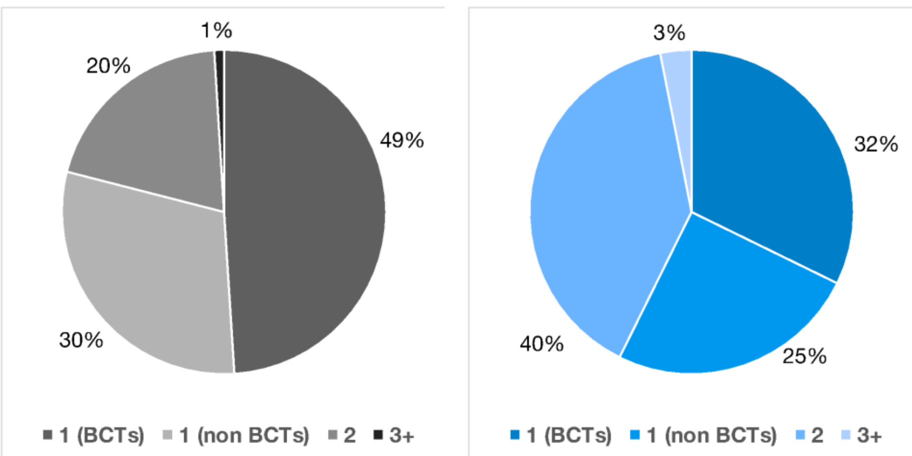

Figure 3. Number of words in colour descriptors in non-COVID (left) and post-COVID (right) respondents

Conclusions

The increase in ‘brown’-naming, along with the increase of using achromatic modifiers in post-COVID respondents provide indirect evidence that their colour vision has been affected by coronavirus. The relatively high frequency of ‘dark’- and ‘dirty’-modifiers may signal a generally “darkened” appearance of colours. Furthermore, an increase in frequency of ‘pale’-, ‘dull’- and ‘pastel’-modifiers hints to desaturation of perceived colours. If confirmed in a psychophysical examination of colour vision, the two phenomena might be indicative of an affected processing of spatial luminance contrast in post-COVID individuals (cf. Bimler et al., 2009).

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References

Bimler, D.L., Paramei, G.V., & Izmailov, C.A. (2009). Hue and saturation shifts from spatially induced blackness. *Journal of the Optical Society of America A* 26: 163-172. https://doi.org/10.1364/JOSAA.26.000163

Castelo-Branco, M., Faria, P., Forjaz, V., Kozak, L.R., & Azevedo, H. (2004). Simultaneous comparison of relative damage to chromatic pathways in ocular hypertension and glaucoma: Correlation with clinical measures. *Investigative Ophthalmology & Visual Science* 45: 499-505. https://doi.org/10.1167/iovs.03-0815

Costa, Í.F., Bonifácio, L.P., Bellissimo-Rodrigues, F. et al. (2021). Ocular findings among patients surviving COVID-19. *Scientific Reports* 11: 11085. https://doi.org/10.1038/s41598-021-90482-2

Griber, Y.A., Mylonas, D., & Paramei, G.V. (2021). Intergenerational differences in Russian color naming in the globalized era: Linguistic analysis. *Humanities & Social Sciences Communications* 8: 262. https://doi.org/10.1057/s41599-021-00943-2

Invernizzi, A., Torre, A., Parrulli, S. et al. (2020). Retinal findings in patients with COVID-19: Results from the SERPICO-19 study. *EClinicalMedicine* 27: 100550. https://doi.org/10.1016/j.eclinm.2020.100550

Session 15

Colour in Aesthetics and Culture

A Phenomenological Approach to Color Theory and Aesthetics

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Abstract

This paper proposes to investigate color theory and aesthetics from a phenomenological point of view, that is, from the point of view of the lived experience. Two angles of study are suggested: one is from the point of view of the artist creating a piece, the other is from the point of view of the audience receiving the work. In each case, it is possible to interrogate the lived experience in order to find some cues about the aesthetic components that contribute to this lived experience, in particular as they relate to color. A tool, the explicitation interview, is proposed as a means to conduct such an investigation.

Keywords: *Phenomenology of Color, A Practice-based Theory of Color, Color and Aesthetics, Color and Emotions, Color as a Lived Experience*

Introduction

For many years, I have approached color and aesthetics from a practical point of view. Being both a scholar and a practitioner, I consider my research in the framework of the creation research paradigm (Magrin-Chagnolleau, 2022a), also called for instance the practice-based research paradigm (Candy, 2018). My practice as an artist being at the foundation of my research on color and aesthetics, it was natural for me to look into phenomenology (Husserl, 1985, 1992), and to approach color and aesthetics from a phenomenological point of view, that is, from the point of view of the lived experience. This was also for me a way to put the creative process at the centre of my research. In other words, I am interested in the creative process as it is experienced by the person who is involved in this process. And I am particularly interested, in this creative process, in the moments when we make decisions that impact the aesthetic of the work at hand, and in particular decisions, conscious or unconscious, that involve color. Phenomenology is a paradigm that puts the lived experience at the centre. But how can we access the lived experience with an approach that is objective enough and can be reproducible? This is where the explicitation interview, developed by Pierre Vermersch, comes into play (Vermersch, 2014). This interview technique allows one to access the lived experience of a subject as it really happened, as opposed to how the subject thinks it happened. Developed initially in the framework of experimental psychology, and particularly in the context of pedagogy, this interview technique has been used by people who were interested in phenomenology, and more particularly in a practical approach to phenomenology (Bitbol, 2017). I have been using this interview technique for the past few years in order to learn about the creative process, about the decisions that impacted the aesthetic dimensions of a creative project, and in particular decisions that had to do with color.

Why is color such an important component of aesthetics? Following the theories of embodied cognition (Varela, 1991), I believe this has to do with the fact that color relates to our daily experiences. Colors are everywhere. And because they are, we have a rich web of associations with them. That means that colors have an important impact on us, in particular emotionally. And that means that artists manipulate colors, consciously or not, in order to create something in the viewer, at an emotional level, but also in more subtle ways. There is a reason why we speak for instance of warm colors and cold colors, in terms of what experience those colors create for the viewer.

I have already written, in the past, about my experience with color as a practitioner (in Film, Theatre, Photography), included for AIC (Magrin-Chagnolleau, 2013, 2021, 2022b). Each time, I have written from the point of view of a practitioner developing a theoretical reflection based on his practice. Here, I would like to go one step further and address the phenomenological dimension of practicing art-making, aesthetics decision-making, and color choices. The ambitious goal of this research would be to develop a theory of color based on practice, that is, based on the lived experience, in other words, a phenomenological approach to color theory and aesthetics. More modestly, in this paper, we will discuss the bases of such an approach to color theory, as well as its feasibility.

A Practical Approach to Phenomenology

What is phenomenology? A phenomenological approach is an approach that deals with the lived experience of a phenomenon. Phenomenology puts experience in the center. Phenomenology tries to get rid of any theory or preconception one can have about a phenomenon, and tries to approach a phenomenon from the point of view of the lived experience, relying only on the lived experience itself to extract any knowledge about the phenomenon (Husserl, 1985, 1992; Heidegger, 1992; Merleau-Ponty, 1976).

What does it mean to have a phenomenological approach of color? It means investigating color as a lived experience, that is, trying to extract knowledge about color as a phenomenon from the experience we have of color. It refers to mostly two broad categories of experiences we can have of color as a phenomenon. One is on the side of reception: how do I experience receiving color? For instance: how do I experience viewing a painting? How do I experience viewing a photograph? How do I experience viewing a film? How do I experience viewing an orange? a tree? etc.

The other is on the side of the creative process: how do I experience making choices about color as I create something? For instance: how do I experience choosing and using a color in a particular area of a painting? How do I experience choosing the color of a piece of cloth for an actor? how do I experience grading color for a particular shot in a film? etc.

Phenomenology can be approached from a theoretical point of view, in which case we deal mostly with the idea of phenomenology. This is sometimes what has been said of Husserl, the founder of phenomenology. But phenomenology can also be approached from a practical point of view. How can I interrogate the lived experience? How can I extract knowledge from the lived experience? How can I use the lived experience to learn something concrete about a phenomenon and the way we experience it?

There is a way to do it through the use of the explicitation interview (Vermersch, 2014). The explicitation interview was created by Pierre Vermersch in the framework of experimental psychology. The interview was developed in order to be able to interrogate a subject on a past experience and have access to what the subject had precisely done during this past experience, as opposed to what they thought they had done. This is particularly useful in the framework of training, when someone makes a mistake during a process, without being able to pinpoint the moment of that mistake. Through conducting an explicit interview, it is very easy to find the moment when the person deviates from the learned procedure. The explicitation interview was then used in the framework of research, in particular as a tool to approach phenomenology from a practical point of view (Depraz, 2011; Vermersch, 2012). What is unique about this interview technique is the fact that it can have access to some pre-reflected knowledge, that is, knowledge that is stored in someone's mind and can be accessed through the interview, but that the subject themselves were not aware about. For instance, when led by a skilled interviewer, this technique gives access to mental operations conducted by the subject while living the experience, such as information taking or decision making.

There is also a version of the explicitation interview called auto-explicitation (Vermersch, 2007, 2008), which consists in administering the explicitation interview to oneself, using in that case particular techniques to be able to be in turn the interviewer and the interviewee.

Now, there is one drawback to the explicitation interview. It takes between 45 and 90 minutes to conduct an explicitation interview, and during such an interview, one can only interrogate a very brief moment of the past experience of the subject. In order to be practical, you usually need to already have a good understanding of the task at hand, and of the particular moment of the task that you want to finely interrogate. Sometimes, you acquire that understanding by first doing some interviews without really knowing what you are after, and then you will conduct some interviews more specifically on a moment that you are interested in.

Relating Phenomenology, Aesthetics, and Color

Now that we have defined phenomenology and how to approach it from a practical point of view, let us have a further look at how we can apply it to aesthetics, and more particularly to color. What does it mean to approach aesthetics from a phenomenological point of view? Let us go back to the way aesthetics can be seen from the point of view of the lived experience. Here again, there are two angles.

The first one is the angle of the artist. As an artist, when creating a piece, I go to a series of decisions, some conscious, some unconscious. Each decision contributes to making me go through a creative process that culminates in the production of the piece. Most of these decisions impact the aesthetic of the final piece. As the artist, this creative process, that is, the succession of all these decisions and actions, are experienced by me. This builds my lived experience of this creative process. By interrogating this process, these decisions, these actions, someone can have access to this process, to this lived experience, and relate all these decisions and actions to the aesthetic of the final piece. This is what I mean by a phenomenological approach of aesthetics. Rather than relying on a preconceived theory about aesthetics, it is possible to have access to the lived experience of the artist and correlate some of the decisions made and actions taken to the resulting piece and its aesthetic.

The same can be said about colors. Some of these decisions and these actions directly deal with color. Therefore, if there is a possibility to have a phenomenological approach to aesthetics, then there is a possibility to have a phenomenological approach to color.

The second angle concerns the way a piece is received by an audience. The audience, when receiving the piece, goes through a lived experience that can also be interrogated. And this interrogation can lead to understanding how the person interviewed experienced the piece and its aesthetic. This is a way to understand, from a phenomenological point of view, how the aesthetic of a piece impacts the lived experience of an audience. And again, part of the lived experience of an audience is impacted by colors, and this can also be interrogated.
I would like to point here that color is an important component of aesthetics, mostly because of the particular relationship between color and emotions. There

is a reason why we speak of warm or cold colors. This refers to the lived experience that we go through when being exposed to such colors. Color is also a component that is easily manipulated by artists in order, precisely, to create such lived experiences in an audience.

Conclusion

In this paper, I have tried to describe what a phenomenological approach of color theory and aesthetics could look like, and how we could develop it through the use of the explicitation interview. It speaks of the possibility of interrogating the lived experience of an artist creating a piece or of an audience receiving it. In both cases, through this interrogation, we can access some elements that relate to the aesthetic of the piece, in particular as it relates to color. By doing that, we can establish some ground rules concerning aesthetics and colors that are free from any preconceived ideas and theories about aesthetics and colors, but rely directly on the lived experience, therefore allowing to establish a phenomenological approach to color theory and aesthetics.

The future of this work will consist in testing the possibility of developing a phenomenological approach to color theory and aesthetics by conducting some explicitation interviews with artists creating pieces and audience members receiving them, as well as using auto-explicitation.

References

Bitbol, M., and C. Petitmengin. 2017. Neurophenomenology and the Micro-phenomenological Interview. In S. Schneider and M. Velmans (Eds.), *The Blackwell Companion to Consciousness* (*2nd Edition*), pp. 726–739. Oxford: Wiley-Blackwell.

Candy, L., and E. Edmonds. 2018. Practice-Based Research in the Creative Arts. *Leonardo*, 51(1), 63–69.

Depraz, N., F.J. Varela, and P. Vermersch. 2011. *À l'épreuve de l'expérience*. Bucarest: Zeta Books.

Heidegger, M. 1992. *Être et le Temps*. Paris: Gallimard.

Husserl, E. 1985. *Idées directrices pour une phénoménologie*. Paris: Gallimard.

Husserl, E. 1992. *L'idée de la phénoménologie*. Paris: PUF.

Magrin-Chagnolleau, I. 2013. The Use of Color in Theater and Film. *Proceedings of AIC 2013*.

Magrin-Chagnolleau, I. 2021. Handling Color in Photography and Film: From Photo Retouching to Color Grading. *Proceedings of AIC 2021*.

Magrin-Chagnolleau, I. 2022a. Reflections on the impact of creation research, practice-based research, and practice as research, and how to define and maximize that impact. *Media Practice and Education*, 23.

Magrin-Chagnolleau, I. 2022b. The Relationship between Photo Retouching and Color Grading. *Color Culture and Science Journal*, 14(1), 79–86.

Merleau-Ponty, M. 1976. *Phénoménologie de la perception*. Paris: Gallimard.

Varela, F., E. Thomson, and E. Rosch. 1991. *The Embodied Mind*. Cambridge: The MIT Press.

Vermersch, P. 2007. Bases de l'auto-explicitation (1). *Expliciter*, 69.

Vermersch, P. 2008. Introspection et auto-explicitation: Bases de l'auto-explicitation (2). *Expliciter*, 73.

Vermersch, P. 2012. *Explicitation et phénoménologie*. Paris: PUF.

Vermersch, P. 2014. *L'entretien d'explicitation*. Issy-les-Moulineaux: ESF Éditeur.

The Story of Colour in Traditional Indian Folk Media and Art

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Abstract

The narrative of traditional Indian folk media and art is elaborated in its brightly coloured / hued visual language. One cannot think of India or its folk formats in absence of colour. Colour is symbolic, is a derivative of sub-content's culture and has a story to tell. This research paper explores the art of storytelling through use of colours in traditional Indian Folk Media and Art. This paper through an extensive review of existing literature, more than a decade long ethnographic studies throughout various parts of India (and specifically in the state of Rajasthan conducted in past by the authors), and through semi-structured interviews with folk artists and scholars; aims to understand why a particular colour is used in the visual storytelling, where does that colour originates from, and what does a particular colour means? This research studies folk formats only from the province of Rajasthan. And finds commonalities of visual narratives in folk paintings of *Phad*, in the area of performing arts like, *Kathputli* (puppetry) and *Khyal* (folk theatre), etc. And to conclude, take out a colour palette to give a visual definiton to Traditional Indian Folk Media and Art.

Keywords: *Colour, Folk Media, Folk Art, India, Cultural Sensitivity*

Introduction

Stories are crucial for human existence as they are symbols that allow the world to understand in a specific form the details of a culture and people who live in them (Cobley, 2001) Folk Stories and narratives weave the stories of the people, the folk. And the visual language in terms of space and colour adds unconscious meaning to the sometimes silent or oral narratives. This paper conceptualises the meaning of Folk, from an Indian perspective, and elaborates what What Folk Media and Art means. Elaborates the socio-cultural environment of Folk Artists and the art they live in. Discover the Folk narratives and some popular stories, themes, etc. Discusses the meaning of colours in Indian context and how they are used in visual storytelling in Folk Media and Art to add subconscious meaning. And ends the Folk journey with a colour palette to give a visual definition to Traditional Indian Folk Media and Art.

Conceptualising Folk, Folk Media & Art

European Enlightenment period, links ‘folk’ to ‘the people’. This idea still holds weight even today, with researchers such as Julia Hollander who writes in her book, *Indian Folk Theatre (2007)*, observing that what makes a folk form distinctive is in fact its local audience, or its ‘folk’.

Folk in Indian terms could also mean belonging to a tradition or belonging to the rural folk. The folk is thought to be the “little tradition” as referred by anthropologist Robert Redfield, the idea which was further extended by McKim Marriott (1955) who drew a bifurcation between Sanskritic textual traditional and Indian village tradition with an emphasis on more number of “small” traditions in the community. Dumont and Pocock (1957) further challenged this notion by exemplifying that villagers in India do not distinguish between the “great” and “little” traditions thus interrelating the element of great among the little, i.e., the villagers also can gain access to the great knowledge through folk articulation (as cited in Barnard & Spencer, 1996), Shalini Attri (2020).

Wang and Dissanayke (1984) define folk media as a communication system embedded in the culture which existed before the arrival of mass media, and still exists as a vital mode of communication in many parts of the world, presenting a certain degree of continuity, despite changes. Folk Media include story-telling, puppetry, proverbs, visual art, folk drama, songs, drumming, and dancing. (Yatish L. Kodavath, 2015).

Edward Said and Gayatri Spivak explored the concept of Orientalism. Traditionally, folk media was studied with a western gaze towards the far 'exotic' east, but now eastern or native researchers are undertaking ethnographic studies in their own social environment. According to Dewan (2018), a researcher may be a native or not; a native researcher may find commonalities that connect him or her to the people and other characteristics that perhaps highlight differences. Folk Media can be defined as indigenous channels of communication, which are entertaining, which were made for expressing socio-ritual, moral and emotional need of the folk through medium such as folk songs, folk arts, folklore, etc. They have no grammar or literature yet but they are nurtured through oral traditions. Folk Media is alive, receptive to new ideas including changes over the time and generations and are colourful forms of presentations. (Rajender, Rekha 2006) Ranganath, for example, described folk media as being massy, rich in variety, readily available at low cost, relished by both sexes, theme carriers traditionally potential for persuasive communication, face-to-face communication and feedback. He believes some folk media can carry modern me compatriot seems to agree, stressing these traits of traditional social change in developing nations. The familiar format and content expressed in colloquial dialects creates a successful communication situation in which there is constant sharing and two way flow of communication and involves everybody in the communication process. These attributes of the media keep spellbound and compelled to join the audience (Rajender, Rekha 2006). Folk media forms are extensively used for development communication and are an actor of social change. Folk Media forms in new settings caught on in the 1970s in Development communications. Use of folk media, either in their traditional rural settings or when adapted to mass media, brought about social awareness of national development plans. After independence, the Indian government chose folk form to convey to rural audiences messages of self-reliance, cooperative effort, rural development, national savings and family planning (Lent, 1980).

Folk art forms are practical, functional, natural, and spontaneous. Folk arts are used for peace education, conflict resolution and a philosophical self enquiry on a wide scale in India. Increasing number of people are turning to theatre by the people for the people and of the people as a means of mobilising people for action for achieving social justice, peace, and harmony. (Yatish L. Kodavath, 2015) The folk art forms also satisfy our innate need for self-expression, belonging, combined with entertainment and for the dramatic and the lyrical. The traditional media preserve and disseminate in a lively manner, the tradition and culture of our forefathers (Sarireha, 1995).

The three dimensions of the functional role of folklore are: (a) literary, (b) exploring its relationship with culture and (c) establishing historical validity of oral traditions. Bascom (1954) too expounds on the purposeful aspect of folklores in "Four Functions of Folklore" as: (a) mirror to culture, (b) validates culture, (c) means of education and (d) conformity to accepted patterns and behavior (as cited in Lopez, 2006, p. 62).

The folklores are illustrated as the accounts of identity and identity ciphers, metaphors, tropes that are able to convey extra-textual connotations to groups which categorize with them. Folk narratives have cultural frames and constitute metaphorical meanings. It is something outside the text and community's identity that questions the fundamental role of ethics and values of society. While acting as a model of epical behavior, it is a representative configuration of history and mythology. Thus, a recurring narrative accomplishes enormity when a particular group categorizes itself with personages and incidents. These narratives survive in the minds of illiterate singers and performers as "memory text". The story must thus be filed to reproduce native ideals, domain values, socio-economic organisations and history recognised by the spectators as elaborated by Shalini Alri (2020).

Folk Culture & Arts in the Art

Hollander expresses that folk expressions are a derivative of a culture and are people's tales, Julia Hollander writes in her book, *Indian Folk Theatre (2007).* Folk narratives are drawn from a particular time, space, sequence, and they find a connection with culture. Lyotard elaborates that stories are crucial for human existence as they are symbols that allow the world to be understood in a specific form, recording the details of culture (as cited in Cobley, 2001, p. 186). For Herder (1969), the term Culture refers to all human enterprises, where he identifies art, industry, commerce, science, political institutions, literature, ideas, beliefs, customs and myths as constituent part of community culture (F. M. Barnard, 1969). Folklore and folk stories are old text, though oral in nature, does the work of uniting and creates new centres of consciousness (cited from Bruce King). The historicity of India has its roots in the folk narratives of the nation that exist as complex, cross-connecting, premodern and pre-national histories of traditions. It cannot be subsumed by the teleology of nationhood. It reinforces the notion of "India '' as a vital and binding cultural space. Pollock (2003) remarks that the literary cultures are prominent and South Asian literary culture represents a long historical experience whose careful preservation in texts make this region of the world so special. Modern culture can be understood with a deeper understanding of the premodern past.

Culture, memory, and history are interrelated and embedded in social and cultural frameworks. Memories are not fixed illustrations of past events, but are in fact advancing stories through which individuals construct their sense of identity. Shalini Alri (2020). Artists in a folk media in specific performative folk media either belong a particular community like *Khayal* is performed by *Bhawai* caste, Phad is told by *Citero* community and *Kathputli* puppetry is done by Bhal community, or if there has been an intervention of Sanskrit% Theatre or new age Theatre may be performed by urban actors. Like in case of discipline *Bhavai* to suit a more urban viewer (V Sebastian 2018).

When the folk media is an art form or handicraft like *Phad, Kavad* it may be also understood as a craft? Then they become traditional occupations of a particular community but also play a vital role in the socio- religious celebration of the region. This may also stand true for some performative media. Traditional crafts are the knowledge systems, creations, innovations and cultural expressions of people in a given geographical cluster. They are transmitted to enhance, safeguard and perpetuate the identity, well-being and rights of the indigenous peoples. Simon John (2010).

Traditional craft education is transmitted from one generation to another, through the skill learning - technical substance which is the knowledge of materiality and the value transmission which is esculturation. From the perspective of the artists who had learnt the skills from direct ancestors. This then forms a model of art education construction within society. Eko et al (2017).

Traditional Folk Narratives of Rajasthan

Stories are what bring people together, in the foyer of a temple, in the middle of the village or in urban theatres. Folk narratives are a part of our collective consciousness, belongingness, and belief. Folk Media include narratives in story-telling, puppetry, proverbs, visual art, folk drama, songs, drumming, and dancing (Yatish L. Kodavath, 2015).

The province of Rajasthan is rich in culture and has may folk formats Theater - *Khayal*, Folk dance - *Ghoomar, Kalbeilia, Bhavai, Chirami, Gair, Tera tali*, Storytelling - *Kavad, Phad*, Folk Music - *Pankhida, Lo5a, Teej* Songs, Folk Art - Phad, Miniature Paintings, *Pichwai*, Puppetry - *Kathputli* (Raghvendra Mishra, 2016) narratives in the province of Rajasthan and in most of the subcontinent is the retelling of the epic of Mahabharata, Ramayana and that of the local legends or local deity (Shalini Alri (2020). It is difficult to delineate folk songs from Folk Theater or dance etc. or performers. The *Khyal* of Rajasthan brings together theatre, song and dance and is said to have its origin in the early 18th century. The word *Khayal* can be best expressed as imagination, idea or thought and is performed by *Bhavai* community. In its origin it started off as an extempore poetic competition than a dramatic piece which it stands for today. Similar to Nautanki from Ular Pradesh and *swang* from Haryana in style of staging and subject maler. The dancing corresponds to Kathak because of its free and flexible form. In contemporary times it is the heroic retelling of Amar Singh Rathore.

The legend goes that Raja Gaj Singh's son, Amar Singh, a great warrior, loyalist, uncontrolled and unyielding by nature, was banished by his father. After which he joined Shah Jahan in the Delhi Sultanate, he was made Jagirdar of Nagaur because of his gallantry. Amar Singh killed Salawat Khan because the emperor's brother-in-law imposed a fine on him, challenging his self-respect. Amar Singh later became a victim of Arjun Gaur and Shah Jahan's plorng, and was killed by Arjun Gaur.

The vengeful Rao's retainers were joined by Rathore Bihari and Champavat Ballu, who attacked the Mughals with the intention to kill Arjun Gaur. The loyal and devoted groups of soldiers were also killed and his wife, the princess of Boondi, came and took away the martyred body of Umrah with which she committed Sati (act of burning oneself in one's dead husband's funeral pyre, historical practice). Shalini Alri (2020).

The story of Amar Singh is a story of gallantry, courage, and self respect, which is the theme for most folklore in the region. Khyal performers include Gods and Goddesses, legendary heroes, tales of Bhakti and miracles having idiomatic speech and colloquial expression with rhetorical flourish. Shalini Alri (2020) Chris and Lee Novetzke (2007). Same narratives are one retold in various folk formats. In

Kathputli and *Khayal* the legend of Amar Singh is narrated. *Kathputli* is a string puppet performance. *Kathputli* means a puppet made of wood. The Bhal community of Rajasthan carry forward their traditional profession, make these puppets and also perform with them. The puppets are usually two feet in height having a wooden head with a huge nose and large eyes. The rest of the body is prepared of colourful and bright pieces of cloth and stuffed clothes which also allow for free movement. The costumes are regional and traditional while the themes that are performed turn around Rajasthani historical tales or local traditions.

Phad is scroll painting of folk deities of Rajasthan, narrated by *Bhopas* (the Priest singers of Rajasthan) There are four main aspects of *Phad* to be noted - *Phad or Par*, the epic of *Pabuji, Bhopas* (the priest singers) and the narrative that binds them all together. '*Phad' or 'Par'* is about 15×5' long sheet / cloth, on which life adventures of *Pabuji* are decorated in hues of desert land. Historian William Dalrymple (2009) in his book Nine Lives describes the Phad as a "panorama of medieval Rajasthan: women, horses, peacocks, carts, archers, balles, washer-men and fishermen, kings and queens, huge grey elephants and herds of white cows and buff camels, many-armed demons, fish-tailed wonder-creatures and blue-skinned gods, all arranged around the central outsized figure of *Pabuji*, his magnificent black mare, *Kesar Kalami*, and his four great companions and brothers-in-arms."

Pabuji lived in the 14th century in Kullu, Rajasthan. He was said to be born of a nymph. At a young age, courageous Pabuji fought the Khinchi Clan who were encroaching the lands and killing the cows in the region (cows are sacred in Hinduism). At about the same time he also acquired a mare from *Charan* community women. This horse was supposedly the reincarnation of *Pabuji*'s mother and he lovingly called his mare Kesar *Kalami. O*n the occasion of his favourite niece *Kalam's* wedding he promised her present Camels as a wedding gift. For which *Pabuji* travelled to the west of Indus river, where camels were found. He defeated the king of Lanka and acquired the camels. On his way back he fell in love with Princess *Pulvati* and later married her. Though the story of *Pabuji* ends here in '*phad*', the local folklore narrates how *Pabuji's* son takes revenge from the *Khinchi* clan, who killed *Pabuji*.

Since *Pabuji* got camels to Rajasthan and also kept his promise to *Charan* women to help them lifelong, both *Rabari (Rabari* tribe are nomads of the Thar Desert who wander with their camels) and *Charan* communities revere him as the local deity. *Bhopas* are the priest singers of Rajasthan. They belong to a low caste community and hail from the village of Pabusar, named after *Pabuji. Bhopa* along with his wife *Bhopi* narrates the entire story of *Pabuji* when the night falls.[8] The more recent versions of narration are more contemporary, with inclusion of local / popular Bollywood songs, *Bhak5* music-dance, usual tea, and tobacco breaks.

These magnificent art panels, *Phads* are painted by professional *phad* painters called *Citero.* The most well know Phad painters are from the Joshi family who have been painting these masterpieces from many generations now. There is a requirement of folk form to be understood as artistic heritage because the artists too have a relation and connection with certain aspects of heritage shaping their identity. Each performer thus has and experiences a dialogue with the heritage, culture, and customs. The voice of their ancestors echo in their words, consequently, they become carriers of history of that region, place, state or their country. Their role becomes more prominent as they construct a relation with the outside world through the performance and retellings of folklores (Shalini Alri, 2020).

Colour, Culture and Meaning

One cannot think of India or its folk formats in absence of colour. Colour is symbolic, is a derivative of sub- continent's culture and has a story to tell. In India colours are an expression of emotions. Colours convey moods, seasons, religious values, customs, and ceremonial occasions. Colours are used to identify communities and social status of the individual. Colours in clothes symbolise aesthetic, psychological and biological connotations.

The colours seen in Rajasthani costumes are divided into two categories. Kachcha or temporary colours, which are used by unmarried women and married women, while the widows only use the pekka or permanent colours. Kachcha colours, represents a temporary marital phase, though widowhood being the permanent phase of a woman's life. Colours like red, yellow, parrot green, and saffron are some colours which are considered to be kachcha. Pakka colours are grey, brown, dark green, dark blue and maroon.

Red is the most popular colour visible in Rajasthani costumes, & Folk Arts alike and is considered auspicious, denoting well-being and joy. It is also a royal colour. Traditionally it is obtained from the root of the manjit plant and can symbolise blood or the force of human life. Red is also a sign of a woman's marital status. The married woman uses red sindur (vermillion), on her forehead as embellishment and also wears a 'red chunri' (a red stole). This colour can symbolise erotic connotations and is used at the time of marriage.
White is the colour of purity and it symbolises an embodiment of light. White is a male colour and is worn extensively by the gender. Married women in Rajasthan never wear any white coloured garments, traditionally. They sometimes wear a combination of red and white which represents both masculine and feminine. White is a negation of splendour and signifies simplicity. However men wear pure

white only at the time of death. Priests wear white for religious ceremonies, and may sometimes even use it with another colour.

Kesariya is the saffron colour and hues of yellow / orange that are extensively used in the arre of both men and women considered an auspicious colours. The colour is extracted from the Crocus sativus flower. The Rajput community used kesariya colour in their wedding robes and was also associated with the brave warriors who died fighting on the ballefield. When defeat was forthcoming, the Rajput warriors immediately would don saffron robes and ascend the ballefield. They termed this as kesariya karna or a brave deed. Marriage was also termed the same, especially, when it resulted in alliances to protect various land and kingdoms. Yellow is a part of all religious ceremonies and also represents the sun God.

The symbolism of colours and their energies is integrated in the everyday area of the Rajasthani people, especially women. Certain colours and designs are worn in certain months. Orange and golden is worn on the occasion of New Year, or the month of Chaith. In high summer colours of kapasi or light yellow, javai or light peach and moti or pearl pink are worn. In the month of Savan or the monsoon green coloured garments are worn, which symbolises prosperity and joy. A green leheriya dupala is worn during this season. A kasuvud or red odhna is worn at the time of teej, a festival celebrated by women to pray for the long life of their husbands. The festival of Diwali is also brightened with colours of red and yellow. The Rajput women usually wear a deep purple odhni on Diwali.

All these colours which are embedded deeply in the culture find its derivative expressions in folk art and media. Use of basic colours Red Green Blue Yellow Black and white but the way natives find in their flora, fauna and sight. Red colour in the folk media art of Phad represents the royal colour worn by the Maharaja / protagonist of the story. Other colours, blues, greens, are used to depict nature as they are seen. Like blue represents water and green the flora Fauna. Mukul Joshi a Phad artsiest elaborates every colour has a meaning for example *Pabuji* wears Red as it is a royal colour. Also red colour brings the emphasis on *Pabuji,* helps in the eye movement when the story is narrated and as a prominent colour in the *Phad* at all times keeps a visual emphasis on *Pabuji* who is central to the narrative. Similarly, folk performances like Khayal and Kathputli, use the colours in the costumes of the artists and puppets to derive meaning.

Figure 1: Traditional Indian Folk - Mehendi Green, Vermilion Red, Indigo Blue, Mango Yellow and Earthy Off White

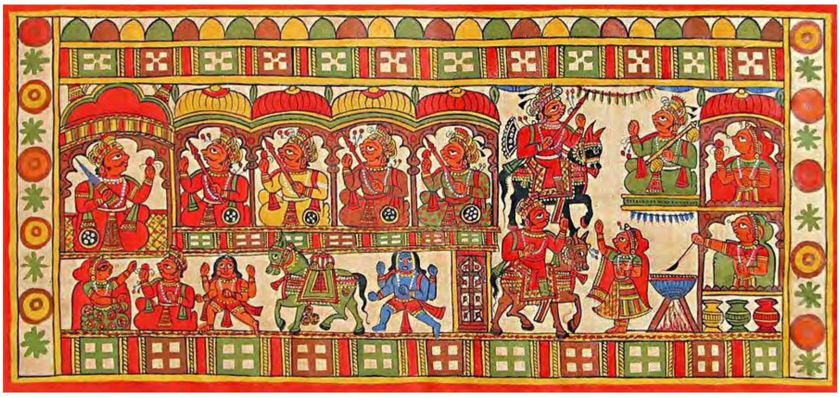

Figure 2: Pabuji ki Phad

Figure 3: Artists Performing *Khayal,* Folk Theatre of Rajasthan

Figure 4: *Kathputli* Puppets

Figure 5: *Kavad* Art of Rajasthan

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References

Alri, Shalini. (2020) Folk Theatre and History: Constructing Indian identity through The Khyal of Amar Singh Rathore. *The Journal of Indian and Asian Studies* Vol. 1, No. 1., World of Sciencetific Publishing

Barnard, A., & Spencer, J. (Eds.) (1996). *Encyclopedia of social and cultural anthropology*. New York, NY: Routledge.

Barnard, F. M. (1969). *Herder on social and political culture*. Cambridge: Cambridge University Press.

Bhaskar, Lavina. (2018) Impact of Story-telling through Indian Textiles - Mata Ni Pachedi and Pabuji Ki Phad. presented at WASET Conference at Sydney.

Bhagat Rekha, Chapke Rajender 2006 Traditional Folk Media: A Potentially Effective Communication Tool In Rural Area, *AIAEE 22nd Annual Conference Proceedings* Clearwater Beach, Florida

Cobley, P. (2001). *Narrative*. London: Routledge.

Crow, David. (2016) *Visible Signs*, Third Edition, Bloomsbury Publishing

Dalrymple, William. *Nine Lives - The Singers of Epics*. (2009) Bloomsbury Publishing

Dewan Mayukh (2018) Understanding Ethnography: An 'Exotic' Ethnographer's Perspective, *Asian Qualitative Research in Tourism*, Springer, Singapore.

Eko Sugiarto, Tjetjep Rohendi Rohidi, Totok Sumaryanto Florentinus, Dharsono Sony Kartika (2017) The art education construction of woven cra? society in Kudus Regency, *HARMONIA : Journal of Arts Research and Education*, CrossMark Publication.

Hollander Julia (2007) *Indian Folk Theatres*, eBook Published Routledge.

Jain, N. (1992). *Indian theatre: Tradition, continuity and change*. New Delhi: National School of Drama.

Lent, John A. (1980) Grassroots Renaissance: Folk Media in Third World Nations, *Folklore* Vol. 91, No. 1 (1980), pp. 78-91 (14 pages). Taylor & Francis, Ltd.

Novetzke, Chris and Lee. (2007) Bhakti and Its Public. *International Journal of Hindu Studies* December 2007, Vol. 11, No. 3 (December 2007), pp. 255-272, Springer.

Pollock, S. (2003). Introduction. In S. Pollock & A. Raghunathan (Eds.), *Literary cultures in history: Reconstructions from South Asia* (pp. 1–32). Berkeley, CA: University of California Press.

Ramanujan, A. K. (1990). Who needs folklore? The relevance of oral traditions to South Asian studies. In V. Dharwadkar (Ed.). *The Collected Essays of A. K. Ramanujan* (pp. 532–553). New Delhi: Oxford University Press.

Ramnrayan, M. (2017). *Khyala theatre of Rajasthan*. Singapore: Amazon Asia Pacific Holdings Private Limited.

Richard Howells, Joaquin Negreiros, *Visual Culture* (2019) Polity Press.

S Simon John (2010) Traditional knowledge of folk crafts in Tamil Nadu, *Indian Journal of Traditional Knowledge* Vol. 9, Published by Anthropological Survey of India Southern Regional Centre, Mysore, Karnataka

Wang, G., Dissanayake, W. (1984) *Culture, Development and Change: Some Explorative Observations. In Continuity and Change in Communication Systems*.

Yatish L. Kodavath (2015) *Folk Media as a Mode of Communication in the Development of Rural Areas*, Global journal for research analysis.

The Persistence of a Personal Palette

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Abstract

This paper aims to share findings about the beneficial use of a color and aesthetic "personal palette," that seems to anchor individual, somatic, and social inner dimensions. These natural and coherent palettes can be used to provide support for a sense of grounding and wholeness, to strengthen self-expression, and to restore wellbeing and balance to the psyche. With the multimodal synesthetic sensibilities over the course of over 25 years of individual and team coaching and visual facilitation with leaders and organizations across sectors and cultures, four expressions of personal palettes have become particularly clear, and thus useful:

1. Inner Biome: stable over time; individually unique, somatically fundamental, this palette supports qualities of interiority and grounding. Links with contemplative, somatic, and meditative practices.
2. Personal Visual Harmonics: visibly coherent colors and patterns enhance feelings of wellbeing, flow and openness.
3. Personal Brand Coherence: Using inner coherence as a litmus to clarifying look and feel that expresses path and purpose that brings palettes from inside-out.
4. Transitional Visual Space: In times of conflict, threat, emotional charge, or otherwise difficult material, stepping back and looking at a bigger picture provides stable transitional space through consistent aesthetic references to events, emotions, people, and contexts.

Keywords: *Colour Science, Perception, Synesthesia, Visual Facilitation, Resilience*

Introduction

A Personal Palette made of inner sensory aesthetics and color associations exists and can be used to support individuals and groups to feel more personally centered and whole, as well as aid in aligned self expression and healthy navigation of difficult material and times. This brief overview of Personal Palettes progresses from the inside out. Then we will explore each of the four palettes, starting with the deepest, pre-verbal, pre-conceptually anchored aesthetic zone I term the personal "Inner Biome." The next level, personal visual harmonics, reference the well-known physiological response to color that finds that visibly harmonious colors tend to feel better, and more personally supportive; as in variations on the popular “Color me Beautiful” approach to helping people wear clothes and patterns in their bestlooking palette. Third, the personal brand coherence palette brings the person out to the world. Thus this next tier palette is best when it can integrate features from the inner biome, combined with aesthetically harmonious color harmonies, to support aligned self expression that can serve individual path and purpose through an aesthetically aligned brand. The fourth area brings together the use of visual mapping with color associations to visibly facilitate a way through difficult, emotionally charged, traumatic, conflictive, complicated, or otherwise challenged situations. In this case the use of a coherent palette and visual anchors creates a symbolic transitional space, which I term “visual third space.”

Moving from inner to outer, the inner biome. This nervous-system settling domain is commonly unknown and unconscious. Breathing, sensing, and bringing awareness to subtler observations are useful.

Synesthesia, and after decades of somatic meditative practices made the aesthetically cohesive inner space I call the Personal Biome discernible. This terrain took shape like a perfectly attuned, aesthetically coherent, somatically easing environmental substance. Nervous system soothing, clarity evoking, and calming into wellbeing, the inner biome feels like an adult wombspace. When in touch with this right-feeling interiority the temperature, textures, smells, humidity, atmospheric pressure, and color of light, tastes, or any inner proprioceptive experience are perfect. Since synesthesia makes subtle states vivid, once stable, investigations with others followed. First, amongst advanced meditators in a community of practice, I guided inquiries to see if inner biomes might be accessible, and once so, if they expressed consistency. Next, I tested with prompting guided inquiry amongst coaching clients. Each was able to become aware of a distinctly personally-suited inner field with perfectly-fitting features that feel fundamentally supportive. The experience seems of a pre-conceptual, pre-verbal inner environment.

Personal Inner Biome

National Geographic describes a Biome as “an area classified according to the species that live in that location. Temperature range, soil type, and the amount of light and water are unique to a particular place and form the niches for specific species,” with six to eleven major biomes, depending on the scientist: forest, grassland, freshwater, marine, desert, and tundra, and subset variations such as freshwater, marine, savanna, tropical rainforest, temperate rainforest, and taiga. Similarities with the fundamental characterizations of outer biomes led me to extrapolate and further explore the phenomana of inner biomes. These images evoke some inner biome features:

Figures 1-4. UL (Figure 1): Grey, translucent, feels & tastes like after rain. UR (Figure 2): Moist, teeming lush, rejuvenating, aliveness. LL (Figure 3): Warm, living light aglow. Shimmery. LR (Figure 4): Tropical marine life. In & out of cooling water.

Each Inner Biome seems like an original environment. Characteristics vary to the person, but once tuned into, the inner space is consistent, and becomes an increasingly stable support. Some imagery has helped to draw out the seemingly subtle preliminary sensing. Yet once discerned, the Inner Biome becomes stable, referenceable, and a deep personal support over time. Each person seems to have a distinct, inner field that works much like a mature amniotic field. It is represented pre-verbally through felt senses, colored and otherwise personally nuanced inner sensing. The Personal Biome is supported by feeling tones and essential associations. It relates to and supports qualities and states of interiority that can be contacted in contemplative, somatic and meditative practices, or simply sensed beneath conventional experience.

Personal Visual Harmonics

Personal color choices such as were popularized in the 1980's (Color me beautiful, etc.), in which colors that seem to reflect well with one's body and coloring tend to practically and visibly enhance inner-outer feelings of confidence and wellbeing.

People have an individual palette that includes colors that visibly harmonize with the undertones in hair and complexion. By engaging colors that harmonize (according to simple color coherence) feelings of authentic congruence arise. Simply put, when we look good, we tend to feel better too. (Color & Vision Matters, n.d.)

Colors can also be thematic and culture-centric as well. For example, Japan, has several traditional aesthetic combinations, such as the use of deep teal, dark red, and tan background with black or charcoal strokes; remaining culturally and aesthetically appealing. Classic cultural aesthetic motifs repeat through contemporary design and arts. Films communicate moods through rhythms, sound, shapes, and strongly through color. Color palettes can convey a mood, scene, story or theme as is seen in the adjacent movie palettes, each of the palettes in Figure 5 makes psychological feeling-toned impacts.

Figure 5 Color Palette Cinema, Instagram. 2022.

Personal Brand Palette

The personal brand represents how a person expresses him or herself in the world. When misunderstood, messaging is derailed by lack of coherence. Often people and businesses hire branding agencies to come up with a look, style and story, making the error of starting an inner story from the outside. Brand incongruity happens when the persons feel their packaging does not genuinely expresses who they are. When ad agencies have chosen palettes to meet the market, (outside-in), the brand can feel alien, and an impostor syndrome can arise, conscious or unconsciously. Worse, inauthenticity undermines credibility and trust usually without people realizing why. Here are some examples of quintessential people who embody their lifework: On top is Nelson Mandela, whose direct, humble, earthy, South Africa loving expressions were his aesthetic. On purple, animated astrophysicist, Neil de grasse Tyson, who frequently features stars, and an ethereal and mysterious cosmos color palette and iconography. Below, are works by local photographer, Brandi Crockett, whose naturally gentle and graceful aesthetic manner is visible in her earthy, romantic, nostalgic photographic style. The intuitive choice to first identify one's natural personal preferences in a palette that feels authentic and self-expressive through sensory exercises or brainstorms creates an integrated base from which to brand from the inside-out.

Figure 5. Three google search collages showing coherent look and feel branding.

Transitional Visual Space

The creation of Visual transitional space arose from the aim of creating a visible neutral space in which to hold multiple points of view that for several reasons were difficult. After September 11, 2001, at the first families, first responders and civic supporter's gathering at Ground Zero, emotions were diversely raw. However, healing, listening, and common ground were needed to draw out and prioritize what would be memorialized. When I mapped these, I kept using similar colors for similar emotions. Creating a place for so many painful stories and emotions, seemed to give relief, and give them inner space to breathe, knowing their concerns were now visible together.

In 2003, when the Columbia crashed, I was at NASA, and visually mapped the shock and outpouring. Afterward, NASA members reported that having their feelings mapped in image and color just when needed, helped them release and process their devastation, possibly mitigating trauma.

Progressively, after Katrina, I created a 100 foot wall onto which I mapped “Storm Stories,” anchoring many strange things that happened, or were left behind. Providing a practical placeholder for people's lost desks, shoes, cats, books, best dress, necklace, and the many things that were looping in their minds, created an off-ramp. The wall of visual story vignettes—simple essential sketches—representing what happened, what needed to be remembered, and hopes or dreams, developed magnetism. More people came to unburden their memories into color and form. It seemed to anchor their experience, free feelings, and allow forward thinking to ensue.

Positioning the difficult material onto an artifact, by listening fully, sketching essential stories provided palpable relief. However, when pastel color was applied in support of sentiments, people would exhale, bodies would release tension, tears would fall. Invisible shells seemed to crack revealing softened eyes and tenderized people. The Storm Stories wall was the Transitional Visual Space, a visual storied artifact representing emotional, psychological and symbolic scaffolding for ongoing recovery. In the case of the Katrina map, I designed it to be broken down and re-used for meetings around the country, like a big visual Winnicottian transitional space (Winnicott, 1971).

Anchoring difficult emotions beyond words made a significant difference in the fullness of grief, and the possibility of resilience. Feelings are beyond words. And talk can re-traumatize. Maybe remaining predominantly emotional and aesthetic allows for a fundamental flow. As Besel van der Kolk found in his longitudinal studies of PTSD, people need embodied ways to release the grip of trauma. Perhaps a place to see their feelings and memories in simple color and images outside themselves cleared space to move forward out of trauma repetitions. From these, and other cases, anchoring hot or jagged events with color and shapes that reflected those feelings, people seemed to feel heard, and able to release their charge by allowing the page to hold their memory, and the body to return to life. By continue living on the transitional art page with simple lines and color anchoring that which might otherwise be relived through traumatic attachment (van der Kolk, 2014).

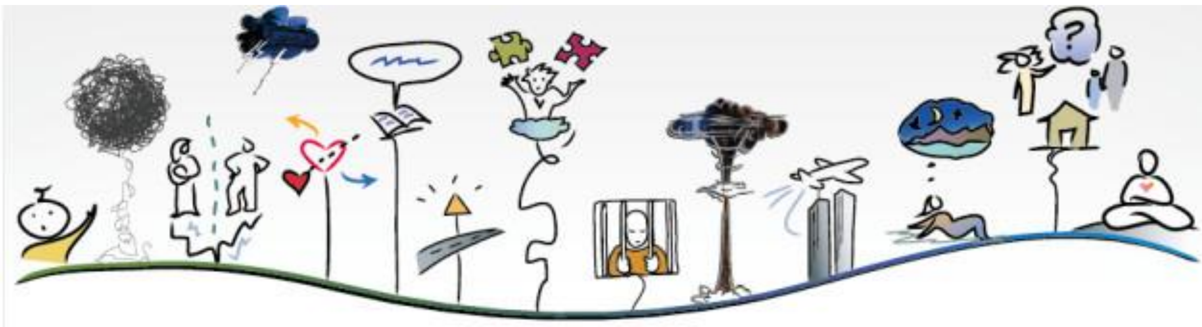

Figure 6. Example of types of trauma that might arise in solo Resilience Mapping. (Usually the journey would include regular life experience representations as well. This is for illustration purposes.)

In conclusion, a personal palette seems to offer a meaningful through line worth further study. This paper shares some ways that have proven helpful to many over the last 25 years at pivotal junctures. Consciously recognizing the possibility of an inner biome in a sensory way may provide grounding support, as well as open inner capacities with benefits for mindfulness, centering, and belonging. Further, it is worth connecting the dots from deep inner aesthetics, to the various stages of self expression. While each correlates to a personal palette, it is not certain if these co-exist as different aesthetic palettes in separate domains, or if there is a through line of consistent meaning. Finally, creating an aesthetic third space provides a transitional field, allowing people to release gripped trauma, create distance and perspective, or as Carl Jung suggested, something very deep can occur in a space where impossible considerations can be held. Perhaps on a page with simple lines and color, a "union of conscious and unconscious contents is consummated. Out of this union emerge new situations and new conscious attitudes," representing the union of opposites, which he called the "transcendent function." (C.G. Jung, CW 9, 1959/1990, para 524, p. 289).

This paper aims to elevate observations of domains in which personal palettes have proved meaningful, therapeutic, and useful to individuals and groups. Even the most subtle palettes have remained consistent over time. Continued engagement seems to stabilize accessibility and usefulness. Further exploration, findings, investigation and collaboration are welcome.

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References

Books:

Andersen, N. 2005. The creating brain: The neuroscience of genius. New York, NY: The Dana Foundation.

Bosnak, R. 2007. Embodiment: creative imagination in medicine, art, and travel. New York, NY: Routledge.

Cahnmann-Taylor, M. 2008. Arts-based research: Histories and new directions. In Cahnmann-Taylor, M. and Siegesmund, R. (Eds.). Arts-based research in education: Foundations for practice. New York, NY: Routledge.

Casey, E. S. 1993. Getting back to place: Toward a renewed understanding of the place-world. 2nd ed. Bloomingdale, IN: University Press.

Collins, R. & Cooper, P. J. 1997. The power of story: Teaching through storytelling. Scottsdale, AZ: Gorsuch Scarisbrick.

Damasio, A. 1999. The feeling of what happens. Orlando, FL: Harcourt.

Hirst, R.J. 1965. Perception and the external world. New York, NY: The Macmillan Company.

Jackson, Carole. 1985. Color Me Beautiful: Discover Your Natural Beauty through the Colors That Make You Look Great & Feel Fabulous! New York: Ballantine Books.

Johnson, K. 2018. The jeweled path: The biography of the Diamond Approach to realization. Boulder, CO: Shambhala Publications.

Kotler, S. 2014. The rise of superman: Decoding the science of ultimate human performance. New York, NY: Houghton Mifflin Harcourt Publishing.

Margulies, N., & Maal, N. (2002). Mapping Inner Space, 2nd ed. Tucson, AZ: Zephyr Press.

McGilchrist, I. 2010. The divided brain and the search for meaning; Why are we so unhappy? New Haven, CN: Yale University Press.

Overton, E. 2012. That funny feeling (October 22, 2012). Montreal, Ontario: The McGill Daily (28:33).

Ramachandran, V. S. (2004). A brief tour of human consciousness. New York, NY: Pearson Education.

van der Kolk, B. 2014. The body keeps the score: Brain, mind, and body in the healing of trauma. New York, NY: Viking Penguin Group

Winnicott, D.W. Playing and reality. London: Tavistock Publications, 1971.

Articles in Journals

Baron-Cohen, S., et al. 1987. Hearing words and seeing colours: An experimental investigation of a case of synaesthesia. Perception 16, 761–767. doi: 10.1068/p160761

Articles in anthologies or proceedings:

Maurer, D., Gibson, L. & Spector, F. 2012. Infant synaesthesia: New insights into the development of multisensory perception. Multisensory Development. 10.1093/acprof:oso/9780199586059.003.0010

"Biomes." National Geographic Society. National Geographic Society. Accessed June 11, 2022. https://education.nationalgeographic.org/resource/resource-library-biomes.

Colormatters.com. n.d. Color & Vision Matters. [online] Available at: <http://www.colormatters.com/color-and-vision/color-and-vision-matters> [Accessed 2022].

Decolonising Skin-Lightening Practises in Selected Ghanaian Universities

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Abstract

This study explored the phenomenon of skin lightening practices using descriptive case study of qualitative research to make meaning of the lived experiences of skin lightening student-practitioners drawn from four universities in Ghana. It explored the views of skin lightening student-practitioners on their own practices and the motivation behind their quest. A sample size of sixteen (16) respondents drawn from four (4) universities in the metropolitan and municipal centres of Ghana namely, Takoradi, Cape Coast, Accra and Winneba was used for the study with the help of critical case sampling technique under purposive sampling. Skin lightening or whiting pills, injections, creams, and oils are the major forms University female students used to change the looks of their skin regardless of the health hazards. The study also revealed that female university students resort to skin-lightening treatments to appear attractive to males; due to peer influence; Eurocentric aesthetic standards emulation; and influences from social media. The African Studies departments, institutes and centres in the Universities should consider including courses in their curricula that would contribute to decolonizing the skin lightening practices to restore pride of being Black and for that matter, African.

Keywords: *Skin lightening, bleaching, decolonisation, black identity, beauty culture*

Introduction

Discrimination against Blacks because of their skin colour is a commonplace issue and remains a sensitive subject matter in their lives. The discrimination against Blacks have fuelled lots of movements, and activism in African American communities. Some of the movements include *Black and Proud*, *Black Power Movement* and the recent *Black Lives Matter*. The Black power movement, for instance, which originated in the 1960s, emphasised racial pride and social equality by creating political and cultural institutions of Blacks.

Skin, as the largest organ of the human body, serves as protective covering and marker of identity. It is an overt indicator used as a basis of stigmatisation, discrimination, and marginalisation. The subject of skin colour discrimination against Blacks have attracted wide scholarship in the USA, perhaps due to the huge presence of African American and other people of colour.

Some available studies have explored the economic outcomes of skin-tone discrimination, and how skin colour serves as a signal for discriminators in the labour market, in the field of education and general living (Goldsmith, Hamilton & Darity, 2006). Studies have revealed high levels of wage discrimination for medium- and dark-skinned. Dark-skinned women are reported to receive more rejections in the context of employment than equally qualified dark-skinned men (Goldsmith, Hamilton & Darity, 2006). This implies that the issues of black skin discrimination have complex undertones including gender inequality, economic repression, and racism which places women at disadvantageous positions.

Apart of the United States, skin colour discrimination and the concept of colourism have also received appreciable amount of scholarly attention in some parts of Asia. Nager's (2018) study suggested that skin-colour may play an important role in mate selection in arranged Indian marriages while Harmon (2018) reported that women of colour spend nearly nine times more than non-Black counterparts on their hair and beauty products. Again, people of African descent regularly feel discriminated against based on skin colour, and racial discrimination in access to private and public housing to a great extent according to European Union Agency for Fundamental Rights (2018) reports.

It is worthy of note that the miseducation of the Blacks, effect of slavery and colonialism, and to some extent effects of globalisation have exposed many Blacks, especially, women to the harsh realities of the skin colour discrimination to the level of feeling the impact in their own African homeland. The colonialists brought their own aesthetic ideal as touchstone for emulation by Blacks, and rewarded those who emulated their whiteness beauty standard culturally, ideologically, economically, and aesthetically (Hunter, 2007). In effect, the colonialists' perception of light skin superiority over Black skin seems to have gained grounds in Ghana. There are pockets of reports about young female students' involvement in skin toning and or bleaching (Agyemang-Duah, et al, 2019). To explore the realities and lived experience of the phenomenon, this study examines the skin toning or lightening practices amongst young female university students, and the underlying motivation behind it, as against their dark skin identities. With regards to students' involvement, Agyemang-Duah, et al (2019) examined the prevalence, patterns and socio-demographic factors associated with skin toning practices among female university students in Ghana using a sample of 389 undergraduate female students. This study explored the phenomenon using descriptive case study of qualitative research to make meaning of the lived experiences of skin lightening practitioner-respondents drawn from four universities. To this end, the study explored the views of skin lightening student-practitioners on their own practices and the motivation behind their quest. This gives them the opportunity to tell their own stories about their beauty culture practices.

Methodology

Descriptive case study constituted the research design for the study. A sample size of sixteen (16) respondents drawn from four (4) universities in the metropolitan and municipal centres of Ghana namely, Takoradi, Cape Coast, Accra and Winneba respectively was used for the study with the help of critical case sampling technique under purposive sampling. Four (4) each were selected from public universities namely Takoradi Technical University, University of Cape Coast, University of Ghana, and University of Education, Winneba. The age of the respondents ranged from 19 to 30 years. Respondents were asked to share their personal experiences of skin lightening and toning practices through in-depth interviews. Semi-structured interview centred on personal experience of skin lightening, motivation for doing it, and possible side effects. Focused Group Discussion was also used. Narrative analysis formed the method of data analysis. For ethical purposes, pseudonyms were used to ensure anonymity of the respondents.

Results and Discussion

All the sixteen (16) respondents shared their views on the various skin lightening practices they prefer. Over 70 percent of the respondents indicated their preference for the use of the pills for skin lightening. They ascribed their reason for their preference for the pills to its resultant effect of not creating darkening variation of black spots on their bodies. To them, using the pills leave little or no dark skirmishes on the skin that give visual hints of skin toning or bleaching. In effect, their preference was linked to the quick and rapid skin toning or bleaching results. In confirmation, one of the student-respondents remarked that:

> Yes! I take pills to make me get light skin. The pills are expensive but I manage to buy them. I take the pills to enhance my skin colour: to make me have light skin. I take that option because it does not give me black spots on my skin as others experience when they use cream that bleaches the skin. But when I take the pills, it makes me have light skin with no black spots. I really like the pills.

This confirms the finding of Agyemang-Duah, et al (2019) that over 40 percent of female respondents in their study had practised skin toning within the last 12 months prior to their survey. The issue of cost impliedly affects the choice of pills, creams, injections, and oils for use for the skin toning and bleaching. The practice, according to the respondents, is not limited to students. Some pregnant women also resort to the use of the pills in their quest to have children with light skin. 'It is so! Some pregnant women want their babies to have light skin. So, while the baby is in the womb, they take skin lightening pills' (Respondent B). Interestingly, the pregnant women acquire the skin toning pill from pharmacies. Respondent C added that:

> I know a certain pregnant student lady who goes to a pharmacy for them to prescribe skin lightening drugs for her to take. When you go to the pharmacy for skin lightening drugs, since the pharmacist wants to make sales, they sell it to you without questioning. They know we ladies are much influenced. The pharmacists tell you, if you take this and that and add up you will get the light skin you want.

The participation of pregnant women in the use of over-the-counter skin toning pills and creams tell the level of participation of females all in the quest for light skin colour. It is, therefore, not surprising that Blay (2010) pegged that 30% of women in Ghana practice skin lightening or toning.

Apart from the pills, creams, oils and injections, there are reports of the use of bleach solution at spa centres to arrive at light skin. "Some of my friends also prefer to go to a spa to 'swim' in a pool of chemicalised solution just to get light skin. Black girls are doing a whole lot just to have light skin" (Respondent C). Respondents also responded to the issue of their motivation for practising skin lightening or toning. The responses revealed that though they have heard and experienced the side effects of the pills and creams, they are burnt on their desire of having light skin. 'Since we want to feel good by having light skin, we don't care about the side effects' (Respondent D). One of the respondents, shared her views:

I personally observed that using those skin lightening chemicals causes some skin burns and itches as one ages. We call that skin burns and colouration in Akan language as *nansoɔbɛn*. This is a negative term in reference to skin burns and multi-dark-coloured spots that usually appear on the face of people which bleach their skins. Besides, the veins appear greenish causing discomfort.

Ladies get concerned about their skin colour. If they are not satisfied with their skin colour, they then introduce creams of different brands just to make them have light skin. Many use creams that transform (bleach) their bodies. Others change their body colour just to impress men or guys. This justified Fukuo's (2009) assertion that light skin women become the preferred choice in terms of marriage, forcing young girls into the act.

Results from the focused group discussion indicated that ladies get worried about what people say about their skin. Negative comments from friends about their skin hurts them deeply. In their worldview, 'one cannot borrow someone's skin to attend a programme' (Respondent E). As a result, they tend to pay more attention to their skin. They also confirmed the influence of the lifestyle of celebs on them, and their wish to look like the celebs. ‘The movies we watch do influence us. The guys seem to *chase* the light skin girls. So many girls would like to have light skin. Through conversation with my male friends, they say that they prefer light skin girls. Yes! They say it!’ (Respondent G).

Skin lightening practices keep increasing among ladies in universities. Sections of society have imbibed the Caucasian beauty culture standards as the ideal standard and therefore resort to different means of achieving that irrespective of the consequences. Existing literature confirms the value attached to having evenly toned and faultless skin complexion as attractive and commendable (Gwaravanda, 2011). Such thoughts have bred low self-esteem amongst some of the youth, who therefore dream of having light skin.

Conclusions

The study revealed that female university students resort to skin-lightening treatments to appear attractive to males; due to peer influence; Eurocentric aesthetic standards emulation; and influences from social media. They also do it to please guys without caring about the harmful effects of the practice and to feel good. For the young Black ladies to feel good for bleaching to have light skin tells their rejection and low self-esteem in wearing the Black African identity. This is a worrying trend that needs urgent solution. The carefree attitude of female University students to resort to skin lightening or whiting pills, injections, creams, and oils to change the looks of their skin regardless of the health hazards is a strong indication of black skin inferiority and low self-esteem in the context of identity. For this identity challenge to make inroads and become attractive to university students who are supposed to be agents of change and decolonisation ambassadors to fertilize society with positive thoughts of being an African tells volumes of the impact colonialists' beauty culture ideals have had on the current generation of young Ghanaians. The African Studies departments, institutes and centres in the Universities studied (University of Ghana, University of Cape Coast, University of Education, Winneba, and Takoradi Technical University) should as a matter of urgency consider including courses in their curricula that would contribute to decolonizing the skin lightening practices to restore pride of been Black and for that matter, African.

Interestingly, students in the universities used for the study have mandatory courses they do in African Studies as part of their education. Creating and mounting courses in relation to African identity and beauty culture standards could be made as one of the compulsory courses that students are to do. The proposed courses should centre on Afrocentric beauty culture ideals and identity. Changing the narrative by making female students have pride in their unique African skin colour should be a deliberate attempt aimed at decolonising the mind of the students to develop positive thought of the self.

In a way, changing the narrative depends on the individual female students as well. They need to be content with their skin colour. Educating young girls about the side effects of bleaching and skin toning through the mass media by the National Commission of Civic Education is equally important in minimising the problem.

References

Agyemang-Duah, W., Mensah, C. M., Anokye, R., Dadzie, E., Gyimah, A. A., Arthur-Holmes, F., Peprah, P. & Yawson, F. (2019). *Prevalence and patterns of skin toning practices among female students in Ghana: a cross-sectional university-based survey* doi: 10.1186/s13104-019-4327-8

Blay, Y. A. (2010). Ahoofe kasa!: Skin bleaching and the function of beauty among Ghanaian women. *Jenda J Cult Afr Women Stud., 14* http://www.africaknowledgeproject.org/index.php/jenda/article/viewArticle/528.

European Union Agency for Fundamental Rights. (2018). *Second European Union Minorities and discrimination survey being Black in the EU.* Publications Office of the European Union.

Fokuo, J. K. (2009). The lighter side of marriage: skin bleaching in post-colonial Ghana. Inst Afr Stud Res Rev. 25(1), 47–66.

Goldsmith, A. H., Hamilton, D. & Draity, W. Jr. (2006). Skin-tone discrimination and economic outcomes, shades of discrimination: Skin tone and wages. 96(2), 242-245.

Gwaravanda, E. T. Shona proverbial implications on skin bleaching: some philosophical insights. *J Pan Afr Stud.* 4(4), 201.

Harmon, S. (2018). Black consumers spend nine times more in hair & beauty. https://www.hypehair.com/86642/black-consumers-continue-to-spend-nine-times-more-in-beauty-report/

Hunter M. (2007). The persistent problem of colorism: Skin tone, status, and inequality. *Sociology Compass*. 1(1), 237–54. https://doi.org/10.1111/j.1751-9020.2007.00006.x

Nager, I. (2018). The unfair selection: A study of skin color bias in Arranged Indian marriages. *SAGE Open,* 1 – 8. https://doi.org/10.1177/215824401877314

Session 16
Colour in the Landscape

Colours of the Land

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Abstract

Colours of the land is a project that will refer to how we experience and connect with nature through color, using Kejimkujik National Park as the case study. The land has multiple stories to tell: the story of its predecessors, the stories of the hundreds of families that visit the park every day, and the story of its non-human inhabitants. When we enter a space, colour has a huge impact on how we perceive that space, how we connect to it, and the kind of memories and personal stories we build around it. Our colour experience in a place is unique. Depending on the moment of the day, the season, and other environmental elements such as clouds, water, vegetation, and human presence, one-of-a-kind palettes are created. These palettes shape our experience and cause physiological and physical reactions. In addition, we interpret these stimuli based on our background, memories, and previous experiences.

Keywords: *Nature, Emotions, Perception, Memory, Art, Landscape*

Introduction

The Site

Designated a National Historic Site in 1995[1], Kejimkujik National Park attests to 4000 years of Mi'kmaq history, making it one of the most important sites in Nova Scotia. Nowadays, it is also a popular destination for camping, paddling, and hiking, and within its cultural landscape there are petroglyphs, traditional encampment areas and more. The park's Seaside is a protected location where people can admire beautiful beaches, lagoon systems and coastal wildlife. Kejimkujik is the perfect place to analyze how people experience colour.

Process Plan

The researcher photographed the land and different elements of the site. A sample of 20 photographs were selected from the lot. Using the software Adobe Color, the dominating palettes from each image were extracted. The palettes were uploaded to a survey, answered by two control groups. The first group consisted of artists who attended a trip to Kejimkujik National Park as part of the

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[1] Parks Canada Agency, Government of Canada. "History." History - Kejimkujik National Park and National Historic Site, July 29, 2020. https://www.pc.gc.ca/en/pn-np/ns/kejimkujik/culture/histoire-history.

class “Land and Parks based practices” taught at NSCAD as an elective to both the MFA and MAEd programmes. The second group were people from outside the institution who have never been to Kejimkujik. Both groups looked at the colours without the reference image and answered how these colours make them feel. They were given a range of emotions taken from the Wheel of Feelings proposed by Dr. Gloria Willcox: sad, mad, scared, joyful, powerful, peaceful.

For a second step of the survey, both groups were shown the picture that originated each palette and asked to give a title to the photograph. The results were compiled and analyzed by the researcher, and subsequently reinterpreted into a visual composition, shown at the group exhibition *RESIDUA* at the Anna Leonowens Gallery in Halifax, N.S.

In the second stage of the project, the researcher compared the data between both groups of interviewees to find out if the reaction to colour changes when connected to an experience or if exposition to the individual colours generates the same kind of emotions in the viewer. How do people who went on the trip connect their own memories and information of the place with their colour experience? How do we construct a narrative around a place based on our colour experience?

Phase 1. Photo selection and palette creation

The first stage of the project consisted of taking photographs on site. These photographs were taken in the month of August, which means it was the end of summer. The colour experience of the same site can change drastically with the change of the seasons. The subjects of the photographs were either general shots of the landscape or close-up shots of elements with an interesting colour scheme such as mushrooms, leaves, and other natural elements.

The following step was to select the photographs that were going to be used for the survey. This selection was made by trying to keep the palettes as varied as possible to try to get a wider sample of colours. The photographs were not adjusted in saturation or hue, the only adjustment made when necessary was the exposure and contrast. This was in order to keep the colours as close to the actual scene as possible. After the final selection was made, the photographs were uploaded to the online software Adobe color to create the unique palettes resulting from each image.

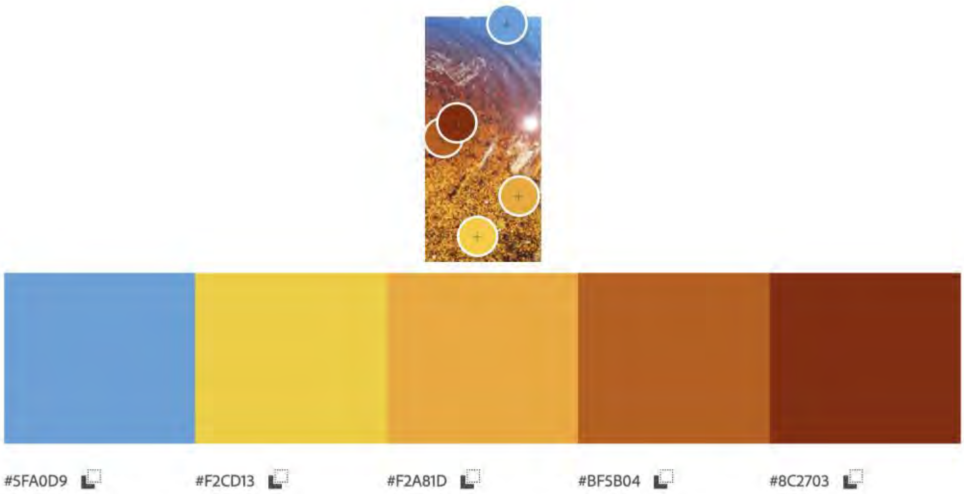

Figure 1. Photograph with colour analysis generated in Adobe Colour.

Phase 2. Survey and collection of data

The second stage of the project consisted of the collection of data through a poll. Participants were divided in two groups, the first one included those that formed part of the class's cohort who had attended the trip and had lived the experience of being on the site and the second group included only external people who had never been to the site. The sample of photographs had to be reduced from 20 to 17 for the survey given that it made the poll too time-consuming and some people were giving up halfway. The images that were taken out from the survey were selected based on their similarity to other existing palettes in the sample.

The poll showed the participants the palettes and asked the feelings that those colours evoked. They were given a list of emotions and they had to rank them in intensity from 0 to 4. The options were taken from Dr. Gloria Wilcox's Feeling wheel, which is designed to help people identify their feelings. The wheel consists of six basic emotions that can then be subdivided into more specific feelings; however, for the purpose of this exercise, only the basic emotions were taken into consideration.

Then, they were shown the photograph from which the palette was extracted and then asked to name the image. The results were then entered into a spreadsheet for further analysis. These were open-ended questions, giving the participant the freedom to describe what they were seeing in their own words.

Phase 3 Analysis and Results

By comparing both control groups, I was able to observe whether the experience of being onsite and being exposed to the land's colours had any true effects on the subjects' emotions. In conclusion, by connecting with the land people's emotions and perceptions of colour were vastly different from the subjects who only answered the survey, but the results were quite varied in relation to the colour palettes, as seen in the following graphs. Due to lack of space, not all the graphs generated from the survey will be included in this paper.

In most cases, the emotional responses for both groups follow the same trends, showing that colors evoke the same emotions regardless of whether the subject has been exposed to the site personally. There are, however, some exceptions. The graphs showed a 70% correspondence between the two groups' emotions, while 30% of the cases showed great variations. I believe that the results are far from conclusive and that more research needs to be conducted to understand why perceptions vary. However, there are some consistent trends and other noteworthy findings.

For example, the palettes including some shades of green seem to be the most consistent, with "joyful" being the dominant emotion. The situation changes with the palettes including warmer hues, where the results differ between the groups. For instance, people who remembered their experience with the reds found in nature were more likely to indicate having positive feelings, whereas the subjects who did not go to the park associated red with danger, for example, there is an image portraying a person swimming in red water. For the group that didn't go to the site, the red and dark colors were automatically related to the emotion "scared" whereas the group that was at the site might recall that the water was red due to its high tannin concentration, and that it is in fact quite beautiful, hence, this group didn't associate the palette with fear. This can mean that, even though there might be a physiological reaction to the colors, our rational and conscious side can influence how we perceive those colors based on memories and our overall life experiences, which also include sensory and emotional elements.

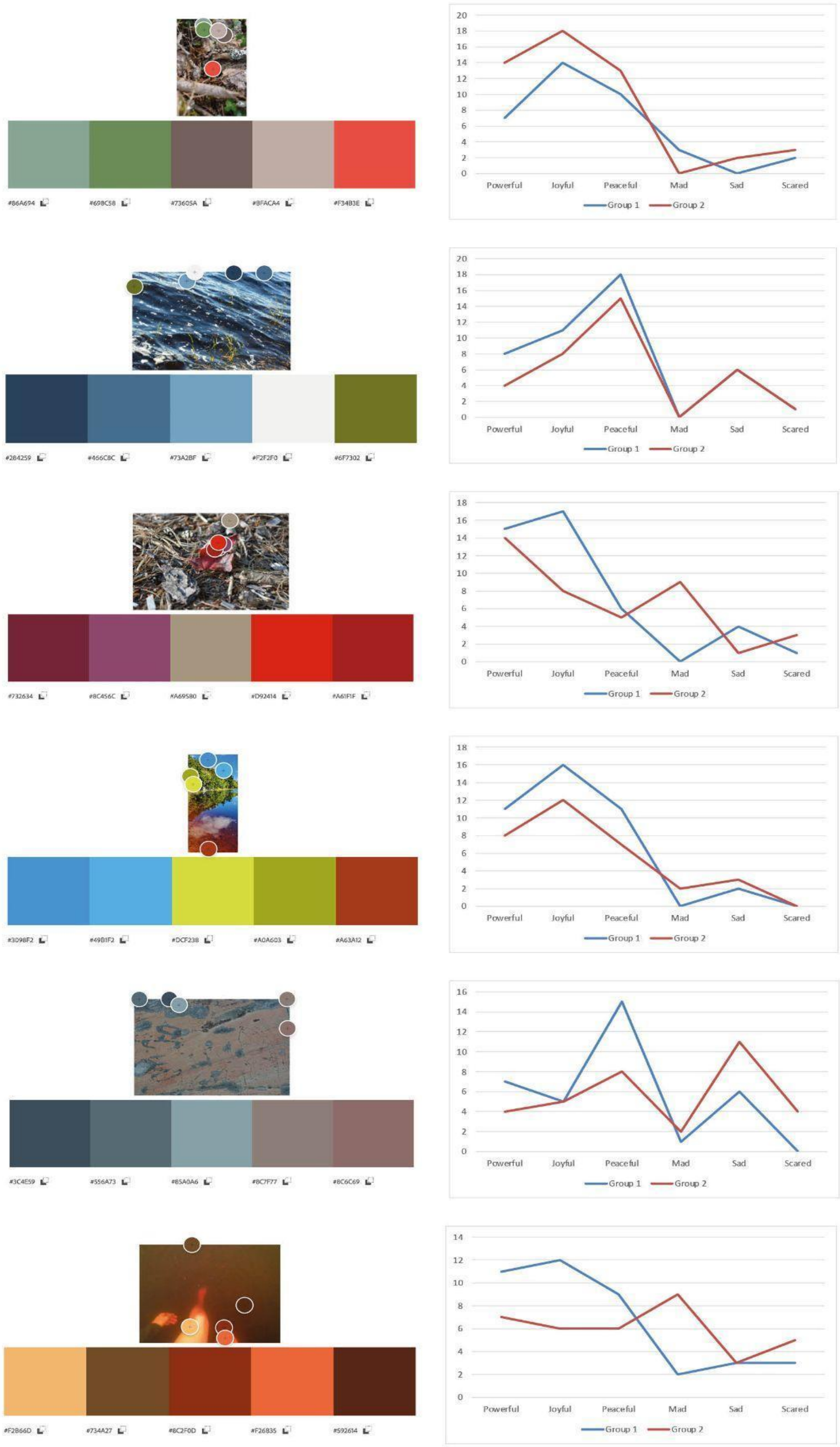

Figure 2. Data Analysis Results: section 1.

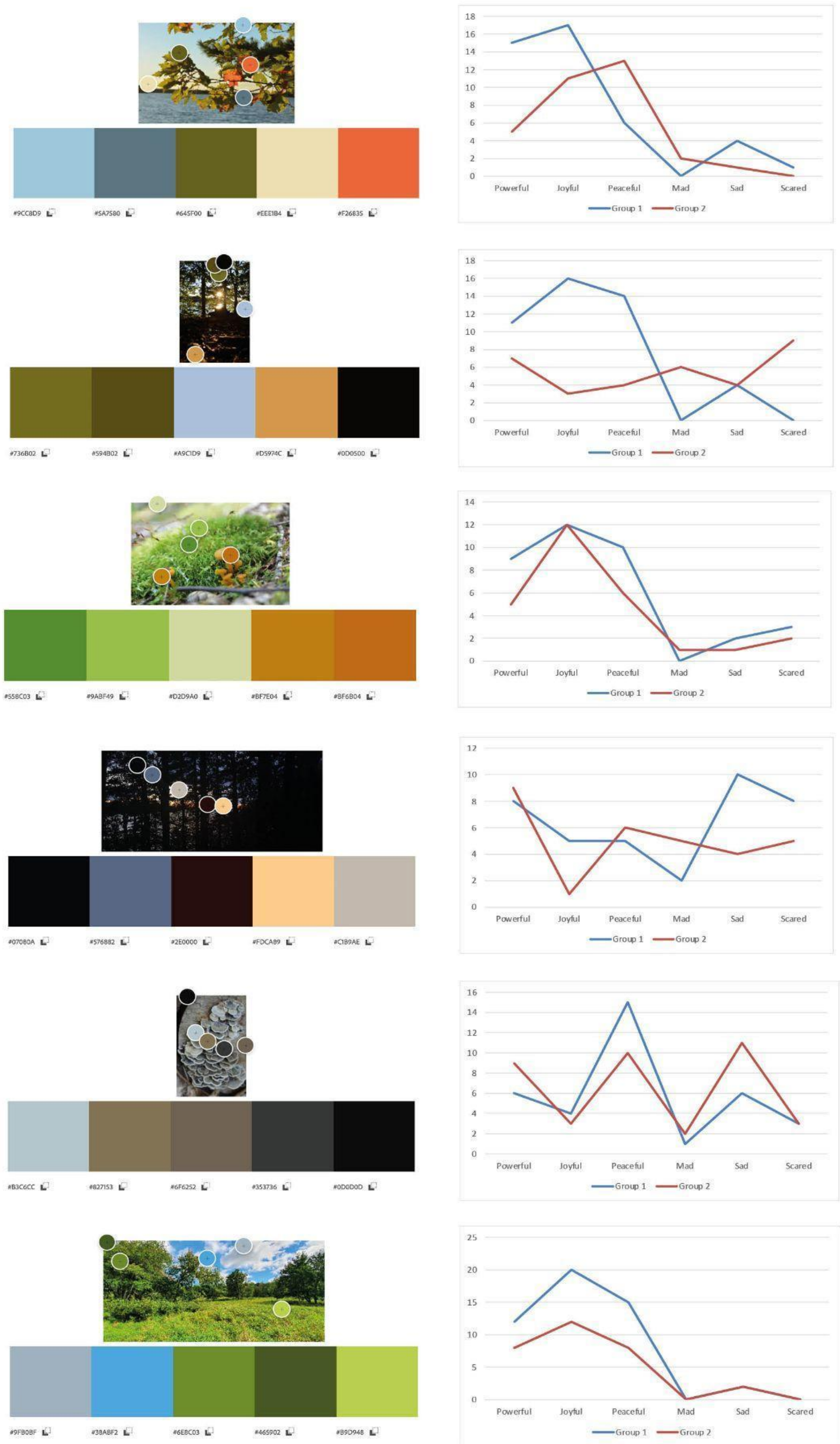

Figure 3. Data Analysis Results: section 2.

Phase 4. Artwork creation and Exhibition

One of the expected outcomes of this project was to produce a piece of art that could be part of the collective show RESIDUA. The premise of the show was to talk about memory, and everything that is left behind when we visit a place. The exhibition took place at the Anna Leonowens gallery from November 22 to December 4th, 2021. For the creation of this piece, I decided to create a composition with the photographs and the palettes together, using a regular grid, slightly inspired by the De Stijl style. The composition was printed in large format for installation in the gallery. Next to the main piece, the palettes were shown on their own, accompanied by the titles that the participants gave them in the survey. The show got very positive reviews from the general public and academics alike.

Final Thoughts

To connect the colour-emotion findings of this experiment to this site and to talk about memory and narrative in relation to the site, I added up all the data from the survey to observe the general emotions this site evokes through its chromatic display.

As shown in the graphics below, when looking at the results from all the images and palettes together, both groups show very similar responses.

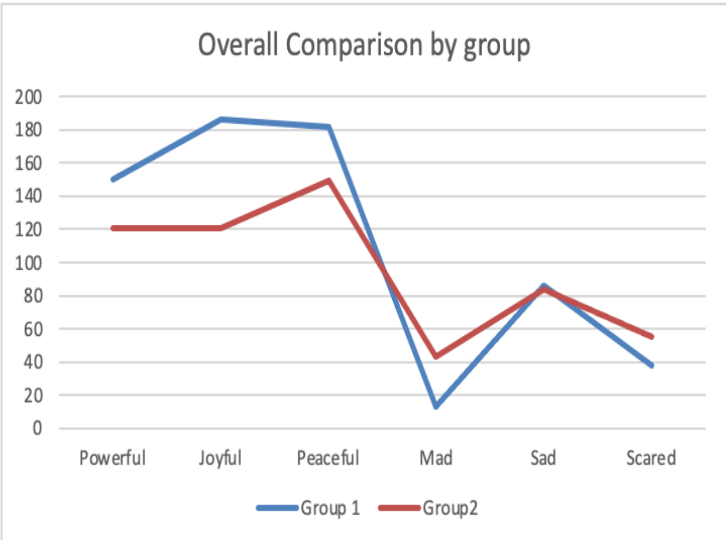

Figure 4. Data Analysis Results: Overall comparison by group.

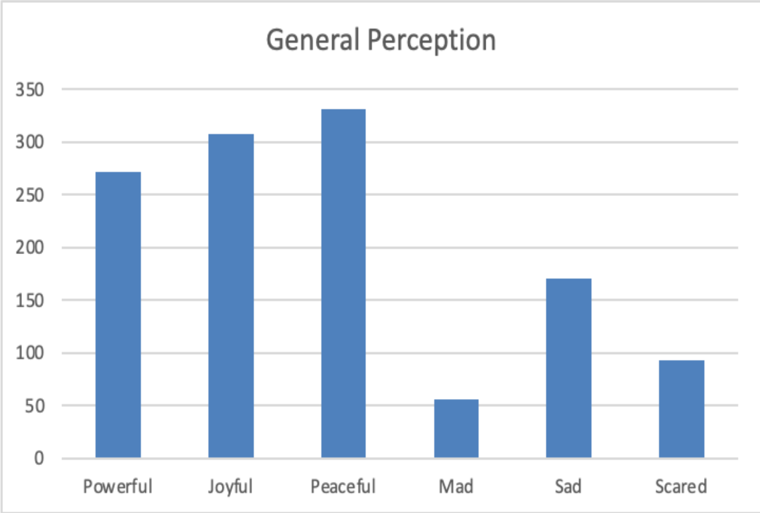

Figure 5. Data Analysis Results: General Perception graphs.

When combining both groups to get the general perceptions and the feelings that the site brought to the participants, we can clearly see that the dominant emotions are **peace, joy, and power**, with **sadness** as a close runner up. Even though both groups seem to have had the same overall perceptions, the participants who experienced the land in person had a much more intense experience, which can be seen in the final results. I believe these emotions match with the story of the place perfectly. Although this majestic landscape inspires such awe, it has also witnessed some sad episodes throughout its history, and its colours serve here as another testament to its sacred history.

References

Heller, Eva. *Psicología Del Color: Cómo Actúan Los Colores Sobre Los Sentimientos y La Razón*. Translated by Chamorro Joaquín Mielke. Barcelona: Gustavo Gili, 2020.

Parks Canada Agency, Government of Canada. "History." History - Kejimkujik National Park and National Historic Site, July 29, 2020. https://www.pc.gc.ca/en/pn-np/ns/kejimkujik/culture/histoire-history.

Willcox, Gloria. "The Feeling Wheel." *Transactional Analysis Journal* 12, no. 4 (1982): 274–76. https://doi.org/10.1177/036215378201200411.

Chroma Calls: Attunement to Ālace through Colour Intra-action in Sculpture

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Abstract

The paper discusses the public sculptural installation *Chroma Calls* presented along the Forth and Clyde Canal in Scotland, to consider how contemporary art practice can help initiate and develop attunement to a place by introducing colour through sculpture. It proposes the idea of *'intra-action of colour',* drawing on the concepts of Josef Albers' *interaction* and Karen Barad's *intra-action*, to approach colour in more entangled and embodied terms and to bring forth invisible natural processes: from the presence of specific colours in a place, to the different ways of sensing colour, and associated ethical considerations. The author develops the concept of *'accromatising'*, derived from 'acclimatising', the process of becoming more accustomed or adjusted to new conditions or circumstances. 'Accromatising' describes the process of gradual attunement towards a place through colour. Ultimately, the paper suggests that colour can be used as an entryway into a more entangled and responsible sharing of places with humans and nonhumans, with art practice offering a platform for merging a range of disciplines to develop awareness of our environment, with its myriad other participants.

Keywords: *Intra-action, Entanglement, Environmental Colour, Place, Art*

Introduction

This paper considers how contemporary art practice can help initiate and expand attunement to a place by introducing colour through sculpture. It is discussed through the public sculptural installation *Chroma Calls*, presented along Forth and Clyde Canal in Scotland, which was conceived and led by the author. It was commissioned by the Falkirk Community Trust and Scottish Canals, and presented to the public in summer and autumn 2021.

Chroma Calls is an installation of twenty abstract sculptures extending along a four-mile (6.5km) stretch of the Forth and Clyde Canal, which crosses central Scotland. Suspended from various species of tree on both sides of the canal, each sculpture is composed of multicoloured minimal abstract shapes designed to mirror the colour palette of one of the bird species which nests on or visits the canal area on their migratory journey, such as the swallow, tufted duck, kingfisher, and mute swan.

The *Chroma Calls* sculptures drew attention to the colours and colour combinations which, although present within this landscape, might remain unnoticed, due to the fleeting presence of the birds and the limitations of human perception. The sculptures also revealed certain colours that might not be easy to spot, like the kingfisher's exuberant coat of bright oranges, greens, and blues. Furthermore, the sculptures drew attention to some colours of the familiar species that might be hidden or not easily discerned, as in the case with some water birds – the ash-black colour of mute swan's feet, or the delicate blue beak of a tufted duck, or the red of the coot's eye.

Colour Considerations

Colour was central to the conception of the *Chroma Calls* sculptures. I worked with the canal ecologist to help me decide on the selection of bird species, aiming for a diverse range in bird genera and coloration. The colours for each sculpture were selected through direct observation of the bird species on the canal, and through a range of printed and digital sources where direct access to a species was not possible. The decision on placement of each sculpture, besides physical access practicalities, was based on colour contrast with individual features of the trees, like the colour of bark and foliage, positioning of tree branches, density, and shape of leaves.

Figure 1. Yulia Kovanova, 2021. *Chroma Calls* sculpture diagram. Photograph by Ian Redding.

Some of the minimal multicoloured sculptures were easily observable within the canal environment, allowing people to immediately link the place with the sculptures' colour combinations. Other sculptures were less immediately noticeable, due to their position on the opposite side of the canal from the towpath or amongst denser tree leaves, thus requiring viewers to be more observant. For those who caught sight of them, the sculptures acted as a simile for bird species, and provided a source of pleasure in discovery and encounter. For people undertaking the entire four-mile walk along the stretch of the canal, the sculptures presented an invitation to become more observant — having noticed a few at the start, one might be more inclined to look out for more and so engage more deeply with the place.

Figure 2. Yulia Kovanova, 2021. *Chroma Calls* sculpture studies. Image by Falkirk Community Trust.

The colour-scape of the place within which the sculptures were emplaced, comprised a combination of generally chromatically ‘available’ colours within the human temporality of perception; from the manmade structures of locks and bridges, to the changing colour of the sky, foliage and flowering plants, to the less apparent colours of the bird species. The experience of the sculptures’ colours was thus always contingent on many variables, including individual colour perception of the visitors. By focusing on the less obvious (to the human eye) colours of the birds, the sculptures helped embed those colours more prominently into the place. The exaggerated scale of the sculptures added further emphasis to those colours and colour combinations. It was my hope that the extended presence of these colour combinations in the environment would ‘train’ the spectator’s eye to look for that colour combination in the environment even when the sculptures had gone. This would be especially likely for people using the towpath as a frequent commute.

The sculptures had the capacity to encourage people to look for colours, become more observant, and link the colour combinations to specific chromatic presences of the birds within the environment. Where the population of certain species may increase or, more commonly, decrease, that colour acts as a reminder of their current or past presence in the particular place.

Figure 3. Yulia Kovanova, in collaboration with Lars Koens, 2021. *Chroma Calls* sculptures based on the colours of herring gull (left), robin (centre) and woodpigeon (right). Birch and bamboo, 800 x 400 x 30mm.

Intra-action of Colour

During the process of research and development of *Chroma Calls*, I started to tune into the chromatic nature of the place, with its myriad human and nonhuman participants, the sculptures emerging as new inhabitants. The intense entanglement of everything within the place became more apparent and this started a thought process about the behaviour of colour, encompassing all chromatic elements within that place, along with associated consequences and ethical considerations.

Colour behaviour was a key focus for artist and educator Josef Albers in his publication *Interaction of Color* (1963). Through a series of practical exercises, Albers encouraged experimentation through direct observation, to develop one's perceptual acuity of how colour behaviour changes depending on form, placement, and quality of light, among other variables. Albers argued that colour is in constant flux, perceived not as it physically is but instead only in relative terms, going so far as to say that 'colour is the most relative medium in art' (1963: 1) For Albers, colour was interactive both in the sense that it cannot be understood outside of its spectrum of mutuality, nor outside of the interaction between the environment, the observer and the colour observed. *Interaction of Color* was not prescriptive or conclusive, but an invitation into the beguiling world of colour, an open-ended journey, and an ongoing enquiry. To this end, and in the spirit of Josef Albers, I would like to consider another way of approaching colour – through colour *intra-action*.

Where *inter*- means 'between' or 'among', *intra*- means 'within'. The term 'interaction' presumes the existence of independent elements, or agencies, and, in our case, individual colours, which pre-exist their interactions. Albers' interaction of colour focused specifically on experimental teaching and studying of colour. I would like to extend this pursuit into a broader approach towards ontology of colour. I develop an argument for intra-action of colour through the agential realist framework proposed by theoretical physicist and feminist theorist Karen Barad. Agential realism sees the universe made up of phenomena – 'the ontological inseparability of intra-acting agencies,' (Barad, 2007: 206) – where agency is a dynamic relationship, rather than an attribute. Barad defines 'intra-action' as the 'mutual constitution of entangled agencies' (2007: 33) and this concept sits at the centre of Barad's agential realist theoretical framework that challenges individualist approaches to metaphysics. Colour can be seen as phenomena, emerging through a dynamic relationship of light, surface, the observer's visual perception, and many other factors. Colour, like other phenomena in Barad's reconceptualisation of metaphysics, can also be considered not individual but formed through the intra-action of various other agencies or phenomena in its dynamic web of relationships; it is a re-articulation of the world, and an ongoing process.

Colour is intrinsic to light. A surface emits a certain wavelength – perceived as a specific colour – and all other wavelengths are absorbed into and become part of that surface. Thus, all colours take part in the phenomena, dynamically entangled with all the elements required for the colour to be perceived. Colour perception is contingent on light conditions, along with sensory and cognitive interpretations. Hence, experiencing colour is always to experience it in a deeply entangled way, always in intra-action. In Barad's view '[t]o be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence. Existence is not an individual affair. Individuals do not preexist their interactions; rather, individuals emerge through and as part of their entangled intra-relating.' (Barad, 2007: IX) Barad stresses that agencies do not exist individually, but always relationally. A singular colour does not exist or become experienced in isolation, but rather emerges through a multilayered relationship of intra-action.

Intra-action of colour, then, is a dynamic process of colour emerging, through an entanglement of ontologically inseparable agencies. These agencies constitute necessary elements for chromatic participation in the world, running through human and nonhuman, time and space, material and discursive. From sources of light, the evolutionary development of distinct colour perception, objects that absorb and reflect light differently, and how different languages shape the conceptualisation - and therefore perception - of colour, is how colour emerges. Intra-action of colour acknowledges the fact that colours do not exist in isolation and do not preexist their relationships, but rather emerge through dynamic intra-relations. Each *Chroma Calls* sculpture is a new entangled reconfiguration of the world. Colour acts as a crucial point of each entanglement. Thus, the colour of the sculptures was generated through a series of more-than-human entangled practices including but not limited to: art history, art practice and artistic imagination, avian evolution of the multiple bird species, scientific and technological advances necessary for the production of associated materials, ecologically aware practices, colour theories, colour perception, evolution of tree species, and canal building practices.

At a simple level, the sculptures might be considered as imperfect representations of the colours of the birds. They are more than this, however. Their presence in the natural environment becomes the lens and locus of different ways of experiencing colour in intra-action in that particular environment. The sculptures reveal the differences, and these differences are crucial. Birds' colouration is infinitely complex, developed over 150 million years of evolution, long before the first human came to be, a mere two million years ago. What might seem at first as highly imperfect iterations of the colours of the birds is in fact a demonstration of the differences that come in at every level of the creation of the sculptures, thus revealing all the agencies that took part in their becoming. As the artist, I saw and defined the specific combinations of colours for *Chroma Calls* differently to how other human participants see them, as well as how bird species would see them. Additionally, each individual of a bird species will have variation in their coloration, which appears differently in different light conditions and different environments. Furthermore, the production of the specific paint, and the choices of colours selected also played their part in the creation of the sculptures. Through the prominent insertion of colour through sculpture within the environment, the place is revealed to an observer more fully as the myriad of colours and the multiplicity of forms of life that comprise it.

Accromatising to Place through Sculpture

I propose the concept of *'accromatising'* as a practice of entering into a deeply entangled way of being and sharing places with human and nonhuman others. Derived from 'acclimatising', meaning the process of becoming more accustomed or adjusted to new conditions or circumstances, 'accromatising' is defined by developing gradual attunement towards a place through colour. It is a practice whereby we learn to look deeply into our surroundings, developing a different way of responding to, and being responsible for those surroundings, via colour.

Similar to acclimatising, the process of accromatising points to gradually coming into, or rediscovering the state of being in tune with the environment. Although rather than the conditions themselves being new, what is new is the way we regard our engagement with colour in the surrounding environment, or rather our intrinsic constitutive part of it, together with many others. The more time I spent on the canal, immersed in research, the more I became attuned to the colours of the place. At some point during the installation, I became guided by the canal birds, whose presence inspired the possible locations for the sculptures. The exuberance of birds' colours, pulsating in a lively dance within the colours of the trees, flowers, each other, and everything else in the environment, including humans, is the radiance of life revealing itself through colour. When one is captured by the brilliance of living colours intra-acting, along with the delight of the experience of colour, inherent knowledge is made explicit, taking one in a chromatic embrace of deeply entangled relationships. Simply taking notice of colours, in passing, is not sufficient; it is the active and ongoing training of our chromatic ‘muscle’ – accromatisation – that is necessary in order to arrive at the experience of colour in its intra-action and respond: responsively, ethically, and justly.

Art practice presents an abundant toolkit of possibilities for entering such entangled, and therefore responsive and responsible, ways of being in the world. In Chroma Calls, I use colour in sculpture as a practice and experience of tuning into the natural environment, through the process of accromatisation. The focus on colour is not arbitrary: the very nature of colour enfolds relationality, making it, as Albers argued, art's most relative medium. My desire to create sculpture is a desire to entangle, with sculpture becoming a meeting point at which human and nonhuman come together in a new configuration. This is a process of attuning and inviting others to attune alongside us.

Ethical Colour

A question of ethics runs through both Barad’s and Albers’ approaches: ethics is an integral part of being in the world for Barad and, for Albers, aesthetics was ethics. Art practice to me is ethical in the sense that it acts as a proactive practice of growing responsibility for this ethical way of being. By responding to and through colour, I immerse myself into the deeply entangled nature of the world. I have termed my process of deep immersion through colour ‘acchromatisation.’ Colour in itself, then, can be conceived of as ethical. By attending to colour within our environment, acknowledging the differences in how it might appear to different participants in all possible conditions and configurations, we become responsible. Colour points to and acknowledges the differences that matter. Barad promotes an ‘ongoing practice of being open and alive to each meeting, each intra-action, so we might use our ability to respond, as our responsibility, to help awaken, to breathe life into ever new possibilities for living justly. The world and its possibilities for becoming are remade in each meeting.’ (Barad, 2007: X) We carry responsibility for sharing places chromatically: every blink of an eye, every turn of our head, offers a new chromatic configuration of the world in its becoming, and is a re-configuring of what matters, and the response and responsibility that comes with it. For Albers too, colour is ethical: ‘I've handled colour as a man should behave. You may conclude that I consider ethics and aesthetics as one.’ (1994) Colour calls for response, it entices, lures, and cajoles; rather than looking at it superficially, it is important to see into colour, all that is absorbed and reflected, diffracted and refracted, and begin to develop an ongoing practice of tuning into the full spectrum of its dynamic entangled intra-actions.

Developing this chromatic ‘muscle’, paying attention, and acting upon those calls responsibly, can lead to a more ethical human existence in a more-than-human world.

Conclusion

Art practice presents a toolkit of possibilities for developing a practice of tuning in, or accromatising, as well as inviting others – human and nonhuman – to tune into the experience. Approaching colour as intra-action, then, presents a more engaged, entangled, and inclusive way of being in the world and thinking about colour. Colour opens up a powerful entryway into this different way of being and sensing. It is capable of what Barad calls 'cutting things together and apart' (Barad, 2007: 179); of coming together, yet at the same time noticing the differences, and acting upon them responsibly.

Colour is not a by-product or add-on to life, but an essential part of it, woven tightly and inextricably into its very fabric. It is not incidental, but a crucial materialisation of millions of years of entangled evolutionary processes. The very presence of colour and its deeply relational nature calls for response and responsibility. The artwork *Chroma Calls* shows colour can be used as an entryway into a more entangled and responsible way of sharing places with humans and nonhumans, with art practice offering a platform for merging a range of disciplines to develop awareness of the environment we are part of, with its myriad intra-acting agencies.

Acknowledgements

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References

Albers, J. 1963. *Interaction of Color*. New Haven Connecticut: Yale University Press.

Albers, J., and P. Overy. 1994. *Josef Albers: A National Touring Exhibition from the South Bank Centre* 1994. London: The Centre

Barad, K. M. 2007. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham, North Carolina: Duke University Press.

Environmental color mapping case study: Uramanat region, Iran

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Abstract

Color plays a key role in environmental assessment. In this context, environmental color contributes to judgements about environmental aesthetics, visual amenity, and congruity. Lynch suggests that environmental color also contributes to Imageability, a term he coined to refer to the qualities inherent in a specific environment that gives it a high probability of evoking a strong image in any given observer. Using a case study approach, the aim of this research was to use environmental color mapping to investigate architectural and contextual color in Sherkan, a village located in the Uramanat region of Iran. This region has recently been listed as an important cultural site on the UNESCO World Heritage List. In this region, locally sourced construction materials often feature in the built environment, and this has contributed to a high degree of visual compatibility with the natural environment. Key outcomes from this study found patterns of color similarity as well as color difference in the colors of the built environment and the village context. It is suggested that patterns of color similarity (at the macro scale) in tandem with color differences (at the micro scale) specific to Sherkan village have a positive impact on environmental assessment and evaluation overall.

Keywords: *Environmental color design, environmental color mapping, Iranian architecture, historic architecture, UNESCO World Heritage List.*

Research context and aims

It is acknowledged that color contributes to environmental aesthetics, visual amenity, and congruity in urban settings. Exploring the impact of color in this context often involves environmental color mapping studies, the outcomes of which are examined to evaluate architectural color and contextual color, and the roles that these may play in respect to environmental assessment.

However, environmental assessment is a complex process and color is just one of a number of different elements that are considered to influence judgements about visual quality in terms of landscape and environmental assessment (Nasar, 1992). In respect to environmental aesthetics, color is one of a number of attributes deemed to influence aesthetic response as well as cognitive judgements relating to the 'fit' or congruity between a building and its context (Polakowski, 1975; Wohlwill & Harris, 1980; Groat, 1992; Urland, 1997; Unver & Ozturk, 2002; O'Connor, 2011). Research indicates that judgements about congruity are not necessarily predicated on specific types of colour constructs commonly found in planning policy such as 'analogous colour' and 'contrasting colour', and it is acknowledged that diversity in respect to responses to colour within this context exists (O'Connor, 2008).

In respect to environmental assessment, Lynch noted that positive response to environmental color in conjunction with form and texture in this context can lead to *Imageability* of a particular location, a term he coined to refer to the qualities inherent in an environment "that gives it a high probability of evoking a strong image in any given observer" (Lynch, 1960, p62). Locations characterized as having *Imageability* include Burano and the Cinque Terre region of Italy as well as Île de la Cité, Paris. However, color is not a consistently similar element across these different locations; that is, some locations feature contrasting colors and others, analogous colors, or a mix of various color relationship constructs. Therefore, *Imageability* can vary considerably in terms of environmental color depending on location.

The aims of this research project were to firstly investigate and analyze the color characteristics within a specific location within the Uramanat region, Iran. A secondary aim was to provide documentation of the environmental color palette evident in architectural design of Sherkan village and finally, to explore the role that environmental color may play in respect to the notion of *Imageability* of the case study location.

Methodology

This research involved cross-cultural collaboration and the application of environmental color mapping within the context of a case study that focused on Sherkan, a village in Uramanat region. This region was selected by one of the research collaborators who is familiar with the region in Iran and photographed the village. To address the aims of this research, both architectural color and contextual color apparent in the case study location of Sherkan village were investigated.

The photographs taken by the collaborator familiar with the village were used to examine and color, map the color data evidently identify, examine, and analyze color data. Photographs were uploaded to Adobe Photoshop evident in the village. In conducting the environmental color mapping study, one research collaborator in Iran collected and recorded color data at Sherkan village. The resulting color data was collated and then reviewed and assessed by both collaborators. Outcomes from the environmental color mapping study indicated patterns of color similarity and color difference at both the macro scale and the micro scale, and these in turn were examined and analyzed.

Case study: Sherkan village, Uramanat region, Iran

The subject of this case study, Sherkan village in the Uramanat region of Iran, is a location that can be characterized as having a strong degree of *Imageability*. Specifically, this region features centuries-old traditional architecture nestled within a landscape that both reflects and enhances the architecture of the region. To place this region in context, Iranian architecture is characterized by a long and ancient history characterized by architectural styles and structures that are strongly associated with Iranian culture. This rich history has long been considered unique for a variety of reasons and as a result, has featured in numerous publications including *Persian architecture: The triumph of form and color* plus *Iran: Past, Present, Future* (Pope, 1965; Hensel & Ghaleghi, 2012).

Across the Uramanat region, locally sourced construction materials are a predominant feature in the built environment, and this has contributed to strong patterns of similarity and visual congruity with the natural environment (Beazely & Harveson, 1982). It is acknowledged that architectural color contributes to a high level of visual congruity and judgements of harmony between the built and the natural environment, and it is likely that this has contributed to a certain extent to the region's recent listing as an important cultural site on the UNESCO World Heritage List (UNESCO, 2021).

Environmental color mapping

The methodology applied in this case study was informed by previous similar studies. Specifically, studies by Lenclos and Lenclos (2009), Foote (1983), Iijima (1997), Porter (1997), Hee Young 2007), O'Connor (2006, 2009), and Angelo and Booker (2018).

The 'geography of color' represents an environmental color mapping process pioneered in the 1960s by Jean-Philippe Lenclos and Dominique Lenclos. Their early studies focused on identifying and analyzing the colors evident across regions of France, including natural pigments found in each region and colors evident in the built environment. After collecting color samples, these were separated into two color palettes of each environment: 'general palettes' and 'dot palettes'. General palettes featured surfaces such as walls, floors and roofs, and dot palettes featured small scale details and surfaces such as doors, window frames and shutters. Lenclos & Lenclos also examined the color palette of the natural environment: vegetation, mountain slopes, hills, water, and sky surfaces.

Subsequent authors including Foote and Iijima followed a similar methodology to Lenclos and Lenclos, with Porter applying the term 'environmental color mapping' to the methodology. O'Connor subsequently incorporated digital technology, using digital photographs and Adobe Photoshop software for the purpose of examining and identifying color data.

This research followed a similar methodology and used a digital camera to capture color data. The relative remoteness of Sherkan village underpinned the use of a digital camera and Adobe Photoshop software was used to isolate and identify color data in pixelated imagery. O'Connor (2006, 2009) noted that this digital method has the capacity to identify color data using common color identification coding systems including Hex codes and RGB codes which can be translated into other color notation systems such as NCS. While there are some drawbacks to the use of digital technology identification of color samples, the identification process has been found to be equivalent and relatively accurate to the manual method. In addition, digital technology allows for the communication as well as archiving of color data across multiple software platforms and applications.

Environmental color mapping: Sherkan village

The first stage involved capturing a viable photograph of Sherkan village in Summer in its mountain location, in good light and without extraneous shadows or details. Several photographs were taken, and one was selected as it was the most representative of the village. Using digital technology and Adobe Photoshop software, the photograph was then used to identify colors by pixel, as illustrated in Figure 1. Using the zoom function, color data was identified at an almost microscopic pixel level.

Figure 1. Stage one: Environmental color mapping of Sherkan village, Uramanat.

The next stage involved focusing on six separate sections of the key photograph. Using these six cross sections, the color data evident in the built environment and the natural environment were investigated and examined. Color data was identified at the macro scale in terms of walls, roofs, and exterior surfaces (general palette) and at the micro scale on the doors window frames and shutter (‘dot’ palette). In addition, the color data in the natural environment was also identified.

Built Environment (Micro Scale)

The colors of the built environment at the micro and macro scale were identified and recorded separately using RGB color notation. At the micro scale, all target samples were zoom-isolated and the colors identified and recorded, as illustrated in Figure 2.

Figure 2. Color mapping of Sherkan village at the micro scale.

Built Environment (Macro Scale) and Natural Environment

At the macro scale, all exterior walls, surfaces, and roofs of the built environment were zoom-isolated, identified, and recorded. These elements featured construction materials (stone) sourced from the surrounding natural environment and elements within the natural environment including vegetation were zoom-isolated, identified, recorded, and clustered by hue as per Figure 3.

(RGB)			
216-200-168		144-136-120	
208-192-160		128-120-104	
200-184-144		120-112-96	
200-184-152		152-136-136	
192-176-144		144-128-128	
184-168-136		136-120-120	
176-160-128		128-120-120	
168-152-120		120-112-112	
184-176-160		136-112-112	
176-168-152		128-112-112	
168-160-144		120-104-112	
160-152-136		120-104-104	
152-144-128		112-96-104	
168-160-136		112-104-104	
160-152-128		112-96-96	
160-152-120		104-96-96	
152-144-120		104-88-88	
152-144-112		96-88-88	
144-136-104		88-80-80	
136-128-112		80-64-64	

(RGB)			
160-168-88		96-120-48	
168-168-96		96-112-40	
160-160-80		96-120-56	
144-152-88		96-120-72	
144-152-80		80-104-40	
136-152-72		96-112-64	
128-144-56		88-104-64	
128-136-56		72-96-40	
120-136-56		80-96-56	
144-144-104		80-104-64	
128-136-80		72-96-64	
120-136-72		64-88-40	
12-128-56		56-80-40	
112-128-80		64-80-56	
88-112-40		56-72-40	

Figure 3. Color data of the built environment of Sherkan village and the natural environment clustered by hue.

Analysis and discussion

Analysis of the color data recorded for Sherkan village revealed a strong pattern of similarity between the colors of the exterior of the built environment (macro scale) and the colors of the stone and timber found in the natural environment. These colors feature variations of light-toned sandy brown and muted ochre hues plus tinted, greyed, and darker shadow variations of these hues. The pattern of color similarity evident in the buildings of Sherkan village and its natural stone surrounding make it somewhat difficult to distinguish between the built and natural (stone) environment.

Analysis of the predominantly painted wood doors indicate an array of colors from white and cream through to variations of brown hues, plus variations of blue, turquoise, and green hues. Analysis of the windows indicate that the painted surfaces of the windows are predominantly blue, cyan, green, white plus brown hues. Some window frames are made of metal and exhibit grey hues.

In addition, the vegetation found in the natural environment features an array of yellowish greens and mid greens with little variation in terms of tonal value.

However, this relatively limited color diversity likely depends to a certain extent on rainfall and seasonal changes.

Figure 4 features a summary of color data identified and recorded from Sherkan village. This color data has been clustered in four groups. Firstly, the colors found at the micro scale (doors and window frames). Secondly, exterior surfaces, walls, and roofs; followed by a cluster of colors identified in the stone and timber of the natural surroundings. Finally, a cluster representing the natural vegetation surrounding Sherkan village.

Figure 4. Color data of the micro and macro elements of the built environment and the natural environment of Sherkan village clustered by hue.

It is suggested that these patterns of color similarity in tandem with color differences that are specific to Sherkan in Uramanat, Iran, have an impact on the environmental aesthetics of the village. Strong levels of analogous colors between the built environment and the location appear to contribute to strong visual congruency of the village buildings. This degree of visual congruity is enriched by the relatively restrained occurrence of contrasting color details that occur at the micro scale. It is further suggested that the color palette of Sherkan village contributes to a high degree of *Imageability* of the site. The mix of predominantly analogous colors plus contrasting color details also adds a sense of 'visual richness' of Sherkan village and likely contributed to the region's inclusion on the UNESCO World Heritage List.

References

Angelo, K. & Booker, A. 2018. *S>C – Proposing a formula for harmonic urban colour composition.* In AIC 2018: Colour and human comfort. Proceedings of the conference of the International Colour Association, Lisbon, Portugal.

Beazley, E. & Harverson, M. 1982. *Living with the Desert: Working Buildings on the Iranian Plateau*. New Jersey: Warminster, Aris & Phillips.

Bentley, I., Alcock, A., Murrain, P., McGlynn, S., & Smith, G. 1985. *Responsive environments: A manual for designers*. London: The Architectural Press.

Craik, K.H. & Feimer, N.R. Environmental assessment. 1987. D. Stokols and I. Altman (Eds.) *Handbook of environmental psychology*. New York: John Wiley and Sons.

Foote, K.E. 1983. Color in Public Spaces: Toward a Communication-based Theory of the Urban Built Environment. Chicago: University of Chicago.

Groat, L. 1992. Contextual compatibility in architecture: an issue of personal taste?, in: J. L. Nasar (Ed.) *Environmental Aesthetics: Theory, Research and Application*. Cambridge: Cambridge University Press.

Hee Young, J. 2007. Case Study on Urban Street Environmental Color Planning Method for Improving the Image of City Environment. Seoul: Ewha Womans University.

Hensel, M. and Gharleghi, M. 2012. Iran: Past, Present, and Future. *Architectural Design Magazine*, Profile No 217.

Iijima, S. 1997. Cross-cultural color differences of commercial facility between Great Britain and Japan, Bulletin of Okayama Marketing University, 33(2): 39–51.

Lenclos, J. P. 2009. The geography of colour. In T. Porter & B. Mikellides (Eds), *Colour for Architecture Today*. New York: Taylor & Francis.

Lynch, K. 1960. *The image of the city*. Cambridge, MA: MIT Press.

Nasar, J. L. (Ed.). 1992. *Environmental Aesthetics: Theory, Research and Application*. Cambridge: Cambridge University Press.

O'Connor, Z. 2006. Environmental colour mapping using digital technology: A case study. *Urban Design International, 11 (1),* 21-28.

O'Connor, Z. 2008. Façade colour and aesthetic response: Examining patterns of response within the context of urban design and planning in Sydney. PhD thesis, University of Sydney. https://ses.library.usyd.edu.au/handle/2123/4093

O'Connor, Z. 2009. Digital Colour Mapping. In T. Porter & B. Mikellides (Eds.), *Colour for Architecture Today*. New York: Taylor & Francis.

O'Connor, Z. 2011. Façade colour and judgements about building size and congruity. *Journal of Urban Design, 16 (3),* 397-404.

Polakowski, K. J. 1975. Landscape assessment, in: E. N. Zube, R. O. Brush & J. G. Fabos (Eds) *Landscape Assessment: Values, Perceptions and Resources*. Stroudsberg, PA: Dowden, Hutchinson, and Ross.

Pope, A. U. 1965. *Persian architecture: The triumph of form and color.* New York: George Braziller.

Porter, T. 1997. Environmental colour mapping, *Urban Design International*, 2(1): 23–31.

Urland, A. 1997. Attempt at finding the objective factors underlying subjective aesthetical evaluations of exterior architectural colour schemes - an experimental research study. Paper presented at the Colour Report: Colour and Psychology F50, AIC Interim Meeting, Gothenburg.

Unver, R. & Ozturk, L. D. 2002. An example of facade colour design of mass housing. *Color Research and Application*, 27(4), 291–299.

UNESCO. 2021. *Cultural landscape of Hawraman/Uramanat*. https://whc.unesco.org/en/list/1647/ Accessed on July 30, 2021.

Wohlwill, J. F. & Harris, G. 1980. Response to congruity or contrast for man-made features in natural recreation settings. *Leisure Science*, 3(4), 349–365.

Poster Papers

Comparative study of the psychological effects of the spectral distribution of daylight and LEDs in office spaces

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Abstract

The purpose of this study is to clarify whether it is possible to obtain the same psychological and physiological effects as daylight by reproducing it with LEDs. In this paper, we focused on the spectral distribution among the elements of daylight. The experiments were conducted in a controlled experimental space imitating an office space, and psychological evaluations of the daylight were compared with that of LEDs which has different spectral distribution and the same correlated colour temperature (hereinafter called "CCT") and illuminance as daylight. As a result of the experiments, there is no difference in psychological evaluation if the chromaticity is close even if the spectral distribution is different, and the effect of the difference in chromaticity between the light sources is more likely to appear in the low illuminance condition. Therefore, when reproducing daylight by LEDs, it would be necessary to consider the chromaticity in addition to the CCT and illuminance.

Keywords: *daylight, LED, spectral distribution, CCT, illuminance*

Introduction

Daylight has the effect of improving health and comfort (Zadeh et al. 2014), however it is not always possible to provide sufficient daylight to the people in closed spaces or office workers who are seated away from the window. Since exposure to daylight has positive effects, there will be demand for daylight-like lighting in such spaces. Recently, LEDs which can reproduce the same CCT, intensity and their fluctuation as daylight in office spaces have been developed, and by using such lighting, we can obtain the effect of daylight more easily. To reproduce daylight efficiently with LEDs, it is necessary to clarify the essential elements. The purpose of this study is to verify the effect of each element of daylighting from the window, such as illuminance, CCT, their fluctuation, spectral distribution, and view. The experiments were conducted in a controlled experimental space imitating an office space to examine the psychological and physiological effects of daylight and LEDs. In this paper, we focused on the spectral distribution. The psychological effects of different spectral distributions were examined by comparing the experimental results of daylight and LEDs which have the same vertical illuminance and CCT as daylight.

Experimental Method

Two types of experiments were conducted to compare daylight and LEDs. The points common to both experiments are described below.
The experiments were conducted in the same experimental space (W: 2700 mm × D: 2700 mm × H: 2200 mm. Reflectance: floor 4.5%, ceiling and wall 74%) shown in Figure 1. The diffusion filter was attached to the opening on the south wall (W: 1200 mm x H: 970 mm) to create the artificial window to irradiate lighting. The total number of subjects were 18 students with normal colour vision (confirmed with Ishihara test).

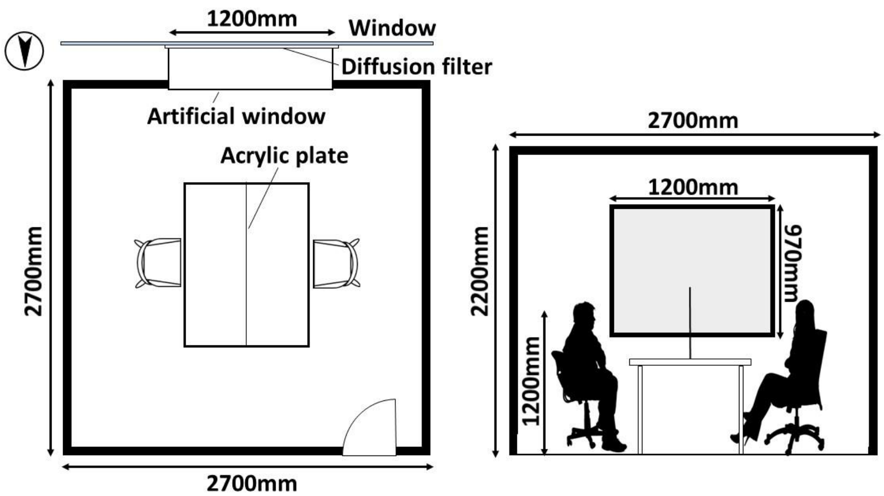

Figure 1. The plan and the cross section of the experimental space in the experiment of daylight.

The experimental procedure was as follows. First, the subjects put on the eye mask and adapted to darkness for 6 minutes. Next, after removing the eye mask and adapting to the lighting conditions for 2 minutes, they worked on the psychological evaluation, 8-minute task, and the psychological evaluation again. Finally, they performed dark adaptation and the above process was repeated for 3 phases in one experiment, which was for about 80 minutes in total. During the experiments, the wearable heart rate sensor was used to measure the physiological effects of lighting. The psychological evaluation examined a total of 55 items regarding light environment, atmosphere, fatigue, and workability. As for the 8 minutes task, we chose "Mind Mapping" (associative work of words) and "Senryu "(creation of short poems) that require creativity, which is important for office workers.

The experiment of daylight

First, the experiment of daylight was conducted from August to November 2021 by setting the artificial window closer to the actual window as shown in Figure 1. During the experiment, the vertical illuminance, CCT and spectral distribution at the eye level (H: 1200mm) were measured at 15-second intervals with CL-500A (KONICA MINOLTA) and luminance distribution was also measured at 5-minute intervals with CCD camera system (camera: Baumer TXG 13c, fisheye lens: FUJIFILM FE185C046HA-1 and programme: L-CEPT by Building Research Institute). Since daylight fluctuates, we need to select the data which had relatively constant CCT and illuminance to compare with the experiment of LEDs without fluctuations. The data in which fluctuation of the illuminance and the CCT during the exposure of lighting met the standard (illuminance: within the average ± 25%, mired: within the average ± 10) were regarded as non-fluctuating data. As a result, we obtained more than ten samples in particular range, whose average CCT and illuminance were about 5500K 120lx, 5500K 300lx, and 5000K 2000lx, and those three conditions were selected as the conditions for comparison with LEDs.

The experiment of LEDs

After the experiment of daylight, the experiment of LEDs was conducted from December 2021 to February 2022 by installing LED fixtures, 300mm behind the artificial window. Two types of fixtures, LED A and LED B, each of which has different spectral distribution were used in the experiment. The lighting conditions were determined as shown in Figure 2, based on the experiment of daylight. In one experiment, subjects were exposed to three conditions.

The results of psychological evaluation between light sources at the same vertical illuminance and CCT were compared. The spectral distribution and u'v' chromaticity of each condition is shown in Figure 3.

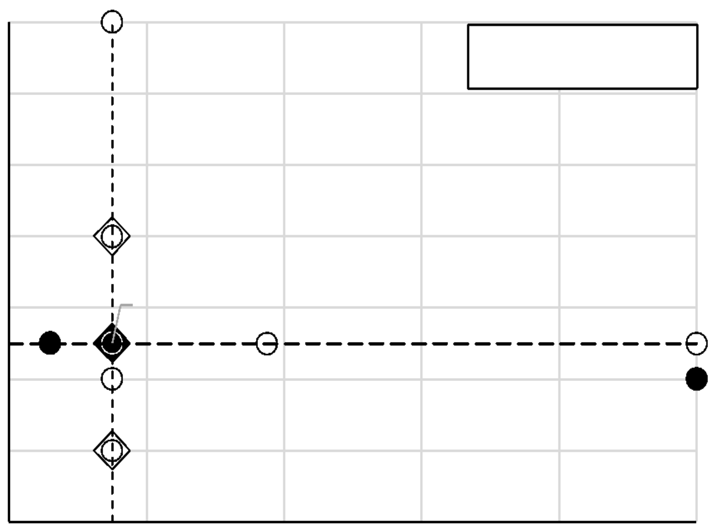

Figure 2. The vertical illuminance and CCT at the eye level under the lighting conditions of LED A and B. Black plots show conditions for comparison with daylight.

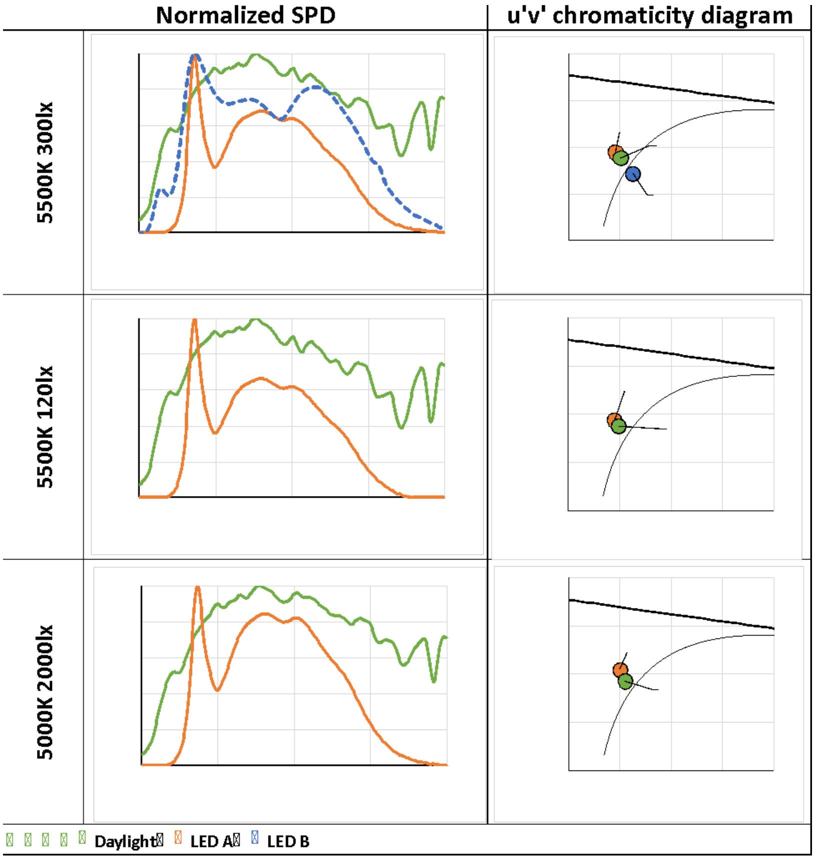

Figure 3. The spectral distribution and u'v' chromaticity of each lighting condition.

Result and Discussions

Comparison of psychological evaluations of Daylight and LEDs

Figures 4-1 and 4-2 show the results of psychological evaluation after an 8-minute task for daylight and LED A and B under the conditions of 5500K 300lx and 5500K 120lx. In this paper, the items of psychological evaluation which have significant differences are mainly mentioned.

Under the conditions of 5500K 300lx, LED B was evaluated brighter on the surface of desk than daylight (** p = 0.022) and LED A (* p =0.072) as shown in Figure 4-1. In the items of atmosphere, LED B was evaluated as having a significantly brighter atmosphere than daylight (* p = 0.062) and LED A (* p = 0.089). There was no significant difference between daylight and LED A, and other items were not significantly different between the light sources. The chromaticity of LED B is on the blue side of the blackbody locus, while the chromaticity of LED A is closer to that of daylight as shown in Figure 3. According to this, there is the possibility that the difference in chromaticity may have caused a difference in the evaluation of brightness.

Under the conditions of 5500K 120lx, there were significant differences between daylight and LED A in the items of atmosphere, such as stability(** p=0.021) and warmness(**p=0.026), and the daylight was evaluated more positively than LED A as shown in Figure 4-2, while there was no significant difference between them in the items of brightness. As shown in Figure 3, the chromaticity of LED A is farther from the blackbody locus than daylight, so this may have affected the evaluation of the atmosphere. However, the chromaticity of the 5500K 120lx is almost the same as that of the 5500K 300lx condition, where there was no significant difference in psychological evaluation between daylight and LED A. The influence of the difference in chromaticity may change depending on the illuminance level.

Under the conditions of 5000K 2000lx, there was no significant difference between daylight and LED A in all items. The chromaticity of LED A is farther from the blackbody locus than daylight, and the difference between daylight and LED A is larger under the conditions of 5000K 2000lx compared with the conditions of 5500K 300lx and 5500K 120lx. Therefore, there is the possibility that the influence of the difference in chromaticity is small under high illuminance conditions.

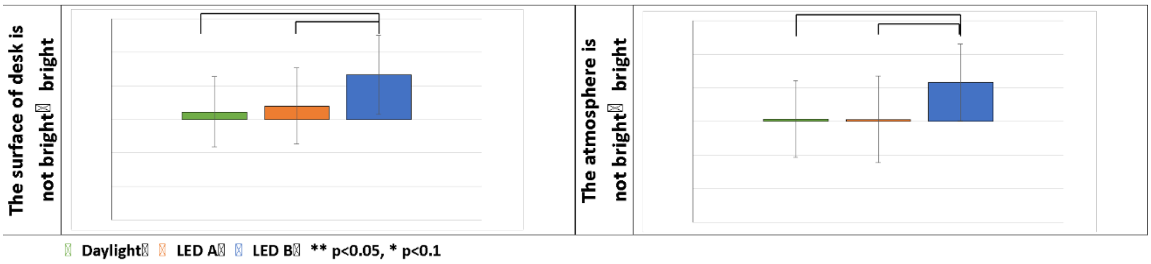

Figure 4-1. The results of the psychological evaluation under the condition of 5500K 300lx.

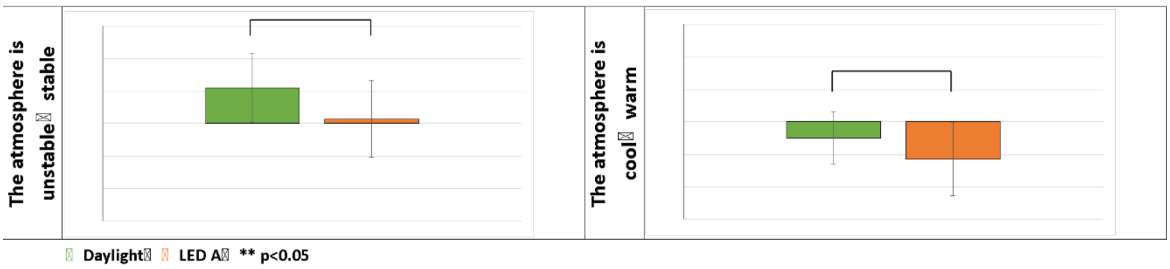

Figure 4-2. The results of the psychological evaluation under the condition of 5500K 120lx.

Figure 5 shows the results of the satisfaction level with each lighting condition. The satisfaction level with lighting was positive under all conditions. Daylight has higher satisfaction than LED A (*p=0.062) under the condition of 5500K 120lx. There is no significant difference between light sources under the conditions of 5500K 300lx and 5000K 2000lx.

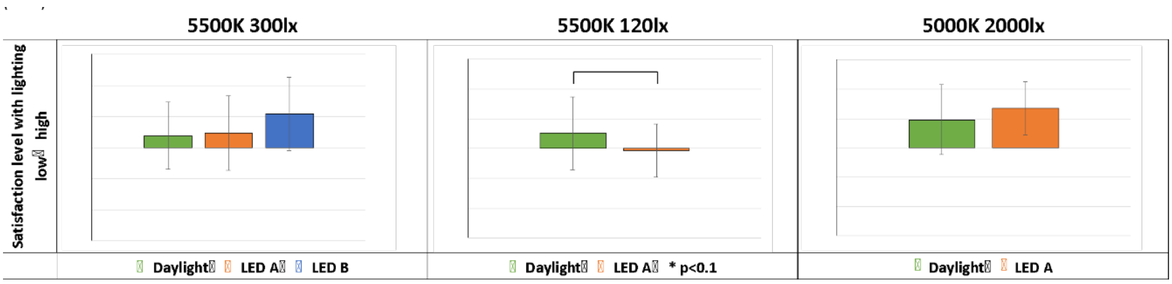

Figure 5. The results of the satisfaction level with each lighting condition.

Comparison of luminance distribution of Daylight and LEDs

The luminance distributions of the two conditions (5500K 120lx,5500K 300lx) which have significant differences between daylight and LEDs in the psychological evaluation were checked to confirm the differences. Figure 6 shows an example of the luminance image and area where the average luminance was calculated. Figures 7-1 and 7-2 show the calculated average luminance under each lighting condition.

As for the 5500K 300lx condition, the average luminance of LED B which was evaluated brighter than other light sources was the lowest among the three light sources in all areas. Therefore, it is unlikely that the difference in luminance distribution affected the evaluation of brightness.

As for the 5500K 120lx condition, the average luminance of LED A was lower than that of daylight in all areas. The balance of luminance distributions was not largely different. Considering that there was no significant difference in the evaluation of brightness, the difference between daylight and LED A in the atmosphere was not likely to be caused by luminance distribution but by chromaticity.

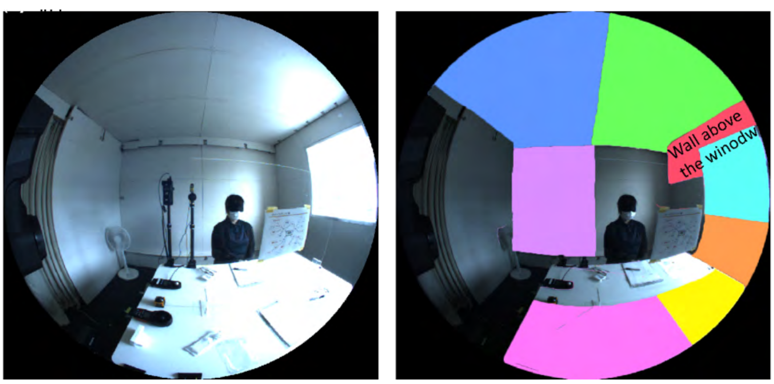

Figure 6. The example of the luminance image (a) and the areas where average luminance was calculated (b). These were taken from the subject's eye level at the west side under 5500K 300lx condition of daylight.

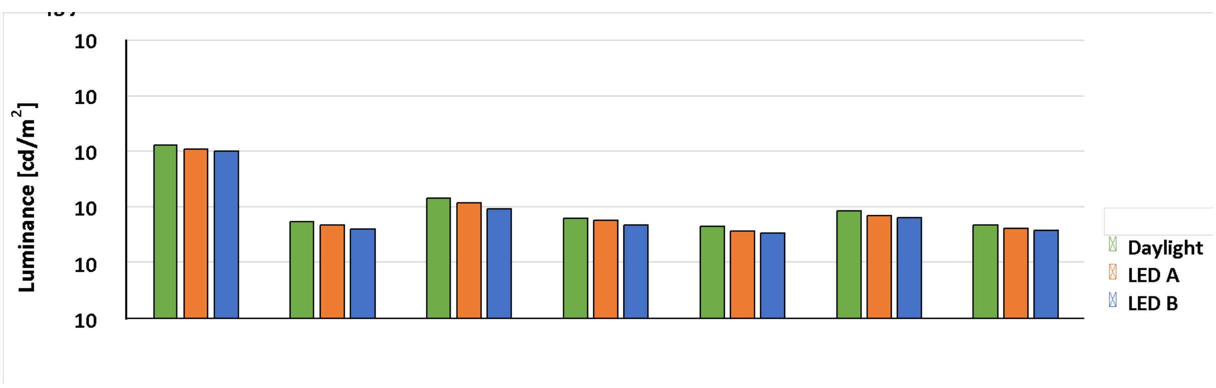

Figure 7-1. The average luminance of each part of the experimental space under the conditions of 5500K 300lx.

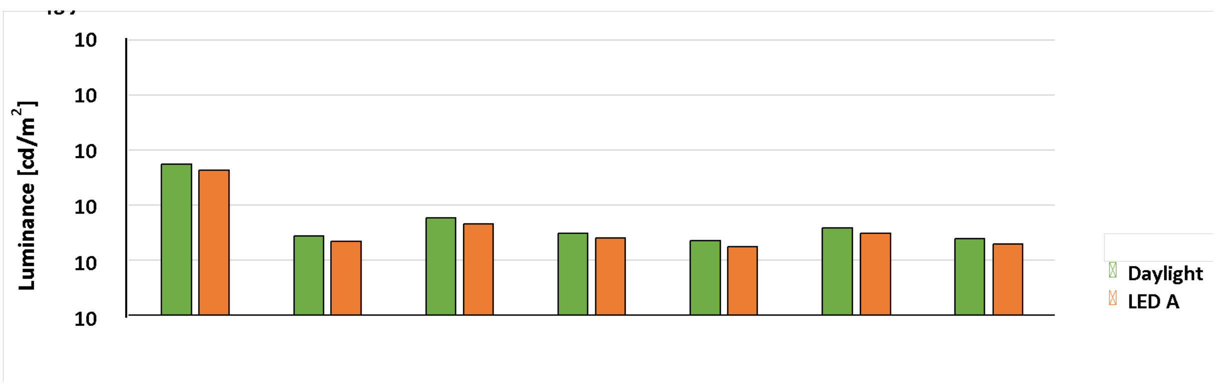

Figure 7-2. The average luminance of each part of the experimental space under the conditions of 5500K 120lx.

Conclusions

In this paper, we examined the effect of the difference in spectral distribution on psychological evaluation under daylight and LEDs. We examined three conditions that can be compared between daylight and LEDs at the same CCT and illuminance level. The result shows that if the chromaticity is close, there is no difference in psychological evaluation even if the spectral distribution is different. The effect of the difference in chromaticity is likely to appear when it is at a lower illuminance level. Therefore, to reproduce the daylight with LEDs, it is necessary to consider the chromaticity in addition to the CCT and illuminance. In the future, we will compare the results of the physiological effects of daylight and LEDs. We will also study fluctuations in illuminance and CCT and view as other elements of daylight to efficiently obtain the effect of daylight by LEDs.

References

Zadeh, R.S., M. M. Shepley, G. Williams, and S. S. Chung. 2014. The impact of windows and daylight on acute-care nurses' physiological, psychological, and behavioral health. *HERD* 7(4):35-61.

Color choice in providing a restorative interior space: a Pilot Study

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Abstract

The main aim of this study is to explore color choice and eventually, patterns for a restorative classroom. To do so, ten interior design students, trained on the color application are asked to choose and "allocate" color in a classroom to provide restorative scenarios and other students (n=13) rated the environments by using the Perceived Restorative Scale, Personal Reactions, and Aesthetic Judgements. Users' ratings of restorative classrooms are compared with each other to determine which color choice enhances restorativeness.

As a result, the blue-green interior hues were the most proposed, followed by yellow, and orange. In addition, the first scenario which is a monochromatic color scheme composed of (RGB: 113, 133, 144), (RGB: 186,186,186), and (RGB: 147, 157,149) shows high score ratings when compared to other scenarios in terms of restorativeness and personal reactions. From a broad perspective, the study, which is a phase of undergoing research, is rather explorative research to contribute further to the knowledge gathered about indoor restorativeness.

Keywords: *Color, Restorative quality, Classroom*

Introduction

To the best of our knowledge, there is only one study on restorative quality in classroom spaces exploiting green color by incorporation of vertical green plants (Van der Berg, Wesselius, Maas, and Dijkstra, 2017). There is, however, no study of color choice applied to architectural elements concerning restorative quality. For definitional purposes, this exploratory study defines restorativeness as the quality of any environment described by using words like relaxing, recovering, contemplative or reflective, or the opposites tiresome, fatigue, and even arousing (See Hartig et al., 1997). It is measured with four psychological constructs such as being away, extent, fascination, and compatibility.

The particular position advocated here is that in undertaking a study of the restorative qualities in an actual indoor built space, where the color aspect should be studied. The restorative quality is crucial in decreasing cognitive loads (stress, anxiety, etc.,) in our demanding everyday life (Kaplan and Kaplan, 1989). In such a context, since we are spending most of our time indoors then how can we be restored in indoor spaces? If yes, then what aspect of the interior space triggers the restorative quality?

This study is carried out in a classroom space for a couple of reasons. First, according to Hartig et al., (1997) to get restored someone should be mentally fatigued beforehand. University students compared to the general population are experiencing higher rates of depression (Ibrahim et al., 2013) and they are exposed to a variety of uncertainties and responsibilities leading to study-related stress, family stress, financial stress, and personal stresses (eg., identity, social relationship, and living situations). Moreover, the learning environment is competitive and high academic expectations are influencing the student's quality of life (Peters and D'Penna, 2020). Secondly, this study ponders if restorative quality may alter the typical color narrative of a classroom environment where white dominates.

Experiment

This exploratory study is designed into two phases; the first phase produces restorative scenarios whereas in the second phase we collect subjective ratings using ZIPPERS Scale to measure Affection, Attentiveness, Sadness, Fear, Arousal, and Anger; the Perceived Restorative Scale (PRS) includes items of Being away, Compatibility, Fascination, and Extent; and Aesthetics judgments (Küller's Scale) including dimensions of complexity, pleasantness, unity, and closedness. The data obtained here provide information regarding the color choice and design for a restorative classroom.

Grouping 1	**Surface Colors Only**				
Naming of the scenarios	Monochromatic color scheme 1	Analogous color scheme 2	Analogous color scheme 3	Split complementary color scheme 4	Monochromatic color scheme 5
Proposed scenarios					
Grouping 2	**Various Composition on Surfaces**				
Naming of the scenarios	Complementary Color Scheme 6	Analogous Color Scheme 7	Analogous Color Scheme 8	Analogous Color Scheme 9	
Proposed scenarios					

Table 1. Scenarios of the color-choice proposal, their identification, and surface composition

Phase 1

Using colors to provide a particular place is not easy, specifically for public functions such as classrooms where different individuals occupy that space. In this phase, an actual classroom image was given to participants in terms of selecting colors in providing a restorative environment. The participants were informed of what restorative is, and they all had prior knowledge of color. The participants used Photoshop to manipulate the actual classroom (See Table 1). In addition, they were limited to applying no less than 3 colors (ex. on floor, wall, and ceiling). After collecting all scenarios, Adobe Color Wheel (See Table 2) is used to objectively identify each color.

	Floor	Ceiling	Wall	Color	C.No	Various composition on surfaces
1	186, 186, 186	186, 186, 186	113, 133, 134 147, 157, 149		3	No
2	159, 155, 118	92, 107, 100	129, 130, 132		3	No
3	no intervention	no intervention	42, 75, 140 40, 109, 116 49, 130, 106 150, 147, 53		4	No
4	52, 57, 76	52, 57, 76	90, 111, 138 149, 107, 159		3	No
5	83, 97, 124	178, 182, 194	178, 182, 194		3	No
6	no intervention	180, 127, 57	234, 232, 233 80, 131, 154		4	Yes
7	156, 143, 124	142, 137, 133	123, 123, 89 97, 89, 78 120, 89, 69		5	Yes
8	163, 159, 141	68, 89, 62 155, 174, 142	28, 38, 21 191, 134, 84		4	Yes
9	no intervention	198, 187, 148 198, 195, 185	105, 138, 109 172, 195, 174 198, 187, 148 198, 195, 185		4	Yes

Table 2. Color codes for each color-choice proposal

Phase 2

In this phase, we ought to compare the proposed scenarios concerning color choice based on the previous paradigms measuring personal reactions using ZIPER's scale, the Restorative Quality of the scenarios using the Perceived Restorative Scale (PRS), and the Aesthetic judgments using Kuller's scale. in a controlled Lab Environment. For definitional purposes, a scenario is a classroom environment referring to the proposals in the first phase. The study used a within-subjects design. Subjects (n=13) used a five-point Likert scale (eg., 1=not all, 5 = very much) to indicate how they felt and perceived the classroom environment. Again the classroom is familiar as a typical learning environment to the subjects. The participants rated each image separately. The whole survey lasted 15 minutes.

Before this, three experts were invited to assess and group the scenarios of the first phase based on the used color. The expert provided a detailed description of the used colors and grouped colors according to their design on surfaces. (See Table 1). A meeting was arranged with experts to have a unanimous naming and grouping In the end, the expert individually named the scenarios in terms of the color scheme (eg., Monochrome, analogous, etc.,). and grouped them into scenarios with 1) surface colors only (scenario 1- 5) and 2) various compositions on interior surfaces (scenario 6-9). The 10th scenario was not included since it was too bright.

Results

The initial question of this study was to check if there is any difference between the classroom scenarios, in terms of personal reaction to them, the restorative quality in the scenarios, and the aesthetic judgments. To answer this question we used One Way ANOVA Test and Kruskal Wallis H Test. Four items of the Perceived Restorative Scale were reversed and then summed into the total score to run the tests and check for any differences. No hypothesis or prediction has been forwarded. The results indicate a difference between scenarios (See Table 3). One Way ANOVA run for the ZIPPER's scale measuring personal reactions showed a difference between the 1st scenario and 2nd Scenario. The PRS scores are higher for scenarios 1,3,4,5,6. Between these scenarios, however, there is a statistically significant difference. For instance, according to the Kruskal Wallis H test there is a significant difference between images 1 and 2 (sig.=0.000<alpha=0.05) , images 1 and 3 (sig.=0.016<alpha=0.05) , images 1 and 4 (sig.=0.021<alpha=0.05) , images 1 and 5 (sig.=0.032<alpha=0.05) , images 2 and 6 (sig.=0.012<alpha=0.05). Whereas for Aesthetic Judgements, scenarios 6 and 8 have higher means when compared to other scenarios.

Dependent Variable	(I) Scenario	(J) Scenario		Mean Difference (I-J)	Std. Error	Sig.
TOTAL_Perceived Restorative Scale	Scenario 1 (monochrome color scheme) 	**2**		21.53846*	3.52646	.000
		3		16.23077*	3.89292	.016
		4		16.53205*	4.00653	.021
		5		13.15385*	3.44583	.032
	Scenario 2 	**6**		-17.15385*	4.09912	.012
TOTAL_Aesthetic Judgements	Scenario 2 	**6**		-3.84615*	1.04768	.043
	Scenario 4 	**6**		-3.51923*	.89763	.031
		8		-3.05769*	.81711	.043
TOTAL_Personal Reactions	Scenario 1 (monochrome color scheme) 	**2**		11.69231*	3.02664	.007

Table 3. Results from the test indicating the differences between scenarios

Discussion and Conclusion

In our multisensorial environment, color is a very powerful design element. Despite this fact, the indoor environment we occupy is a composite of many entities and layers and as such, it may influence how we perceive the space. Thus one of the main limitations of this research can be having many entities and layers. Throughout the analysis, there are existing conditions that may have influenced the results. For instance, the way how students use Photoshop can be a limitation too. It is assumed that differences arise based on which surface (wall, and/or floor, and/or ceiling) we are applying the color. Such a difference is observed in scenarios 1 and scenario 2. Also, there exists a difference between scenarios 1 and 3, 1 and 4, and 1 and 5 (See Table 1). In this case, the reason for such a difference can be the chroma intensity too. There can be no relevant interpretation for aesthetic judgments. There is a high score for both the 6th and 8th scenarios, which belong to the second group having various patterns(See Table 1).

In this research, however, different scenarios of the same classroom were produced and were rated in terms of their restorative quality, personal reactions, and aesthetics. The results showed a difference between them that needs a further investigation in terms of chroma intensity, which may influence the perception of the restorative quality.

Briefly, after the statistical tests and interpretations of the data we may say that:
(1) There is a higher frequency for blue-green hue choice as shown in the 1st phase (see Tables 1 and 2)
(2) The Restorative quality for a sample of (n=13) is higher in the 1st Scenario
(3) Personal Reactions for a sample of (n=13) are higher in the 1st Scenario (see Table 3).

Acknowledgment

The authors would like to thank all the undergraduate students of the Interior Architecture and Environmental Design Department who voluntarily participated in this survey and the three experts R.K, S.K, and I.Y who agreed to assess the scenarios.

References

Ibrahim, A. K., S. J. Kelly, C. E. Adams, and C. Glazebrook.. 2013. A systematic review of studies of depression prevalence in university students. *Journal of psychiatric research* 47, no.3: 391-400
Hartig, T., K. Korpela, G. W. Evans, & T. Gärling.. 1997. A measure of restorative quality in environments. *Scandinavian housing and planning research*, 14, no.4: 175-194.
Kaplan, R., and S. Kaplan. 1989. *The experience of nature: A psychological perspective*. Cambridge University Press.
Peters, T., and K. D'Penna.. 2020. Biophilic design for restorative university learning environments: A critical review of literature and design recommendations. *Sustainability*, 12, no.17: 7064.
Van den Berg, A. E., J. E. Wesselius, J. Maas, and K. Tanja-Dijkstra. 2017. Green walls for a restorative classroom environment: a controlled evaluation study. *Environment and Behavior*, 49, no.7: 791-813.

Intermediate and tertiary pigment colours: Mathematically 'why' they can't be the 'same'

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Abstract

Colour exists as visual, mathematics, logic, and language,defining life and living in fluidity. Within this fluidity dwells intermediate and tertiary pigment colours making their understanding and difference very difficult for its identity and separation in concept and visual property. This paper approaches these differential difficulties in both ideas, optical properties, and mathematics to show the differences between these two-colour concepts. The study concludes that in applying mathematical expansion and factorization, three pigment colours should be obtained as the equation's results to justify the third position concerning 'tertiary'.

Keywords: *Tertiary pigment colour, Intermediate pigment colour, Grouping like terms, Expansion, and Factorization*

Introduction

Intermediate and Tertiary pigment colours are ambivalent colours in art education's theoretical and practical study of colour. This paper deals with these pigment colours' ambivalence, complexity, and misinterpretation. The tertiary pigment colour formula needs a 'third' stage or step (variable) to tertiary the colour mixture. The study also challenges the theoretical approach to practicals in applying theory without physical materials (colours/hues).

Neighbouring Tertiary and Adjacent Intermediate Colour Pigments

Intermediate colours mean the colour between two colours or are the intermediary of primary and secondary. This paper calls these particular colours neighbouring tertiary or neighbouring intermediate colours based on their interpretation of mixing a primary colour and its neighbouring secondary colour and the staging process information or composition as the third stage or steps.

Intermediate and tertiary colours are products of a primary and adjacent secondary colours. For instance, mixing yellow with green yields yellow-green, Eiseman (2017) and Paterson (2004) says that the result of combining one of the primary colours with another of the secondary colours justifies the same use of adjacent and neighbouring colours. Opara & Cantwell (2014) added more confusion and difficulties distinguishing the two colours.

Neighbouring Tertiary Colours - Adjacent Intermediate Colours Formula

From the authors' definitions of adjacent intermediate and neighbouring tertiary colours, we can deduce that colours such as *Red-Orange, Blue-Green, Blue-Violet, Yellow-Orange, Yellow-Green, and Red-violet* from the adjacent intermediate and neighbouring tertiary colours. The formula we will work for may stand for these two-differential colour theories.

Therefore:

Red-Orange

Now let us expand (EXP) **Red-orange** into its primary constituent colours; (EXP) **Red-orange** = R + R + Y.
Now let us group like terms (GLT) of the expanded colours; R+R+Y = (GLT) = 2R + Y. **Blue-Green** = (GLT) = 2B + Y., **Blue-Violet** = (GLT) = 2B + R., **Yellow-Orange** = (GLT) = 2Y + R., **Yellow-Green** = (GLT) = 2Y + B., **Red-Violet** = (GLT) = 2R + B.

Primary colours must be named first, followed by secondary colours in naming intermediate colours. An intermediate colour's naming is based on the dominant colour or the repeated colour in the colour's composition 'and' shouldn't be used to separate the two colours, but rather should be called out by blurring one colour sound into the other.

Summing up the Formulas in Adjacent Intermediate Colours and Neighbouring Tertiary Colours

Neighbouring intermediate/ neighboring tertiary colour of Red- Orange = 2R + Y, Blue-Green = 2B + Y, Blue -violet = 2B + R, Yellow-Orange = 2Y + R, Yellow -Green = 2Y + B, Red -Violet = 2R + B.

Establishing a common Formula for Adjacent Intermediate Colours and Neighbouring Tertiary Colours

In the formulation of adjacent intermediate and neighbouring tertiary colours, it is realized that two colours repeated or dominated in the expansion and grouping of like terms. It is believed that the repeated colours (2R,2B,2Y) should be represented by '2x' and the single remaining colour (B, R, Y) should be represented by 'y'. So, the formula for this particular "tertiary colours of intense" also becomes 2x + y = Adjacent Intermediate colour or Neighbouring Tertiary colours or "Tertiary colours of intense."

Analysis/Interpretation of the Formula

Neighbouring tertiary & Adjacent intermediate colours = 2x+y.

'**2x**' represents two of any repeated primary colours to be added to the remaining primary colour (y). Then, 'y' becomes any different primary colour chosen differently from the two repeated primary colours (**2x**), and the two separated variables join with the plus sign (+).

Example:
Adjacent Intermediate/ Neighbouring Tertiary colour of Yellow- Orange = 2Y + R. So, 2Y + R becomes 2x + y = 2Y + R. Practically, the formula displaces the secondary colour. They have two same primary colours (2Y or 2B or 2R) plus another primary colour which establishes that neighbouring tertiary colours and adjacent intermediate colours have no 'third' colour or stage in their combination to be justified as tertiary colours.

Unique Tertiary Colours and Odd Intermediate Colours

The concept of odds/unique came from focusing on definitions from authors who stick to the differentiation of intermediate and tertiary colours as the mixing of primary and secondary colour without any common relation of hue among them. In this case, the odd primary and unique secondary colours should contain different properties of hues, making this concept the complement of primary and Secondary colours.

The formula for Unique Tertiary Colours and Odd Intermediate Colours

Here I decided to select a primary colour not found in a secondary colour. Then, I factorized it and checked if the formula could maintain three constituents of the primary colours with one repeated or dominant primary colour giving us a tertiary property of colour.

Unique Primary Colours are; Red, Yellow, and Blue, and Odd Secondary colours are; Green, Violet, and Orange. Let us expand (EXP) **Red and Green**, **Blue and Orange**, and **Yellow and Violet**, into its primary constituent colours and group the like terms (GLT) of the expanded colours.

Example: Red and Green
Let us expand (EXP) Red and Green into their primary constituent colours; (EXP) **Red and Green** = R + B + Y.

Therefore: **Red and Green, Blue and Orange**, and **Yellow and Violet** all equal R + Y + B, which can be group-like terms, now gives us the formula x + y + z.

The term "tertiary colour" is used to describe a colour combination of primary and odd secondary colours. In the formula, x + y + z = Red + Yellow + Blue, but now when we add all the colours such as Red, Yellow, and Blue, the result will be achromatic colour (Neutral colour).

Tertiary Colour: Two Secondary Colours Combination

In tertiary color, we say it is the process whereby two secondaries, like orange and green, are mixed. This thorough mixing of two secondary colours will distinguish between 'intermediate' and 'tertiary' definitions. The difference is also identifiable in their colour intensity. In intermediate colours, bright, pure colours are experienced, such as red-orange or blue-green. In the tertiaries, one will experience dull colours with names like olive or bronze (orange plus green), slate (Green plus violet), or Russet (Orange plus violet).

Tertiary Colour of two Secondaries Formula

Let us expand (EXP) **Citron** = Green and Orange, **Olive** = Violet + Green, and **Russet** = Violet + Orange, into its primary constituent colours, and group their like terms (GLT) of the expanded colours.

Example: Russet = Tertiary colour of Red,
Russet =Orange + Violet.
Now let us expand (EXP) Orange and Violet into their primary constituent colours; (EXP) = **Orange + Violet**= R + Y + R + B.
Now let us group like terms (GLT) of the expanded colours; (GLT)= R + Y + R + B = 2R + Y + B, therefore, **Russet = 2R + Y + B.**
I then conclude that, **Russet** = 2R + Y + B, **Citron** = 2Y + B+ R, and **Olive** = 2B+R+Y.

Standard Formula for Tertiary Colours of Two Secondaries

The formula for the tertiary colours of two secondary colours combined becomes 2c + y + x = Tertiary colour. The formula also shows that the 3rd stage of expansion or combination of colours should lead us to getting our three different primary colours back, but with one dominant primary colour.

Testify the Formula for Tertiary Pigment Colours with Two Secondary Colours Combination

Our formula now is **2c + y + x**. We are to substitute the three primary colours (R, Y, B) and not the three secondary colours because the formula is the composite of the combination of two secondary colours.

In the substitution, we are to alternate the colours to make sure that all the three colours have taken their turn as ‘2c’.

First Alternate = (R) Y and B,
Formula: 2c + y + x,
substitution: 2R + Y + B = Russet,

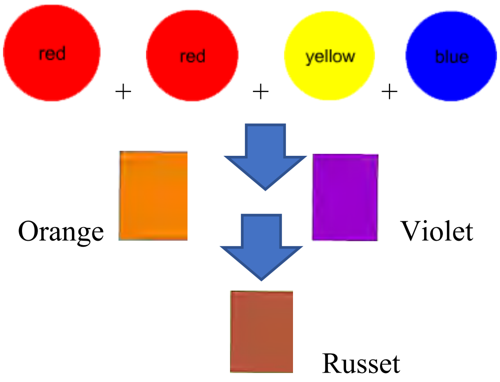

Figure 1. Combination: Tertiary Red (Russet).

Second Alternate = (Y) R and B,
Formula: 2c + y + x,
Substitution: 2Y + R + B = CITRON,

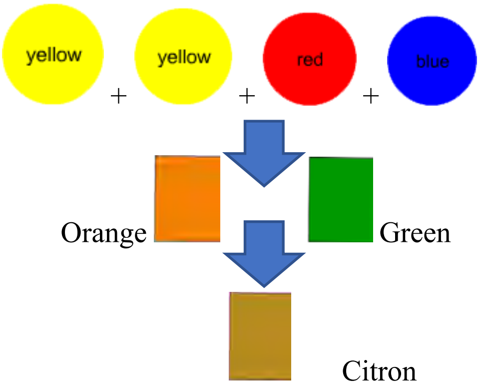

Figure 2. Combination: Tertiary Yellow (Citrine/ Citron).

Third Alternative = (B) R and Y,
Formula: 2c + y + x,
substitution: 2B + R + Y = OLIVE,

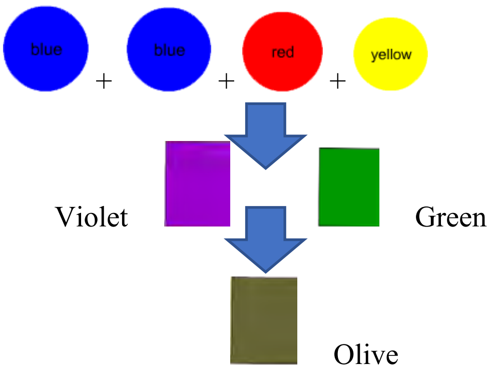

Figure 3. Combination: Tertiary Blue (Olive).

Conclusion

The challenge for this article is to integrate mathematics formulas into the study of Tertiary and Intermediate colours. Integrating disciplines will help to reveal the liminal experience and knowledge. The article suggests that tertiary colour can be different from intermediate colours by combining two equal proportions of secondary colours.

References

Barry, D. 2013. *Around the Color Wheel*. Clarkston, Michigan USA.

Bleicher, S. 2012. Contemporary Color Theory & Use (2nd E.D.). Clifton Park, USA

Call, A. V. 2017. *Color: A Practical Guide to Color and Its Uses in Art.* Walter Foster Publishing Group USA.

Choudhury, R.K.S. 2014. Principles of Colour Appearance and Measurement Volume 1: Object Appearance, Colour Perception, and Instrumental Measurement. Woodhead Publishing Limited, U.K.

Edwards, B. 2004. *Color a Course in Mastering the Art of Mixing Colors*. Penguin Group (USA) Inc. New York.

Eiseman, L. 2017. *The Complete Color Harmony.* Quarto Publishing Group, USA.

Getlein, M. 2016. *Living with Art, (11th e.d).* Eleventh Edition. Mcgraw-Hill Education, New York.

Hornung, D. 2012. *Color A Workshop for Artists and Designers (2nd E.D.).* Laurence King Publishing Ltd, China.

Mittler, G. 2006. *Art in Focus (5th e.d*). Glencoe/McGraw-Hill

Opara, E., and J. Cantwell. 2014. *Color Works: Best Practices for Graphic Designers: An Essential Guide to Understanding and Applying Color Design Principles.* Rockport Publishers, USA.

Paterson, I. 2004. *A Dictionary of Colour: A Lexicon of the Language of Colour.* Thorogood Publishing Ltd.

Eileen, S.P. 2008. *Art is Fundamental: Teaching the Elements and Principles of Art in Elementary School*. Zephyr Press, USA.

Rhyne, T-M. 2017. *Applying Color Theory to Digital Media and Visualization*. Taylor & Francis Group, LLC.

Pink Marketing: How does it work? Why is it (still) working?

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Abstract

Gender marketing takes advantage of gender research, modifying some products to respond to the allegedly specific needs of women. The aim is to double profits by offering two gendered versions of the same product. Pink is then massively used to particularise a product "for girls/women", which has often been criticised by feminist researchers and activists as sexist. The intent here is to explain how and why such a marketing strategy persists, even though it is in decline. Through gender studies, the article will first show how the gendered use of pink in marketing manages to construct a "feminine mode of consumption", referring to Christian Derbaix and Pierre Gregory's model of the "doors of persuasion" to show how the colour pink can activate different levers likely to modify the attitudes and behaviour of female consumers. The article will then consider Jean Baudrillard's semiological approach to consumption in order to explain female consumers' adherence to this "pink marketing". Finally, using the concept of "extended-self" developed by Russel W. Belk, it will show how the consumption of these "feminine products" allows consumers to prove their belonging to the category of "women", while reinforcing their feeling of "being a woman".

Keywords: *Gender Marketing, Consumer culture, Femininity, Consumerism, Extended-self*

Introduction: The Uses of Pink in Gender Marketing

Gender marketing is a strategy that emerged in the 1970s, taking advantage of the research on gender that was developing at the same time, in order to produce targeted marketing according to the sex of the audience[1]. As much as marketers are very familiar with gender studies, gender marketing strategies differ from them in that they are not aimed at gender criticism, but at profit. In particular, marketers rely on studies of behavioural differences between men and women in terms of decision-making, risk-taking or self-confidence; as well as on the design preferences – shapes, sizes, colours of objects – that men and women express, and the reasons that motivate them (Moss, 2009). They can then apply these results by changing the shape, colour or even the functionality of a product, by changing the colour or textual elements of its packaging, or by working on a specific advertising promotion. The aim is then to double the benefits by offering two gendered versions of the same product.

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[1] In reality, gender marketing is much more about targeting women than men: while brands are increasingly interested in men, they are feminising their ranges for female consumers rather than masculinising them for male ones.

While it is now common to find a product available in several shades, pink is specifically used to make products available in a version for women (Bartow, 2008). Thus "pinkified", a product becomes exclusive to girls or women, while the rest of the range becomes both "neutral" – suitable for everyone –, and "masculine" – thought to be intended for men. For marketers, this "pink factor" allows for a doubling of profits (Orenstein, 2011: 43). This however does not mean that all goods or services targeted towards women are pink, but rather that all pink products – and there are many – are targeted to women: pink razors, pink toolboxes, pink ear plugs, pink pens, and even pink laxatives (Fig. 1).

Figure 1. Various pink products from gender marketing, 2021 (brand names have been masked)

The use of pink to label a product "for women/girls" has been repeatedly criticised by academics (e.g., Coy, and Garner, 2010; Fine, and Rush, 2016), feminist associations[2] and the media – particularly on the internet[3] – as reinforcing sexist gender stereotypes. Why then does pink marketing continue to work, renewing itself, but always relying on the same discursive and visual resources – chromatic in particular? Using psychology and theories of advertising persuasion, then semiology and the sociology of consumption, I will sketch out hypotheses to explain the success of gendered marketing, even today.

[2] Some examples include the Unstereotype Alliance initiative of the US association UN Women (https://www.unstereotypealliance.org), or the French campaign Marre du Rose of the associations Osez le féminisme !, and Les Chiennes de Garde (https://marredurose.olf.site).

[3] For instance, the association Pépite Sexiste (http://pepitesexiste.fr) relays via social networks (Twitter, Instagram, etc.) examples of gender marketing sent by its readers. The initiative is now replicated in several other countries.

The Woman, that special consumer: Pink Marketing through theories of persuasion

Colour and advertising typologies

Consumer acceptance of a product depends on the communication strategies used, the type of product to be sold, but also on the expected target and the context in which the advertising is broadcast or received (Aylesworth, and Mackenzie, 1998). However, sociologist Benoît Heilbrunn reminds us that "[t]he consumer is a social construct insofar as the people we meet in shops or who are said to consume products or services are flesh and blood beings with a history, affects, desires, budgetary and temporal constraints, etc." [own translation] (2005: 27). On this basis, it is understood that it is not possible to control all the parameters influencing consumers' persuasion, such as their personality (Haugtvedt, and Petty, 1992) or their mood (Bless *et al.*, 1990).

Numerous models of the process of advertising persuasion have been developed since the 1980s, broken down into two typologies: a cognitive one, based on memory and reasoning; and a second one, emotional, based on effects (Georget, 2005). This distinction corresponds more or less to the categorisation of types of content proposed by Christopher P. Puto and William D. Wells: on the one hand, they distinguish informational advertisements which disseminate a factual message about the product, and involve a process of cognition; and on the other hand, more recent transformational advertisements which engage the effect of consumers (1984).

Mathieu Kacha attempts to move beyond such a distinction, arguing that colour can influence or even change consumers' attitudes towards a product by acting on both the cognitive (congruence of the message with the symbolism of the colour) and the emotional (liking or disliking a colour) dimensions (2009: 184). The use of pink to particularise products targeted towards women fits perfectly with the cognitive aspect of this hypothesis: the feminine symbolism of pink is not only well established, but also shared by the majority of countries (Bideaux, 2021: 369-371). However, on the emotional side, we are confronted with the repulsion that pink arouses in many women[4], which should not therefore be beneficial to advertisers' strategies, especially as the criticisms made of stereotypical pink toys (Orenstein, 2011), of the instrumentalisation of feminist discourse by advertising (Hains, 2009), and of the inequalities produced or perpetuated by gendered marketing (Bartow, 2008), are numerous and massively disseminated by the popular media.

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[4] In a German survey, only 3% of women surveyed declared pink as their favourite colour, while 17% cited pink as their least favourite colour (Heller, 2000: 179). A meta-analysis compiling several surveys from 22 US and Canadian universities showed that only 5% of North American women declared pink as their favourite colour (Ellis, and Ficek, 2001).

The "Gates of persuasion"

Why then does marketing continue to use pink to segment its market according to gender, if this means running the risk of customer defection? According to Christian Derbaix and Pierre Gregory, it is possible to change consumers' attitudes and behaviour through persuasive communication (2004). To do this, they identify four "gates of persuasion", which are conceptual levers usable by advertisers, which Kacha subsequently associates with the characteristics of color (2009: 189-190):

- (1) The "gate of logic" corresponds to cognitive learning, which refers for Kacha to the meaning of colours;
- (2) The "gate of imitation", which corresponds to interpersonal relationships, and for Kacha to colour manifestations in fashion or tradition
- (3) The "gate of feelings and emotions", linked by Kacha to personal experiences with colours (memories, habits);
- (4) And "the gate of automatisms", which corresponds to the conditioning of consumers, and for Kacha to the almost unconscious associations made with a brand or a product.

If we apply Kacha's correspondences to the use of pink as a sign of femininity in marketing, we can see that the strategy is to operate all these levers at once:

- (1) Pink is a colour recognised as a symbol of femininity almost everywhere in the world;
- (2) It has been established as a symbol of femininity, and continues to spread as such, simultaneously through the layette tradition and women's fashion;
- (3) Girls are conditioned from childhood – via television, toys,... – to associate pink with femininity (Bideaux, 2021: 439-483);
- (4) Finally, as Mary Celeste Kearney points out, "it is very difficult to associate it with anything other than females and femininity" (2010: 29), which corresponds to the last gate of automatisms.

It seems to me at this point that I can invoke the "cradle to grave" marketing strategies that target women from childhood as the reason for the effectiveness of what I call "pink marketing". The mercantile association of pink with the feminine is diffused through all strata of daily life, to the point of creating a form of continuity between childhood and adulthood. Female consumers are thus conditioned from birth to own pink objects, making pink marketing a real tool of persuasion specific to female targets, playing on both the cognitive and emotional registers, and having repercussions on gender relations.

Having and being (pink): Consumer goods as social markers

Consumption of symbols and symbol of consumption

The effectiveness of pink marketing can also be explained from the point of view of semiology. In *La Société de consommation*, Jean Baudrillard showed that consumption is also a non-verbal language and that possessions have meaning beyond their desired functionalities (1970: 20). A few decades later, Grant McCracken supplemented Baudrillard's thesis by postulating that the cultural significance of consumption is projected from the world of cultural values and symbols to consumer goods, by two major instruments of transfer, namely advertising and fashion systems, which forcefully associate symbolic characteristics with the functional attributes of the product (2005: 104-106). Baudrillard spoke in this sense of consumption as a concept like a mythology, *i.e.* "*a statement of contemporary society about itself*, the way our society speaks itself. [...] the only objective reality of consumption is the *idea* of consumption" [own translation] (1970: 311-312).

Referring to Claude Levi-Strauss's totemism (1962), Marshall Sahlins proposes to consider consumer goods as new totems that can be understood as means of objectifying differentiated social identities, *i.e.* they allow social groups to be distinguished from one another (like animals and plants for certain tribal populations) (1976). Beyond its market value or its capacity to satisfy a need, the object of consumption is thus also a social marker, which is confirmed by Heilbrunn when he specifies that consumption, when it participates in social and cultural identities, does it both in the mode of social reality, but also of the idealisation specific to individuals in these social categories: "The self-concept is enhanced through the transfer of the socially accepted meanings from the product or brand to the person" [own translation] (2005: 94-96).

I consume pink so I am a woman

Based on these assumptions, it is possible to consider the pink objects produced by gender marketing as a way for some women to signify their femininity through the consumption of these objects, or more accurately, a way to signify their conformity to a model of femininity[5]. The desire to respond to social codes of femininity would therefore prevail over personal preferences – which explains why pink marketing can continue even though women do not specifically like pink –, and sometimes also over personal convictions – particularly feminist ones.

Consuming "in pink" can therefore be seen as a new way of expressing femininity and constructing a gendered identity, specific to our contemporary societies. Lynn Peril speaks of "Pink Think", which she defines as "a set of ideas and attitudes about what constitutes proper female behavior [...] pink think is the belief that one's success as a woman is grounded in one's allegiance to such behavior" (2002: 6-7). Among these feminine behaviours is consumption; Ann Bartow develops: "Choosing pink against her own inner wishes constitutes consummate pink thinking by a female, reflecting self-sacrifice, conformity to gender norms, and

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[5] This may explain the emergence of a craze for pink as a symbol of femininity in 1950s America, which was obsessed with the roles assigned to men and women (Bideaux, 2021: 317-325). Historian Penny Sparke also explains that at that time "[t]he objects became, first and foremost, symbols, sacrificing their utilitarian features to their symbolic functions', notably by signifying femininity" (1995: 10-11).

acquiescence to the dictates of mainstream consumer culture" (2008: 37-38). Thus, it does not matter whether women like pink or want to have pink objects, the important thing is that they buy these pink products – that they consume pink – because to consume pink is to consume femininity (Peril, 2002: 218).

Pink marketing's effectiveness is therefore made possible by all the social pressures imposed on women, which from childhood – via toys or clothes bought for them by their parents (Picariello et al., 1990; Pennel, 1994), socialisation at school (Darroux, 2007), ... – condition them to respond to the cliché of stereotypical femininity. The role of the colour pink is then to maintain a symbolic cohesion that is immediately recognisable and technically replicable on different media. The "cradle to grave" marketing strategy aimed at targeting girls and women throughout their lives then shows its full effectiveness: it not only makes it possible to retain female customers, but also to ensure a renewal of the clientele through the intergenerational transmission of a supposedly feminine taste for pink.

Conclusion: Pink as a prosthesis of femininity

For psychoanalyst Serge Tisseron, "[t]he human being inhabits the objects that surround him as he inhabits his own body" [own translation], a way to "peripheralized" his psychic life, to extend his spirit (2016: 216), *i.e.* to invest objects symbolically as an extension of oneself. Russel W. Belk highlights this postulate by developing the idea of "extended self" through the possession of objects: "It seems an inescapable fact of modern life that we learn, define, and remind ourselves of who we are by our possessions" (1988). According to him, possession would define not only what is "mine", but also what is "Me", implying a definition of identities through objects, their acquisition, consumption, or collection. Moreover, Belk, as well as Tisseron, extend the concept of "object" beyond the mere consumer good: to money, animals, monuments, a gesture, etc. We could include in this non-exhaustive list colour, and in particular for our purposes, pink. *To possess something pink is to be pink oneself*, and to be what it symbolises: the feminine.

Through pink marketing, femininity becomes artificial, superficial, externalised and conditioned by the possession of feminine objects, in contrast to masculinity, which is manifested and proven through acts, physical or mental ritual tests (Hoquet, 2009: 174). Femininity then appears accessory, in the sense that it is "worn": it is an extra-corporeal artifact but nevertheless necessary for women, who have to buy it, to consume it, in order to claim to belong to the category "women" as defined by gender and shaped by stereotypes. In this sense, Belk points out that the extension of the self is also part of a collective plan: it is acknowledged and even expected by society (1988). Pink in gender marketing is therefore a paradox: it symbolises femininity in order to respond to women's "natural" needs and, at the same time, it refers femininity to an artificial aesthetic process that is consumed, that is accessory. Pink objects are thus visible markers of femininity that make it perceptible and measurable. To paraphrase French feminist Simone de Beauvoir, if “one is not born, but rather becomes, a woman” (1949: 274), then it is clear that women become women in part through consumption of “women’s pink things”.

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References

Aylesworth, A. B., and S. B. Mackenzie. 1998. Context is the key: The Effect of program induced mood on thoughts about the ad. *Journal of Advertising* 27 (2): 17-31. https://doi.org/10.1080/00913367.1998.10673550.

Bartow, A. 2008. Trademarks, commoditization, gender, and the color pink. IP Colloquium (Chicago, February 12). https://urlz.fr/icRq.

Baudrillard, J. 1970. *La Société de consommation*. Paris: Denoël.

Beauvoir (de), S. 1949. *The Second sex*. Translated by H. M. Parshley. London: Jonathan Cape, 1956.

Belk, R. W. 1988. Possessions and the Extended Self. *Journal of Consumer Research* 15 (2): 139-168. https://doi.org/10.1086/209154.

Bideaux, K. 2021. *La Vie en rose. Petite histoire d’une couleur aux prises avec le genre*. PhD thesis, University of Paris 8 - Vincennes-Saint-Denis. https://tel.archives-ouvertes.fr/tel-03579107.

Bless, H., G. Bohner, N. Schwarz, and F. Strack. 1990. Mood and persuasion: a cognitive response analysis. *Personality and Social Psychology Bulletin* 16: 331-345. https://doi.org/10.1177%2F0146167290162013.

Coy, M., and M. Garner. 2010. Glamour modelling and the marketing of self-sexualization: Critical reflections. *International Journal of Cultural Studies* 13 (6): 657-675, https://doi.org/10.1177%2F1367877910376576.

Darroux, É. 2007. Des stéréotypes de genre omniprésents dans l’éducation des enfants. *Empan* 65: 89-95. https://doi.org/10.3917/empa.065.0089.

Derbaix, C., and P. Grégory, 2004. *Persuasion : la théorie de l’irrationalité restreinte*. Paris: Economica.

Ellis, L., and C. Ficek. 2001. Color preferences according to gender and sexual orientation. *Personality and Individual Differences* 31 (8): 1375-1379. https://doi.org/10.1016/S0191-8869(00)00231-2.

Fine, C., and E. Rush. 2016. “Why do all the girls have to buy pink stuff?” The Ethics and science of the gendered toy marketing debate. *Journal of Business Ethics* 149 (44): 769-784, https://doi.org/10.1007/s10551-016-3080-3.

Georget, P., 2005. La Persuasion publicitaire : application des modèles théoriques de la psychologie sociale. *Market Management* 5: 27-46. https://doi.org/10.3917/mama.021.0027.

Hains, R. C. 2009. Power feminism, mediated: Girl power and the commercial politics of change. *Women’s Studies in Communication* 32 (1): 89-113. https://doi.org/10.1080/07491409.2009.10162382.

Haugtvedt, C. P., and R. E. Petty. 1992. Personality and persuasion: need for cognition moderates the persistence and resistance of attitude changes. *Journal of Personality and Social psychology* 63 (2): 308-319. https://doi.org/10.1037/0022-3514.63.2.308.

Heilbrunn, B. 2005. *La Consommation et ses sociologies*. Paris, Armand Colin, 2010.

Heller, E. 2000. *Psychologie de la couleur. Effets et symboliques*. Translated by L. Richard. Paris: Pyramyd, 2009.

Hoquet, T. 2009. *Virilité. À quoi pensent les hommes*. Paris: Larousse.

Kacha, M. 2009. *La Couleur, variable d’action marketing*. PhD thesis, University of Nancy 2. http://www.theses.fr/2009NAN22005.

Kearney, M. C. 2010. Pink technology: Mediamaking gear for girls. *Camera Obscura* 25 (2): 74. https://doi.org/10.1215/02705346-2010-001.

Levi-Strauss, C. 1962. *Le Totémisme aujourd’hui*. Paris: Presses Universitaires de France, 2000.

MacCracken, G. 2005. Culture and consumption II. Markets, meaning, and brand management. Bloomington: Indiana University Press.

Moss, G. 2009. *Gender, Design and Marketing. How Gender Drives Our Perception of Design and Marketing*. London: Routledge, 2016. https://doi.org/10.4324/9781315254593.

Orenstein, P. 2011. Cinderella ate my daughter. Dispatches from the front lines of the new girlie-girl culture. New York: Harper Collins.

Pennell, G. E. 1994. Babes in Toyland: learning an ideology of gender. *Advances in Consumer Research* 21: 359-364. https://www.acrwebsite.org/volumes/5972/volumes/v21/NA-21.

Peril, L. 2002. *Pink Think. Becoming a woman in many uneasy lessons*. New York: W. W. Norton and

Company.
Picariello, M. L., D. N. Greenberg, and D. B. Pillemer. 1990. Children's sex-related stereotyping of colors. *Child Development* 61 (5): 1453-1460. https://doi.org/10.1111/j.1467-8624.1990.tb02874.x.
Puto, C. P., and W. D. William. 1984. Informational and transformational advertising: The differential effect of time. *Advances in Consumer research* 11: 638-643. https://www.acrwebsite.org/volumes/6323/volumes/v11/NA-11.
Sahlins, M. 1976. *Stone Age Economics*. London and New York: Routledge, 2017.
Tisseron, S. 2016. *Comment l'esprit vient aux objets*. Paris: Presses Universitaires de France.

The effect of colour temperature of morning light exposure on wellbeing

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Abstract

This study investigated the effect of correlated colour temperature (CCT: 2500k, 5000k, 8500k, 18000k, 500lx) on healthy adults (N=16) exposed to light for one hour in the morning based on three measures. PANAS was used to assess mood, KSS was used to assess alertness and tympanic temperature was also recorded. There was evidence that the CCT affected tympanic temperature with lower temperatures being induced by higher CCT in general. The KSS data was consistent with other related studies in that higher CCTs resulted in increased alertness and the lowest CCT (2500K) resulted in decreased alertness compared to the baseline condition (3500K). The CCTs were found to differentially affect positive and negative emotions measured using PANAS. The 8500K condition, in particular, induced an increase in positive emotions and a decrease in negative emotions. Overall we find some evidence that exposure to light (500 lux) in the early morning could positively affect wellbeing for healthy adults. The study raises questions about the suitability of low CCT (e.g. 2500K) in homes and offices.

Keywords: *Colour Temperature, Alertness, Mood, Tympanic temperature*

Introduction

Illumination has effects that go beyond the simple requirement to see Papamichael (2017). Light has many effects on the human body through non-image-forming (NIF) vision Westland et al. (2017) and may affect, for example, hormone secretion, body temperature and, of course, sleep Wahl et al, (2019). Studies have found that people's mood and tympanic temperature may be affected by lighting and important factors are the spectral composition, the colour temperature and the intensity of the illumination. In particular, the combination of high colour temperature (psychologically cool) and high intensity may lead to improvements in behaviour and mood. However, such claims for bright cool lighting have mainly been confirmed in patients with Alzheimer's or seasonal-affective depression Pail et al. (2010). Lighting can have potential and long- term effects on people's mood and cognitive behaviour McCloughan et al. (1999) especially in the treatment of seasonal depression Fournier and Wirz-Justice (2010).

There is growing interest in applications of lighting with healthy adults. Activation of cells in the retina results in signals being sent to the hypothalamus Pickard et al.

(1987) and this can affect body temperature, biological rhythms and other critical physiological processes Chaudhri et al. (2006). Different wavelengths and intensities have varying degrees of influence on subjective well-being and alertness, and circadian rhythm Grote et al. (2013). CCT has been recently found to affect subjective well-being Omidvar and Brambilla (2021). Whereas there is currently great interest in the role of light in the morning of people with Seasonal Affective Disorder and the effect of evening light exposure on sleep, this work focuses on the role of early morning exposure to light on the wellbeing of healthy adults.

Experiment

This study explores the immediate effects of CCT (2500k, 5000k, 8500k, 18500k) of morning light on well-being and tympanic temperature. The lighting was provided using a ThousLite luminaire system that allows spectral control of the room illumination (Figure 1 and Figure 2). A total of 16 participants (8 males and 8 females aged 21-27) were recruited for the within-subject study. Participants were asked to complete a Participant Information Sheet before the experiment started which collected some basic personal information and physical condition information (psychological, visual condition history, travel across time zones, daily caffeine intake, and daily alcohol consumption). At the start of each session (which took place at approximately 9am each day) each participant was placed in a room with a 3500k, 500 lux baseline light source for 15 minutes for adaptation. The first data collection (under the baseline light source) took place at the end of the 15-minute period and explored three aspects: mood (using PANAS), and alertness (using KSS). Afterwards, participants were exposed to a test illumination (with a CCT of either 2500k, 5000k, 8500k, or 18500k at 500 lux) for a further 40 minutes. A binaural tympanic membrane temperature measurement was performed every ten minutes (to avoid data errors during the measurement, a single binaural tympanic membrane temperature was collected twice, and the average was taken). At the end of the 40-minute period the second data collection was made which was identical to the first. Figure 3 shows a schematic summary of the experimental conditions.

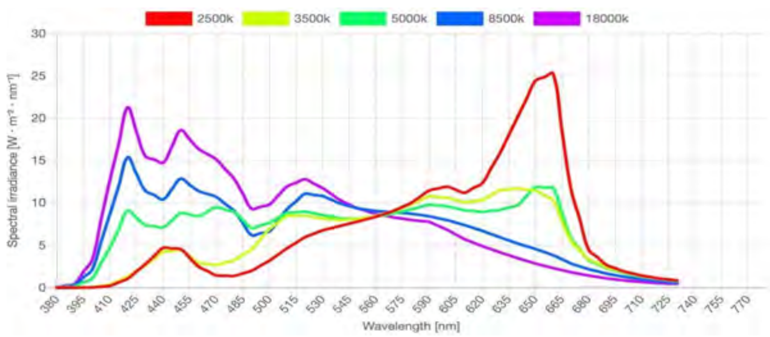

Figure 1. Spectral composition of the test lights and the baseline condition (3500K).

Figure 2. The experimental room with (from left to right) 2500k, 5000k, 8500k, 18500k illumination.

During the one-hour period in which the participants were in the experimental area, they were given a document to read.

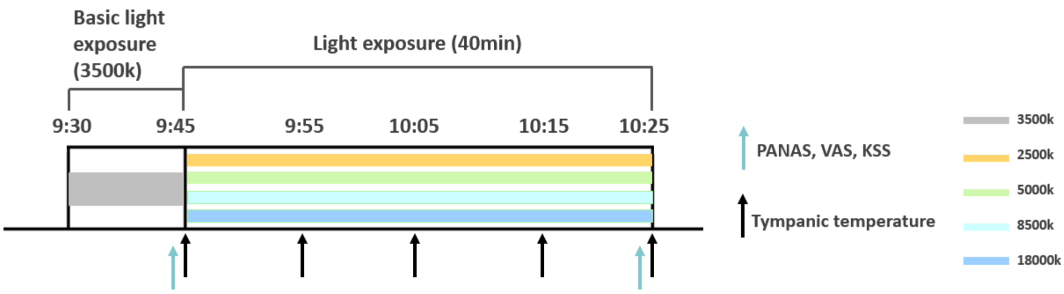

Figure 3. The experimental design of the study.

Results

Tympanic Temperature

There was a significant effect of CCT on ear temperature (F43,36; $p<0.05$). Figure 4 shows the average tympanic temperature under the four lighting conditions. Generally, there is some evidence that ear temperature falls with increasing CCT although the temperature at 5000 K is higher than at 2500K. The variation of temperature over time (averaged over all participants and days) is shown in Figure 5. With the exception of 2500k there is some evidence that temperature fell during light exposure.

Some studies have shown that the core temperature of the human body will show a downward trend shortly before sleep. The results from this study are slightly confusing. Figure 5 shows that ear temperature generally fell during exposure to light (Figure 5) but mean temperatures were lowest for the highest CCTs. However, note that in this study measurements are made in the early morning when participants are unlikely to be feeling sleepy anyway.

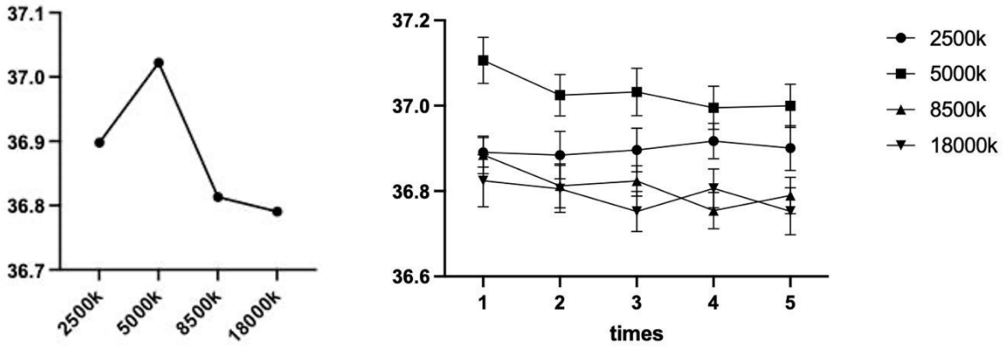

Figure 4 (L). The average value of tympanic temperature under different lighting parameters.
Figure 5 (R). Changes in tympanic temperature during light exposure. These values are temperature averages obtained over consecutive 10-minute intervals during exposure.

KSS (Karolinska sleepiness scale)

Figure 6 shows the difference in KSS scores under the four lighting parameters. The more positive the change in KSS the more sleepy and less alert the participant. Negative changes indicate increases in alertness. There is strong evidence that according to KSS data alertness increases with increasing CCT (though perhaps this is not the case for very high CCT). For 2500K participants were less alert than under the baseline CCT (3500K) .

Figure 7 shows the changes in the KSS score under different lighting parameters for each of the three days; curiously there is some suggestion that although the 2500K CCT condition increased light conditions during three days of the experiment. P<.01. sleepiness, its effect reduced slightly as the study progressed. Generally the results from this part of the study are consistent with previous studies that show that high CCT is alerting and low CCT induces sleepiness.

PANAS

Regarding the mood scale, we observed that 'light conditions' and 'time' had significant effects when looking at the entire course of the experiment. After the first period of standard light exposure, the first collection of mood scales was conducted. Subsequently, after completing the second period of separate light exposure, the second collection of mood scales was conducted. The change in positive emotions can be seen intuitively from the statistical difference between the two collected data. Figure 8 compares the differences between PA-P (positive emotions) and PA-N (negative emotions) for the four CCTs. From Figure 8 it is evident that high CCTs induce an increase in PA-P and low CCTS induce a decrease in PA-P. However, PA-N also decreased, at least at three CCTS with a small increase at 18000K. Note that for the 8500K condition, positive emotions are increased and negative emotions are decreased. Figure 9 shows the changes in PA-P and PA-N for each of the three days separately for each of the four CCT conditions. There is some evidence (see the 8500K for example) that the effect weakens over time.

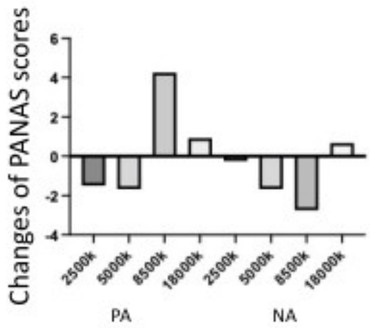

Figure 8. Overall changes of PA-P and PA-N under different lighting parameters.

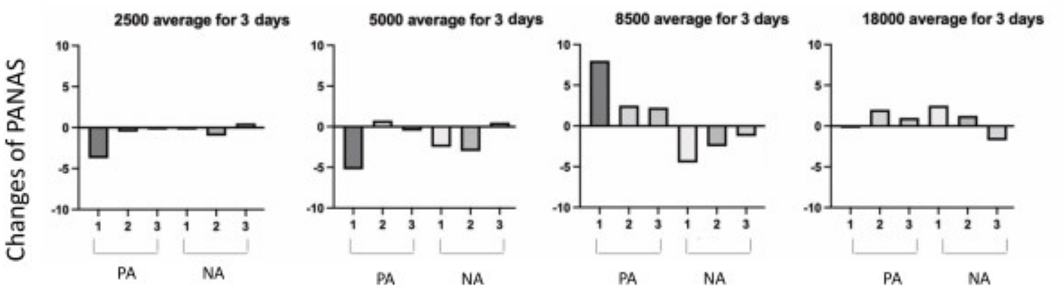

Figure 9. Changes of PA and NA under different light parameters in three-day experiment

Conclusion

This study investigated the non-visual biological effects of the low colour temperature of 2500K, neutral colour temperature of 5000K, high colour temperature of 8500K and ultra-high colour temperature of 18000k on the human body in an indoor environment. The 8500K condition induced increased positive emotions, decreased negative emotions and increased alertness and is therefore evidence that light exposure in the morning can be beneficial for wellbeing. We also find some evidence that ultra-high colour temperature may be less beneficial. Other methods, such as melatonin collection from saliva and actigraphy, were not used in this study but could be incorporated in future work. The timing and duration of the light exposure may well affect the results. Whilst there is quite a lot of evidence to support bright-light therapy for people with, for example, seasonal-affective disorder this study suggests that the therapy could be useful for healthy adults. It may not be sensible to advocate using the same lighting in young people and the elderly Fournier et al. (2010), for example. However, this study does suggest that morning light may improve human mood. Further work is needed to ascertain threshold effects for intensity and duration of light exposure.

References

Chaudhri, O., C. Small, and S. Bloom. 2006. Gastrointestinal hormones regulate appetite. *Philosophical Transactions of the Royal Society B: Biological Sciences* 361 (1471): 1187-1209.

Fournier, C., and A. Wirz-Justice. 2010. Light, Health and Wellbeing: Implications from chronobiology for architectural design. *World Health Design: Architecture, Culture, Technology* 3 (1): 44-49.

Grote, V., C. Kelz, N. Goswami, H. Stossier, E. Tafeit, and M. Moser. 2013. Cardiac-autonomic control and wellbeing due to oscillating color light exposure. *Physiology & Behavior* 114: 55-64.

Magyar-Moe, J. L. 2009. Therapist's guide to positive psychological interventions. Academic press.

McCloughan, C. L. B., P. A. Aspinall, and R. S. Webb. 1999. The impact of lighting on mood. *International Journal of Lighting Research and Technology* 31 (3): 81-88.

Omidvar A, and A. Brambilla. 2021. A novel theoretical method for predicting the effects of lighting colour. temperature on physiological responses and indoor thermal perception. *Building and Environment*, 203:108062.

Papamichael, K. 2017. Adaptive Lighting for Energy-Efficient Comfort and Wellbeing. SID Symposium Digest of Technical Papers.

Pickard, G. E., M. R. Ralph, and M. Menaker. 1987. The intergeniculate leaflet partially mediates effects of light on circadian rhythms. *Journal of Biological Rhythms* 2 (1): 35-56.

Pail, G., W. Huf, E. Pjrek, D. Winkler, M. Willeit, N. Praschak-Rieder, S. and Kasper.. 2011. Bright-light therapy in the treatment of mood disorders. *Neuropsychobiology* 64 (3): 152-162.

Westland, S., Q. Pan, and S-J Lee. 2017. A review of the effects of colour and light on non-image function in humans. *Coloration Technology* 133 (5): 349-361.

Wahl, S., M. Engelhardt, P. Schaupp, C. Lappe, and I. V. Ivanov. 2019. The inner clock—blue light sets the human rhythm. *Journal of Biophotonics* 12 (12): e201900102.

Watson, D., and L. A. Clark. 1997. Measurement and mismeasurement of mood: Recurrent and emergent issues. Journal of Personality Assessment 68 (2): 267-296.

The impact of colours fading on our sense of 18th century tapestries

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Abstract

When one approaches the subject of 18th-century colours, the common thought is immediately oriented towards pastel or even dull colours. Tapestries from this period are no exception to the rule. However, current research shows that the dyes of the time were bright and contrasting. This study proposes to show how it is possible to recover a hypothesis on the original colours of tapestries from different chemical or numerical analysis techniques. An experimental setup was installed in the laboratory to study the degradation of reference samples. The analyses and our reflections on the colours were applied to a tapestry kept at the Cité Internationale de la Tapisserie in Aubusson. Indeed, the *Grande Verdure aux Armes du Comte de Brühl* is a high-quality piece called "*Grand teint*", dyed and woven from the materials identified as the most solid in the 18th century. The lining of the reverse side of this object has been removed for restoration, giving us an excellent opportunity to study it from both sides (the side exposed to light and the side protected by the lining).

The digital restitution of the colours of this tapestry calls into question the vision that we had until then of the colours of the 18th century and the aesthetic choices made despite the rapid degradation of certain dyes present on the tapestry.

Keywords: *Tapestries, Colour fading, Spectrocolorimeter; Micro Spectrofluorimetry*

Introduction

When one approaches the subject of 18th-century colours, the common thought is immediately oriented towards pastel or even dull colours. Tapestries from this period are no exception to the rule. However, current research shows that the dyes of the time were bright and contrasting. Texts, dyer's notebooks or memoirs by chemists of the time attest to the significant interest of these professions in the vivacity of colours. This is evidenced by the names given to dyeing recipes, such as "*ecarlate*" or "*aurore*"(Hellot 1750; Macquer 1761; Cardon 2003).

This study proposes to show how it is possible to recover a hypothesis on the original colours of tapestries from different chemical or numerical analysis techniques. This research was carried out in several stages. First, a colour chart of more than 600 references based on recipes from 18th-century treatises was created, thanks to a collaboration with the Myrobolan dyeing workshop (Brussels). The reference spectra of these new samples were then recorded with several non-invasive analysis methods (HSI-VIS-NIR, FORS, LEDμSF...), creating a database that will finally be compared to the spectra recorded on the tapestries studied, having undergone the effects of time, thus allowing the identification of the materials used at the time. In a second step, a methodology for studying degradation was set up in the laboratory to study the loss or change of colours exposed to light used in the tapestries. Finally, all these data collected allowed the implementation of a methodology for the digital restitution of the original colours.

The analyses and our reflections on the colours were applied to a tapestry kept at the Cité Internationale de la Tapisserie in Aubusson. Indeed, the *Grande Verdure aux Armes du Comte de Brühl* is a high-quality piece called "*Grand teint*", dyed and woven from the materials identified as the most solid in the 18th century. The lining of the reverse side of this object has been removed for restoration, giving us an excellent opportunity to study it from both sides (the side exposed to light and the side protected by the lining).

The digital restitution of the colours of this tapestry made from the recorded analytical data calls into question the vision that we had until then of the colours of the 18th century and the aesthetic choices made despite the rapid degradation of certain dyes present on the tapestry. This study thus raises the question of the priority interest of the manufacturers in the 18th century, namely an immediate quality of colour (at the exit of the workshop) and thus an aesthetic choice, a perennial rendering in time or a selection of materials made in the conscience of their degradation and evolution over time.

Materials and Methods

Aubusson Manufactory

The Aubusson tapestry studied in this paper, bearing the arms of Count Heinrich von Brühl (Figure 1), was woven around half the 18th century. It was made after a cartoon by Jean-Joseph Dumons, a renowned painter. This tapestry depicts a landscape, a speciality of Aubusson at that time, and belongs to the category known as Verdures fines (Bertrand 2013).

Figure 1: Tapestry (3,44 m x 7,32m) with the arms of Count von Brühl after a cartoon by J-J. Dumons, 1753 (date of purchase), Aubusson Manufactory, © Cyril Fressillon- CNRS Photothèque/Iramat

Reference samples

Dyed samples of wool and silk were investigated to compare with similar colours on the tapestries: (i) indigo on wool, (ii) indigo and weld (giving green) based on wool, (iii) indigo on silk and (iv) indigo and weld (giving green) based on silk. The comparative reference samples were dyed at the Myrobolan dye workshop in Brussels. The blue shades were prepared from *Indigofera suffruticosa* from Central America and used as pigment with fructose as a reductant. Weld was chosen for the yellow component of the green dye with indigo. The reference sample was first dyed in an indigo bath according to the indigo vat protocol and then mordanted with alum before undergoing a second dye bath with weld.

Spectrocolorimeter

This method is based on the phenomenon of reflectance. It gives an objective, standardised and quantified value of colour. It allows the coordinates of a colour to be recorded in systems defined by the Commission Internationale de l'Éclairage (CIE). One of the most widely used systems described in 1976 (CIEL*a*b*) is recognised and readable by the entire scientific community. Three parameters define these coordinates:

L is the luminosity, a value between 0 (black) and 100 (white)*
a is the chromaticity value on the green to the red axis*
b is the chromaticity value on the blue to the yellow axis*

The colour coordinates (L*, a*, b*) are measured with a Minolta CM-2600d spectrophotometer (360-740 nm). The spectral resolution is 10 nm, and the diameter of the analysis area is 3 mm. The standard illuminant D65 corresponds to natural daylight in a temperate zone. The observation angle is 10°. The colour difference, noted ΔE*, corresponds to the distance between two colours (e.g. that of an original dye and the same one altered).

$$\Delta E *= \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

Natural light ageing

A 2 cm^2 square piece of the dyed textile reference samples was hung on the wall. Aluminium foil was used to protect part of each sample from the light to act as a control during light exposure. The amount of illumination on the reference sample was an average of 3mW/cm^2.

Micro Spectrofluorimetry

The fluorescence emission spectra were obtained with the portable LEDµSF with an analysis of 4 s to 200 ms.. The wavelength goes from 200 to 1000 nm with a low power LED providing a 375 nm excitation wavelength (5 mW), filtered above 455 nm. The investigated area on the sample is typically a 2 mm diameter disk for a working distance of 4 cm (for more see (Mounier et al. 2016)).

Results and discussion

Spectrocolorimeter made it possible to record colour coordinates on both sides of the tapestry for comparison. It was thus possible to measure the colour difference, called ΔE*, between a specific area of the obverse side, exposed to light, and the same spot on the reverse. The results of those measurements are summarised in Table 1. It shows this difference in different shades. The colour difference ΔE* is visible to the human eye from 3 (Ezrati 2013). On the Aubusson tapestry, the average ΔE* is 11 indicating a significant colour change between the obverse and reverse. The ΔE* can be observed according to the shade. The colorimetric measurements made between the front and back of the tapestry bring much information.

It is interesting to note that the pink and red shades have a high ΔE* (13.2 and 14.6), possibly due to the dusting of the tapestry more than a photochemical alteration of the dye. The green and blue shades show very different variations. In these shades, only blue 2 shows a slight colour difference (ΔE* of 1.5). The hue of green 2 changes from dark green on the backside to a dark blue on the front side. As a consequence, the 3 coordinates L*a*b* are changed. The light colours (blue 1, yellow, light green 1) are much less dark on the front than on the backside, significantly increasing the L* coordinate. Thanks to a previous identification of the textile materials, it is shown that the green/light blue shades are dyed on silk. On the contrary, blue 2 and green 2 are dyed on wool. The colour alteration thus meets two criteria depending on the type of textile fibres: a significant loss of colour (increase in lightness) for the shades dyed on silk and a slight change in colour for the shades dyed on wool.

Shade	Recto				Verso				ΔE*
	L*	a*	b *		L*	a*	b *		
Blue 1	64	-7	-1		47	-6	-9		18.8
Blue 2	23	-4	-9		24	-4	-8		1.4
Yellow	67	5	45		64	8	52		8.2
Light green 1	63	-3	20		56	-6	24		8.6
Green 2	29	-7	7		33	-8	15		9.0
Red 1	35	48	28		48	48	30		13.2
Pink 1	43	12	23		55	20	21		14.6

Table 1: Colorimetric coordinates L*a*b* and ΔE* of the front and back of the tapestry.

These observations led to the study of blue and green shades dyed on wool and silk in the laboratory. As indigo is known to be a very stable dye, the low ΔE* (2.3) The value of indigo on wool after 60 days of exposure to natural light is consistent. However, as a consequence of an increase in lightness the colour difference (ΔE*) observed on indigo on silk is equal to 9.3. The sample appears bleached. The discolouration of the models suggests photolysis of the molecular bond and is a consequence of oxidation of the dye by light (Tello Burgos et al. 2021; Sousa et al. 2008). This ΔE* is relatively high after only two months of exposure. This reflects the instability of indigo on silk dyed according to the protocol in this study when exposed to light.

Concerning the green samples, unlike indigo on wool, green on wool has a ΔE* more significant than 3, resulting from the presence of yellow. The silk undergoes a significant loss of blue, resulting in a very high ΔE* value of 27.5. In this measurement, L* is no longer the only coordinate affected, but also a* and b* since there is a change in hue. This loss of indigo on the green results in a shift in hue from green to yellow.

Micro Spectrofluorimetric analysis (Figure 2) was carried out to probe the chromophores present in the textile samples and to observe any degradation of the fluorescence emission spectra. The emission bands (around 720nm) are similar before and after degradation on both textile fibres and show only a slight shift for the indigo samples. This is because fluorometry is very sensitive in detecting a dye even in low concentrations when used alone. Experiments on the green samples showed that the chlorophyll 'a' present in weld (at 670 nm) disappears rapidly after exposure to light (de La Codre et al. 2021). This phenomenon was already observed in the previous study on the degradation of yellow dyes. In contrast to the samples where indigo is dyed alone, indigotin is no longer observable on the silk after exposure to light. The fluorescence emission of flavonoids (around 570 nm) seems to cover this signal when indigo is in low concentration.

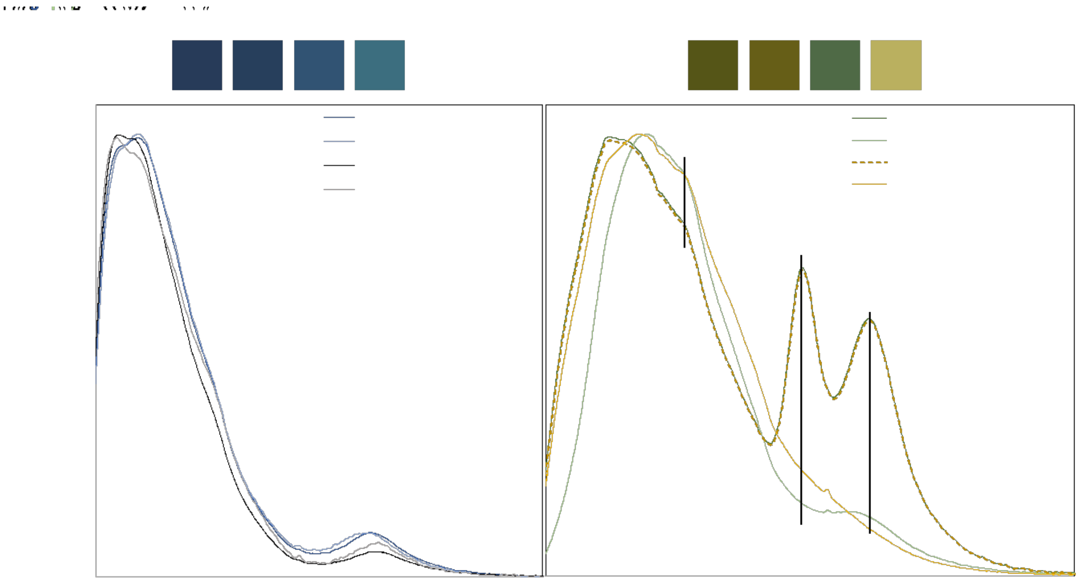

Figure 2: (Squares) Colours of the reference and exposed samples (Left)Emission fluorescence spectra (λex=375 nm, analysis time =4s) of indigo on wool and silk before (REF) and after exposure to natural light during 60 days (Right) Emission fluorescence spectra (λex=375 nm, analysis time =4s) of green (indigo+weld) on wool and silk, before (REF) and after exposure to natural light during 60 days

Conclusion

This study also observed a significant degradation of particular colours on the tapestry. The greens and blues show an actual physicochemical alteration if the reds seem to be subject only to dusting. Indeed, on wool, indigo behaves as a very stable dye on both sides of the tapestry. On the contrary, when dyed on silk, the loss of colour is almost as significant as whether it is protected from light. The colours of the tapestries can be reconsidered: blue on wool would have been green and, on the contrary, the yellow on silk was potentially a green originally. These observations and data are essential for our perception of current colours and have been used to digitally record the tapestry thanks to the creation of a digital palette. Based on physical measurements of the colour and experiments, this virtual restoration will make it possible to reconsider the colours and the very interpretation of the tapestry, profoundly modifying its rendering and the perception of the colours of the 18th-century.

References

Bertrand, P.. 2013. *Aubusson, tapisseries des lumières: splendeurs de la manufacture royale, fournisseur de l'Europe au XVIIIe siècle*. Corpus albicans 2. Heule: Snoeck.

Cardon, D. 2003. *Le monde des teintures naturelles*. Belin.

Ezrati, J. 2013. « Les effets de la composition spectrale des sources électriques sur la conservation des objets du patrimoine ». *La Lettre de l'OCIM*, n 146 (mars): 5 、11. https://doi.org/10.4000/ocim.1193.

Hellot, J. 1750. L'art de la teinture des laines et des étoffes de laine en grand et petit teint, avec une instruction sur les déboulés. Paris: Vve Pissot.

La Codre, H. de, C. Marembert, P. Claisse, F. Daniel, R. Chapoulie, L. Servant, and A. Mounier. 2021. « Non-invasive Characterization of Yellow Dyes in Tapestries of the 18th Century: Influence of Composition on Degradation ». *Color Research & Application* 46 (3): 613-22. https://doi.org/10.1002/col.22646.

Macquer, P-J. 1761. *Art de la teinture en soie*. Desaint. Paris.

Mounier, A., S. Lazare, G. Le Bourdon, C. Aupetit, L. Servant, and F. Daniel. 2016. « LEDμSF: A New Portable Device for Fragile Artworks Analyses. Application on Medieval Pigments ». Journal 126 (mai): 480 87. https://doi.org/10.1016/j.microc.2016.01.008.

Sousa, M.M., C. Miguel, I. Rodrigues, A.J. Parola, F.P.J. Sérgio, S. de Melo, and M.J. Melo. 2008. « A Photochemical Study on the Blue Dye Indigo: From Solution to Ancient Andean Textiles ». *Photochemical & Photobiological Sciences* 7 (11): 1353-59. https://doi.org/10.1039/b809578g.

Tello Burgos, N., A. López-Montes, E. M. Valero, J. Luis Nieves, and Mª Rosario Blanc. 2021. « Characterization of the Evolution of Indigo Blue by Multispectral Imaging ». *Color Research & Application*, août, 1-12. https://doi.org/10.1002/col.22721.

Aerial perspective: Alteration of color due to the interposition of air

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Abstract

Leonardo da Vinci observed that colors at a distance undergo significant changes in an effect that he denominated *aerial perspective* (AP). Similarly, in his Notebooks, he mentioned that there are three types of perspective: linear; color, and disappearance. Considering that his proposal is exceptionally correct in terms of the optics of color at a distance, and that there is little information on the theme, his observation has been taken up again with a current view of physics and perception. With the purpose of establishing the manner in which color alters AP, the thesis assumed that the air, in spite of its transparency, affects color at a distance in three fundamental aspects: in its diminution; its disappearance, and its modification, depending on the air mass separating the object from the observer. This is an effect that, although perceived by landscape painters, eludes commonplace persons in composing a perceptual activity that, for the purpose of this study, has been termed constancy of aerial perspective. This assay has as its objective to render an approximation of the optics of aerial perspective under a hypothetical focus of five planes at a distance and to expose why constancy of the aerial perspective limits the vision of color in exteriors.

Keywords*: Aerial perspective, color, constancy, planes, distance.*

Introduction

Leonardo da Vinci (1452-1519) discovered that colors at a distance are modified in terms of an optical effect that he denominated *aerial perspective* (1999, p.45). In his Notebook, he wrote (1964, p. 74): "The eye appreciates neither the distance between objects nor the distance in which are found diversely distanced things; without the perspective of colors, linear perspective would not be sufficient for determining distances' '. In addition to this mention in his notes, da Vinci represented aerial perspective (AP) in some of his paintings, such as *The Annunciation*, *The Madonna of the Carnation*, *The Virgin of the Spinning Wheel*, and the *Mona Lisa*, among others (Figure 1). Notwithstanding this, da Vinci documented his findings, and these, from the Renaissance, were suggested by many painters through the line of landscape painting. A bibliographic review noted that there is little information on AP, a fact that moved toward taking this matter up again, but now concerning what is known about light and perception. In this respect, it is noteworthy that, although it appears that optics and perception accompany each other in the same sense, in reality they deal with different *languages*: on the one hand, we find the **optical** or the physical effect of sunlight that, on crossing through the atmosphere, makes contact with the bodies that we can consider as *reality*, and on the other, the process in which the sensory impression, on passing through a perceptual filter, gives rise to an interpretation of the visual world that we can call ***illusion*** (Gombrich, 2000). Both focuses are comparable with the distinction between the gaze in quotidian uses and that which has stimulated artists through direct observation of the phenomenon of distance. The artist sees the world in a manner notoriously different from how ordinary people see it (Müller-Freienfels, 1966, pp. 273-275)

Objective. This assay has as its objective to produce an approximation of the optics of aerial perspective under a hypothetical focus of five planes at a distance, and to expose why the constancy of the aerial perspective, proposed in this work, causes this phenomenon to be not perceptible by the look that has not been stimulated to perceive properties of color in exteriors.

Thesis. Deriving from the proposal of da Vinci that there are three types of perspective, this work in turn derives from that the air, in spite of its transparency, affects the optics of colors in three fundamental aspects: in their diminution; in their disappearance, and in their modification, depending on the aerial mass separating the object from the observer.

Constancy and aerial perspective

Aerial perspective (AP) originated and was developed in the field of art. Painting in great spaces made artists take note of the fact that the landscape was in reality an aggregate of chromatic qualities integrated into a complex organization. Perfect harmony was the result of the interaction of diverse factors: the local color of each body; lights and shadows; changes of color due to the caprices of the climate; modification of the illumination at different times of day, and, of course, the variation of the colors at a distance. Only to the extent that the confused panorama can be seen as a configuration of directions, geometric sizes, forms, and colors or textures that are clearly differentiated, can it be said that the panorama can be truly perceived. (Arnheim, 2008, p. 61)

Many of the qualities of shape (form), distance, and colors are not perceived by the majority of individuals; these qualities are those termed by the Psychologists as **perceptual constancies**, in which “The properties of the objects tend to remain constant in the consciousness, even though our perception of the conditions changes.” (Coren, Ward & Enns, 2001, p. 335). Among the most common constants, we can mention that of the *form* (shape); the *size*; the luminosity or whiteness and the **constancy of the color** or the shade. All constants have in common that they perceive the *complete* object. A few traits not only determine the identity of a perceived object, but also, in addition, they render it so that it appears to us as a complete or integrated schema (Arnheim, 2008, p. 59) thus responding to the Law of Prägnanz (of *good figure*) (Schiffman, 2001, p. 535): “The general Gestalt principle that refers to the tendency to perceive the simplest and most stable of all of the possible perceptual alternatives.”

It is given that illumination in open spaces is particularly voluble; the changes in atmospheric conditions produce an extensive gamma of the colors of the sun, the sky, and of terrestrial objects (Mueller & Mae, 1974, p. 100). The modifications in the wavelengths, the perception could be interpreted as *different* objects; precisely, in order not to lose one's way in the sensory impressions, the constancy of the color adjusts the vision to chromatic patterns in order to conserve the properties of the objects that can belong to the landscapes. This leads to supposing that AP would comprise a derivation of that of the color; however, the affectation of the color that causes the air makes the optical phenomenon of distance possess its own particularities of a constancy, which moves us to propose that in the landscape is also expressed the constancy of the aerial perspective, which is a novel focus of visual perception that supplies continuity and permanency to the objects perceived at different distances from the observer. While the **constancy of the aerial perspective** takes into account the physical effect of the light's absorption and reflection, it also considers the interposition of the aerial mass that measures the observer and the object at which they are looking. This constancy explains why the optics of distance stimulated landscape painters, whenever they needed to extract visual information to provide the impression of depth on the plane surface of the canvas. "We can resoundingly affirm that the so-called refinement of the senses does not lie in the keenness of "sensory" perception, but instead in a certain much more complex and complicated capacity of differentiation and, of course, one distinct from the sensory function". (Müller-Freienfels, 1966, pp. 273-274)

Aerial and linear perspective

Leonardo da Vinci, in his Notebook (1999, p.21) and with respect to what he called the science of the visual rays, observed that there are three types of perspective: linear perspective; color perspective, and the perspective of disappearance. In that his proposal notably approximates the optics of distance, we again herein address the latter to sustain our thesis, except that da Vinci generates his proposal in the environment of the Renaissance, while we take current optical and perceptual elements in the impression of distance. We understand by perspective the impression of depth caused by the reflection of light on objects situated at different distances in terms of the point of view of the observer. An essential characteristic of perspective is diminution, which exists in two senses: the linear and the aerial.

Linear perspective. is the conical projection of the axes of light into the interior of the eye that, by means of reflection, emits the bodies at different distances from the observer. It is the rectilinear projection of light that supports a geometric order, while *diminution* refers to the *reduction* of the size of the bodies to the degree at which they are contemplated.

Aerial perspective. This is the optics that, through reflection, appears in the objects once the rays of the sun have transferred into the *atmosphere*, which is the air, constituted of various types of gases that cover the earth. The atmosphere will unfailingly affect the colors of the bodies in three senses: by the intensity of the light that the bodies receive; the changes in the atmospheric conditions (climate), and the volume of the air mass that interposes itself between the observer and what they are looking at. “Naturally, the greater the space between an artist and an object, the more air will be present in that space.” (Ballinger, 1977, p. 42). Although AP originated in the artistic milieu and for its own purposes, it also permeates the field of physics, in the optics that give rise to sunlight on its coming into contact with the atmosphere. “If we increase the amount of dust or water vapor, other colors will also be produced. The day-to-day variation of the aspect of the sun is a magnificent example of how these changes occur.” (Mueller & Mae, 1974, pp. 100-101)

Affectation of color by the air mass

AP entails an interesting paradox: on clear and limpid days, the transparency of the air allows us to see up to the limits of the horizon; however, in that sharpness, the colors are altered by the air itself. It is clear, then, that AP is subordinate to the atmospheric gases; however, in order to understand how this affects the optics, we must distinguish two types of air masses that, on contact with sunlight, will give rise to two different physical responses: that which is above the observer, which covers the celestial vault, and that which interposes itself between the observer and the object. Given the importance of both of these, it is convenient to highlight the qualities of each.

Mass at the level of the view. The view, naturally, is projected forward; thus, it must be added that the mobility of the body permits seeing what is around it. The visual world is perceptible because of the **reflection of the light**, the principle of the opaque bodies that receive the light, absorb determined wavelengths, and release others that the eye perceives in a process denominated selective absorption (Griffith, 2008, pp. 328-329). Therefore, considering that color is perceived by reflection and absorption, to the AP we must add the volume of the air mass that interposes itself between the observer and what they are looking at. In this regard and for the effects of our study, we understand by *distance*, the volume of air mass that separates the subject who perceives from the object that is perceived.

Aerial mass above the observer. Regardless of the aspect of the sky, it will always result from the coordinated action of the *white* light of the sun with the atmospheric gases. On clear days, the sky looks blue and it will be more intense according to how clean the environment is. The sky itself, but in the afternoons, is tinted with innumerable tonalities of ochres, oranges, browns, and blues. These colorations are due to two physical responses: Rayleigh scattering and Mie diffusion (Griffith, 2008, pp. 330-331). Regardless of the appearance of the sky, it will influence the temperature of the color that, were it a delicate tint, will affect the color of the objects that share the same environment. Temperature manifests itself in a tenuous coloration, barely perceptible, but one that can catch the educated eye of an expert. Distinction of the two air masses will aid us in understanding how the air affects the colors by means of the reflection and dispersion of light.

Diminution and *disappearance* of color in the aerial perspective

According to our thesis, colors are subject to a continual process of transformation in which they not only diminish, but also tend to disappear. In reality, the color is not eliminated, but instead it acquires other characteristics as the distance increases.

Proximate colors. At a distance of a few meters, local colors, proper to opaque objects, show themselves to be intense and of good aspect. In proximity, the bodies exhibit colors that are not seen in the distance, such as reds and vermilions, and all those with high levels of saturation, such as sepias, purples, and sea blues. On the increase of the air mass, the local color begins to become diluted, eventually disappearing. The most significant aspect of the *disappearance* is noted when that which is near is by nature polychromic, while at a distance, the far-away hills demonstrate a clear and uniform monochrome.

Diminution of the contrast. The contrasts between the complementary colors, as would be the case, for example, of the greens with respect to the reds or of the purples in relation to the yellows, also diminish and disappear at a distance.

Affectation of the albedo. In AP, with respect to the levels of reflectance, it would appear that, in some cases, these levels fade, or they increase, but in no case do they exhibit these levels when they are close by. For example, the white in proximity will be seen as whiter than that of the body found kilometers away in distance. In spite of that the albedo is transformed, it will not disappear. There are other *diminutions* akin to the color, as in the case of the size, detail, the luster, and the borders that separate one body from another.

Luminosity, color, and planes at a distance

In the transformation process of color, luminosity will play a fundamental role, understanding this property as the “Quality of the surface (degree of grey, ranging from white to black), which is relatively independent of the illumination.” (Schiffman, 2001, p. 536) It is the response of the opaque bodies that, because of the reception and reflection of light, exhibit different levels of clarity or obscureness. Therefore, this is related with achromatic colors, in which black is the absence of light, white is the greatest clarity that the body reflects, and that, between both, a surprising play of lights and shadows unfolds that invariably affects the colors. Notwithstanding that luminosity is the result of a complex combination of factors (Cetto, 2003), for the purpose of our study, we underscore the role that it plays in the transparency of the air, as if luminosity were outside of a veil of air.

In AP, luminosity is related to what in artistic jargon is known as planes at a distance, which are points on which the observer focuses toward the horizon in a clean and illuminated environment. The planes make it known that under no circumstance will the color be recovered of the plane that precedes it, it will have other characteristics, which leads to noting the disappearance of color. Under this focus, our study will recreate a hypothetical space of five planes at a distance. Bearing in mind that the visual cone establishes that nearby objects are seen as large, and those that are far as small, the planes, in reality, are great hills that appear in the distance in such a way that the first hill is the nearest hill, the second is that which follows it, and so on successively. It is not considered flat at a distance of meters; however, nearness is the point of departure for observing how colors are transformed at each one of the points that the observer sees. The planes will compel us to notice how luminosity is affected by the air mass that is above the observer (dispersion) and that which is found in the direction of the view of the observer (reflection).

First plane. The most proximate hill significantly reduces many of the qualities of the local color, such as saturation, contrast, luster, and the play of lights and shadows. Due to the bodies blurring with respect to their borders, the optical effect will result from the integration and eventual organization of the local colors into groups related with the visual scene. For example, the hill could have many brown stones, but each of these will not be seen in particular, but rather, there will appear a more-or-less uniform mass of brown color. That will happen with the bushes, soils, plants, etc., which will remain in an optical organization of similar shades resulting from the entirety of the local colors.

Second plane. As in the first plane, this plane reveals the entirety of the local colors; the second plane produces the integration and eventual chromatic organization of all of the color groups comprising the hill. Given that this plane reduces the chromatic properties of the groups, the hill appears as a uniform mass of two predominant tonalities, one of which is in the light and the other of which is in the shadow, which confer on the hill a flatter and more uniform appearance than the former. This plane demonstrates a curious particularity of AP; in its general aspect, the luminosity fades, which drives it to exhibit darker tonalities, although, at the same time, an increase is noted in the clarifying, due to the imposition of the air. For example, if this hill is upholstered with trees, it will be seen as a green tending toward darkening, although at the same time, the general tone clarifies a transparency that exhibits a species of aerial mist.

Third plane. This plane exhibits an interesting paradox: notwithstanding that the hill is found in the full rays of the sunlight, it notoriously darkens but, at the same time, and by means of the air, it clarifies, creating an interesting effect of darkness that appears in the clarity of the transparency. The hill is shown as a dark mass, flat and uniform that, consequently, has eliminated the lights and shadows and the greater part of the color of the first two planes, expressing it thus: the “disappearance of the color” that da Vinci mentions. Given that this hill is the darkest of the visual scene, it is that which separates and distinguishes the chromatic behavior of the hills that preceded it, in which the predominance of color due to reflection is noted, and in those that preceded it, whose optics will tend toward dispersion, toward the temperature of the color that prevails in the sky at the moment of its viewing. The shady aspect will never come to be completely black; in fact, cold tonalities come to shine through that, normally, range from bluish tones, although greens, violets, or browns can appear, depending on the environmental conditions. As we can see, the luminosity that, in detriment, appeared in the first planes, and from this point, will begin to increase, until seeming like that of the sky.

Fourth plane. In this plane, the luminosity turns contrariwise into what was shown in the first three hills, whose tendency was toward darkness. Here there initiates a slow clearing caused by the increase in the air that interposes itself between the observer and what it is being looked at. In terms of coloration, this hill and the consequent ones have nothing to do with the first two planes, because the greater part of the shades of the color sets have disappeared and, in their place, the influence can be noted of the aerial mass that is above the observer, rendering to the hill a clear and uniform appearance. The colors advance toward the temperature of the color that the sky is exhibiting at the moment that the view is affected, which, due to the dispersion of light, can be cold or warm. For example, if the color of the temperature is a clear sky blue, or, in another case, if during the sunset, these same hills will present a clear amber appearance, meaning that the aspect can vary during one and the same day.

Fifth plane. This hill, being farther away on the horizon, has a greater volume of air that interposes itself between the object and the observer. Taking into account the tendency of the clearing of the luminosity deriving from the latter hill (the hill-in-question), this will be clearer in the visual scene and there will not be another that surpasses it, but not due to the effect of the albedo, and instead due to the influence of the air. This makes it noticeable that the farther away the last planes are, the more the dispersion exerts a greater influence than the reflection. The aerial mass that is above the observer intervenes, although in no way does it eliminate the reflection. “To the painter, the color of the air is the color of the sky. (Ballinger, 1977, p. 42) It is noteworthy that the farther away that the hill is gazed at from, the more it will appear to integrate itself into the sky, as if vanishing into it.

Figure 1. The three types of perspective that Leonardo da Vinci registered in his Notebook: the linear perspective; the color perspective, and the perspective of disappearance. Da Vinci applied these in his painting *Annunciazione* (Galleria Uffizi, Florence).

Figure 2. Planes at a distance are masterfully exhibited in this painting by John William Casilear (1811-1883) *Lake George*.

Conclusion

In order to understand the role of air in aerial perception, this essay was based on a hypothetical approach. This proposal cannot be taken as a norm that is applicable to any type of situation. Real optics is subordinated to the innumerable time, spatial, and climatic factors proper to each situation; thus, this exercise served to underscore the process of the alteration of colors at different distances from the observer. These are environments that evade this pattern, as would be the case, for example, of deserts in which mirages provide illusory visions; mountains covered with snow; those with high levels of albedo, or humidity-charged climates that noticeably reduce visibility from a distance. Due to the environmental volubility itself, it is not possible to establish the optics of each plane in kilometers or miles from a distance. Bearing in mind that this is an assay exploratory in character, the optics of aerial perspective needs, on the one hand, to be polished and, on the other, to drive lines of investigation, as would be case of the constancy of the aerial perspective (approached in this work); planes with high levels of albedo (snowy mountains), or studying the manner in which aerial perspective in the Munsell color system. Given that this is an extensive theme framed within a very small space, the hope is that it will have awoken in the reader an appetite that motivates them to follow this research line, already known to be interesting in its being related with the view of exteriors.

References

Arnheim, R. 2008. *Arte y percepción visual.* Madrid: Alianza Forma.
Ballinger, H. R. 1977. *Painting Landscapes.* London: Watson-Guptill.
Cetto, A. 2003. *La luz. En la naturaleza y en el laboratorio.* Ciudad de México: Fondo de Cultura Económica.
Coren, S., L.M. Ward, and J.T. Enns. 2001. *Sensación y percepción.* México: Mc Graw-Hill Interamericana.
Da Vinci, L. 1999. *Cuadernos de notas.* Madrid: Edimat Libros.
De Vinci, L. 1964. *Tratado de la pintura.* Madrid: Espasa-Calpe.
Gombrich, E. H. 2002. Arte e Ilusión. Estudio sobre la psicología de la representación pictórica. Londres: Phaidon Press Limited.
Griffith, W. T. 2008. *Física conceptual.* México: McGraw-Hill/Interamericana.
Mueller, C. G., and R. Mae. 1974. *Luz y visión.* Estados Unidos de Norteamérica: Time, Inc.
Müeller-Freienfels, R. 1966. Tu alma y la ajena. Una psicología práctica para todos. Barcelona: Labor.
Schiffman, H. R. 2001. *La percepción sensorial.* México: Limusa.

A new method for measuring the spectral sensitivities of a camera

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Abstract

In this study, a new method of estimating the spectral sensitivities of a camera based on a multi-channel LED cube was introduced. This method required the measurement of the camera responses and the spectral power distribution of each LED channel. The estimated spectral sensitivities were comparable to the results calibrated by a monochromator. The accuracy was verified by capturing a colour chart in a LED viewing cabinet. The results showed the proposed method to be effective to estimate the spectral sensitivities of the camera.

Keywords: *digital camera, spectral sensitivity, LED*

Introduction

Spectral sensitivity functions (SSFs) represent the colour property of a digital camera. It has been widely applied in many fields, including the spectral reflectance recovery, camera colour correction and the optimization of filters in multispectral imaging *et al*. The standard method of calibrating the spectral sensitivities of a camera is to use a monochromator (Vora 1997). However, it is a high-cost device and needs professional operations. A simple method is to estimate the spectral sensitivities of a camera by capturing physical samples such as a colour chart with known spectral reflectance. However, the problem is that the spectral reflectance of the real objects is generally smooth and has low dimensionality, usually can be expressed by 6-8 basis functions. This makes the reflectance matrix rank-deficient and it's ill-posed to estimate the spectral sensitivities directly (Darrodi 2015). Various algorithms have been applied to estimate the spectral sensitivities of a camera, including Tikhonov regularization (Hansen 1993), basis functions (Jiang 2013), metameric blacks methods (Alsam 2007), window filtering (Zhu 2020), rank-based method (Finlayson 2016), multi-scale convolutional neural network (Zhou 2021) *et al*. While some studies used LED-based method. DiCarlo *et al* (2004) developed an emissive chart based on narrow band LEDs arranged in a grid pattern. A singular value decomposition method was used. Due to the independence of the different LED channels, the singular values of the incident light signals decreased slowly so that the spectral sensitivities could be estimated with more degree of freedom. Bartczak *et al* (2015) used a 46-channel LED-based spectrally tunable light source to estimate camera spectral sensitivities. They concluded that the variation in the sensor's response increased with wavelength which could be related to larger FWHM values for LED channels in this wavelength range.

In this study, a new LED-based method of estimating the SSFs of a digital camera was introduced. The camera responses and the spectral power distribution of each LED channel were needed for the optimization of camera SSFs. The results were compared with those obtained by a monochromator. The accuracy of SSFs was evaluated using the colours in an XRite Macbeth ColorChecker chart (MCCC) by means of the estimation of the camera responses and of the CIE colorimetric values via a colour correction matrix.

Method

The camera responses follow a linear model as given in Eq.(1), where R is the camera responses, S is the spectral sensitivities of the camera, L is the diagonal matrix of the spectral power distribution (SPD) of the light, and r is the reflectance of objects. In this model, the noise in camera responses is ignored.

$$R = Slr \qquad \text{Eq.(1)}$$

In this study, an 18-channel spectrum tunable LED system was used. By capturing each LED channel using the camera and measuring the SPD using a spectroradiometer, the SSFs of the camera could be estimated. The key component of the device includes a LED cube placed on the bottom. After reflection and uniformity, the light was emitted horizontally from the circular aperture. Figure 1 shows the hardware of the device.

The measuring procedure was described as follows. Firstly, use a given camera to capture each channel of LED cubes at the light emitting plane. The whole measuring process was conducted in a dark room. The position of the camera was adjusted so that the principal axis of the lens was aligned perpendicular to the light emitting plane, and the image of the light source was located in the center of the whole image. The setup of the camera (ISO, shutter speed, F-number, focal length *et al*) should keep the same. The luminance of each LED channel was adjusted so that when capturing each LED channel, the camera response was always within the range of 80%~90% of the maximum response, in order to achieve high signal to noise ratio (SNR). The camera responses were extracted from the RAW images.

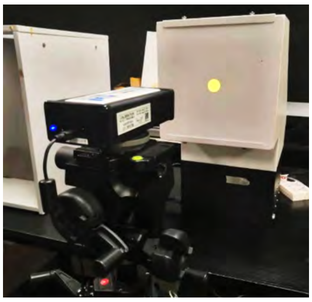

Figure 1. The hardware of the proposed method to estimate camera SSFs.

Secondly, the spectral power distribution (SPD) of each LED channel was measured using a JETI-Specbos 1211 spectroradiometer. The spectroradiometer was placed in the same place as the camera. The intensity of each LED channel was set to the same level as the intensity captured by the camera.

Finally, the spectral sensitivities of the camera were estimated using the camera RAW responses and SPD of the 18 LED channels following the proposed algorithm. Firstly the SSFs were represented by basis functions in order to reduce the dimensionality. In this study, a six-order polynomial was used as the basis function. Then a rough solution of SSFs was calculated by least square regression with non-negative constraint. The solution was used as the initial value for the subsequent optimization. In the optimization process, the sum of squared difference between the measured and estimated camera responses of the 18 LED channels was used as the cost function. The shape of SSFs was modulated iteratively by Gaussian functions centered at different wavelengths in order to minimize the cost function. The detailed algorithm will be given in our subsequent publications.

Results and Discussion

The SSFs of a Canon 650 D digital camera were measured following the proposed method, and the results were compared with those calibrated using a monochromator. Figure 2 shows the results of SSFs estimated from the proposed LED-based method and calibrated using a monochromator. It can be seen that the shape of SSFs obtained from the two methods was quite similar, proving the effectiveness of our proposed method.

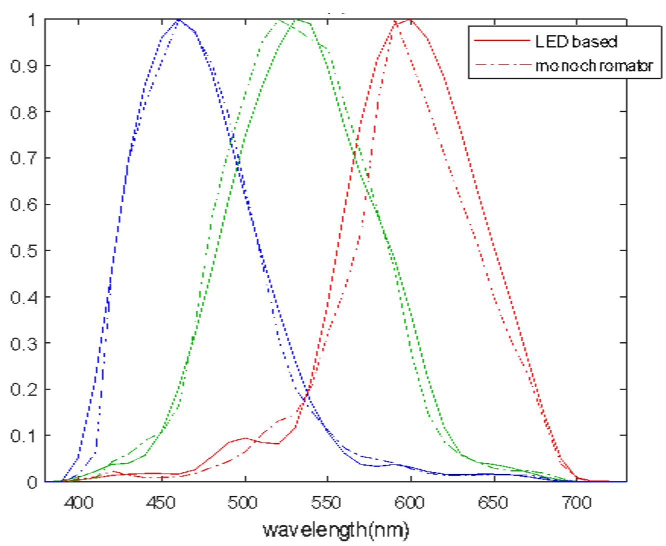

Figure 2. The SSFs estimated from the proposed LED-based method and calibrated using the monochromator.

The accuracy of the estimated SSFs was further verified by capturing a MCCC target and the results were compared between the camera measured responses and the SSFs estimated responses. The chart was placed on a holder with an angle of 45° to the horizontal plane in a LED viewing cabinet. Figure 3 shows the experimental situation. The camera was used to capture the chart under test illuminant D65. The viewing/illumination geometry was 0/45°. A gray board was also captured for the correction of illumination uniformity (Liang, 2016). The camera responses estimated from SSFs were calculated following Eq.(1). The SPD of the light was measured using a JETI-Specbos 1211 spectroradiometer and a white plate placed on the center of the bottom of the viewing cabinet. The reflectance of the patches on MCCC was measured using a Datacolor SF600 spectrophotometer. Both the measured and estimated camera responses were normalized to the range of 0 to 1.

Figure 3. The experimental situation of capturing MCCC in the LED viewing cabinet.

Table 1 lists the accuracy of SSFs measured using the two methods. It can be found that the accuracy of SSFs estimated based on LED was similar to or even slightly higher than that calibrated using a monochromator. It proved that the camera responses calculated from the 2 SSFs were quite close.

Methods	$\|\Delta R\|$	$\|\Delta G\|$	$\|\Delta B\|$	ΔE_{rgb}	$\|\Delta R\|/R\%$	$\|\Delta G\|/G\%$	$\|\Delta B\|/B\%$	mean %
LED-based	0.0033	0.0040	0.0034	0.0068	1.22%	1.79%	1.41%	1.47%
Monochromator	0.0043	0.0058	0.0032	0.0085	1.53%	2.39%	1.28%	1.73%

Table 1. Accuracy of SSFs (RGB error between camera measured RGB and estimated RGB) using 2 methods.

The colour correction matrix to transform from the camera responses to the CIE tristimulus values XYZ was calculated using the measured and estimated camera responses, respectively. It was a 3 by 3 matrix as given in Eq.(2), where R and X are the camera responses and XYZ values, respectively, and M is the colour correction matrix. The XYZ values were calculated using CIE 1931 colour matching function. The least squares method was used to calculate M, following Eq.(3).

$X = MR$ Eq.(2)
$M = X(R^t R)^{-1} R^t$ Eq.(3)

Table 2 lists the accuracy of the colour correction matrix under D65 in terms of the mean and max CIEDE2000 (ΔE_{00}). It can be found that prediction errors calculated from the estimated camera responses of the two methods were quite close. To some degree, it verified the accuracy of the estimated SSFs using the proposed method.

In addition, the mean prediction error ΔE_{00} calculated using the estimated camera responses was slightly smaller than that calculated from measured camera responses. It could be due to the potential noise in the measured camera responses.

	ΔE_{00} mean	ΔE_{00} max
Measured	1.08	2.25
LED-based	0.90	2.55
Monochromator	0.80	2.03

Table 2. Accuracy of colour correction matrix under D65 in terms of the mean and max ΔE_{00} using measured and estimated camera responses from the SSFs of the two methods.

Conclusion

In this study, the spectral sensitivities of the camera were estimated based on a multi-channel LED cube. This method is simple and accurate. The estimated spectral sensitivities had a close match in shape compared with that calibrated using a monochromator, and could give similar accuracy in predicting the camera responses of a colour chart.

References

Alsam, A., and R. Lenz. 2007. "Calibrating color cameras using metameric blacks." *Journal of the Optical Society of America a-Optics Image Science and Vision* 24 (1):11-17. doi: Doi 10.1364/Josaa.24.000011.

Bartczak, P., A. Gebejes, P. Falt, J. Parkkinen, and P. Silfstein. 2015. "Led-based spectrally tunable light source for camera characterization."

Darrodi, M. M., G. Finlayson, T. Goodman, and M. Mackiewicz. 2015. "Reference data set for camera spectral sensitivity estimation." *Journal of the Optical Society of America a-Optics Image Science and Vision* 32 (3):381-391. doi: 10.1364/Josaa.32.000381.

DiCarlo, J. M., G. E. Montgomery, and S. W. Trovinger. 2004. "Emissive chart for imager calibration." 12th color and imaging conference.

Finlayson, G., M. M. Darrodi, and M. Mackiewicz. 2016. "Rank-based camera spectral sensitivity estimation." *J Opt Soc Am A Opt Image Sci Vis* 33 (4):589-99. doi: 10.1364/JOSAA.33.000589.

Hansen, P. C., and D. Prost O'Leary. 1993. "The Use of the L-Curve in the Regularization of Discrete Ill-Posed Problems." *SIAM journal on scientific computing* 14 (6):1487-1503. doi: 10.1137/0914086.

Jiang, J, D. Liu, J. Gu, and S. Susstrunk. 2013. "What is the space of spectral sensitivity functions for digital color cameras?".

Liang, J, X. Wan, Q. Liu, C. Li, and J. Li. 2016. "Research on filter selection method for broadband spectral imaging system based on ancient murals." *Color Research & Application* 41 (6):585-595. doi: 10.1002/col.22004.

Vora, P. L, J. E. Farrell, J. D. Tietz, and D. H. Brainard. 1997. "Digital Color Cameras - 2 - Spectral Response."

Zhou, M., W. Chen, T. He, Q. Zhang, and J. Shen. 2021. "Scan-free end-to-end new approach for snapshot camera spectral sensitivity estimation." *Opt Lett* 46 (23):5806-5809. doi: 10.1364/OL.440549.

Zhu, J., X. Xie, N. Liao, Z. Zhang, W. Wu, and L. Lv. 2020. "Spectral sensitivity estimation of trichromatic camera based on orthogonal test and window filtering." *Opt Express* 28 (19):28085-28100. doi: 10.1364/OE.401496.

Fifty Shades of grayscale: Orthopedic structures as perceived by a manual therapist with synaesthesia

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Abstract

Congenital synaesthesia is an inherited trait in which stimulation of one sensory or cognitive pathway leads to involuntary experiences in a second sensory or cognitive pathway. Grapheme-color synaesthesia is a trait by which a synesthete perceives individual graphemes as colored. Lexeme-color synaesthesia is the experience of perceiving entire words in color. In this context, letters, digits, and words are the inducers of synaesthesia, and the color is the concurrent. Research into cross-sensory perception documents instances of the immediate transfer of synaesthesia to a novel inducer, for example, the transfer of a synaesthete's color for the Roman alphabet grapheme "R" to the Cyrillic alphabet grapheme "Я", despite the graphic differences between the two letters. Anecdotal evidence from synaesthetes suggests that various systems of order including sequences, hierarchies, maps, etc. can serve as the novel inducer fostering a color concurrent. "Fifty Shades of Grayscale: orthopedic structures as perceived by a manual therapist with synaesthesia" explores the transference of grapheme-color and lexeme-color synaesthesia onto novel inducers: anatomical structures and orthopedic fractures as revealed through medical imaging. Using grayscale radiographs printed to paper, I apply mixed media to reveal injuries, anatomical landmarks, and pathologies as I see them in vivid hues through my synaesthetic perception.

Keywords: *synaesthesia, perception, neurodiversity, neuroscience, radiography*

Introduction

Synaesthesia is a perceptual phenomenon experienced by approximately 4% of the global population. This neurocognitive difference comes in numerous iterations of cross-sensory combinations; however research by Simner et al (2006) notes that synaesthesiac in which an inducer yields a color concurrent is the most common variety. These color synesthesia account for up to 95% of all types reported.

Grapheme-color synaesthesia is one of the most frequently researched forms of cross-modal perception. For the individual with grapheme-color synaesthesia, letters and numerals are the inducers of the synaesthesia, and the perceived color is the concurrent. The synesthete might, for example, experience the numeral 1 as inherently yellow, 2 as violet blue, 3 as grass green and so on. Research by Brang et al (2013) reports these color associations typically begin in childhood and remain extremely consistent throughout one's lifetime.

Individuals with grapheme-color synaesthesia are described as either *associators* (89%) or *projectors* (11%) Dixon et al (2004). Grapheme-color synaesthesia association reports that their colored graphemes are experienced internally in the space of the “mind's eye”. Projector synaesthetes experience their color concurrents as pushed out into the visual field. These projected colors appear “as though a transparency bearing a colored number was placed on top of the written digit” Dixon et al (2004).

CC Hart: Chromatic Alphabet

Figure 1. *Chromatic Alphabet*, CC Hart, mixed media, 2016.

I am a poly synesthete, an individual with multiple forms of cross-modal perception, including grapheme-color synaesthesia, which I typically experience as associated, but occasionally as projected onto objects. As noted in the research by Brang et al (2013), my colored letters have been with me since early childhood, and they have remained consistent throughout my lifetime. See Figure 1, an illustration of my brightly hued graphemes.

My experiences with neurocognitive differences, particularly the ways that my grapheme-color synaesthesia influences my sensorium, motivated my interest in developing the International Association of Synaesthetes, Artists, and Scientists (IASAS) a United States registered 501(c)3 nonprofit corporation. Founded in 2016, the IASAS hosts international symposia focused on the art and science of synaesthesia. The organization held its first events in 2017 at the University of California, Los Angeles: synaesthesia expert Dr. Richard Cytowic MD, PhD served as a keynote speaker.

In conversation with Dr. Cytowic at the initial IASAS symposium, I shared my experiences with perceiving my grapheme-color synaesthesia transferred onto a novel inducer: the grayscale radiographs that I frequently view in my manual therapy practice. I stated that every orthopedic landmark, every bone, and even the injuries I witness in these medical images have an overlay of projected color that matches the first grapheme in the name of that structure, a form of lexeme-color synaesthesia. With Cytowic's encouragement, I began a literature review to support my understanding that synaesthesiac could indeed be transferred onto novel inducers. I also began coloring grayscale medical images to reflect how they are stained by the hues of my grapheme-color and lexeme-color synaesthesia.

Novel inducers and ideasthesia

In research conducted by Mroczko et al (2009) grapheme-color synesthetes who used the Roman alphabet were exposed to novel Glagolitic graphemes, a precursor to the modern Cyrillic alphabet. The research subjects quickly transferred semantically representative colors onto the novel graphemes. For example, if the synesthete perceived the Roman grapheme “R” as purple, then they would transfer that same shade to the Cyrillic alphabet grapheme "Я", despite the graphic differences between the two letters. The findings of this study suggest that synaesthesia is a much more malleable phenomenon than has been previously understood.

A similar conclusion was drawn from research conducted by Nikolic et al (2011) in which swimming strokes evoked a color concurrent for synaesthetes in the study group. Butterfly, freestyle, and backstroke are not modes for pure sensory induction, such as sound or flavor, but are instead conceptual inducers that evoked synesthetically perceived color in two of the subjects. The results of this study suggest that, similar to the work by Mroczko et al, synaesthetic inducers do not operate solely within the sensorium. They are also anchored in semantic representations where ideas are activated by sensation.

Fifty shades of grayscale

The creation of the works in *Fifty Shades of Grayscale* begins with analogue or digital radiographs printed via thermal inkjet to 100 pound white paper. Using colored pencils and occasionally pastels, I shade these x-rays as I see them through the transfer of my grapheme-color synaesthesia onto novel inducers: orthopedic structures. Figure 2, *On the Run* depicts the overuse injury *chondromalacia patella* (L) which is commonly called *runner’s knee* (R). Note the color difference between the words *chondromalacia* (cerulean) and *knee* (a dark sea-foam green).

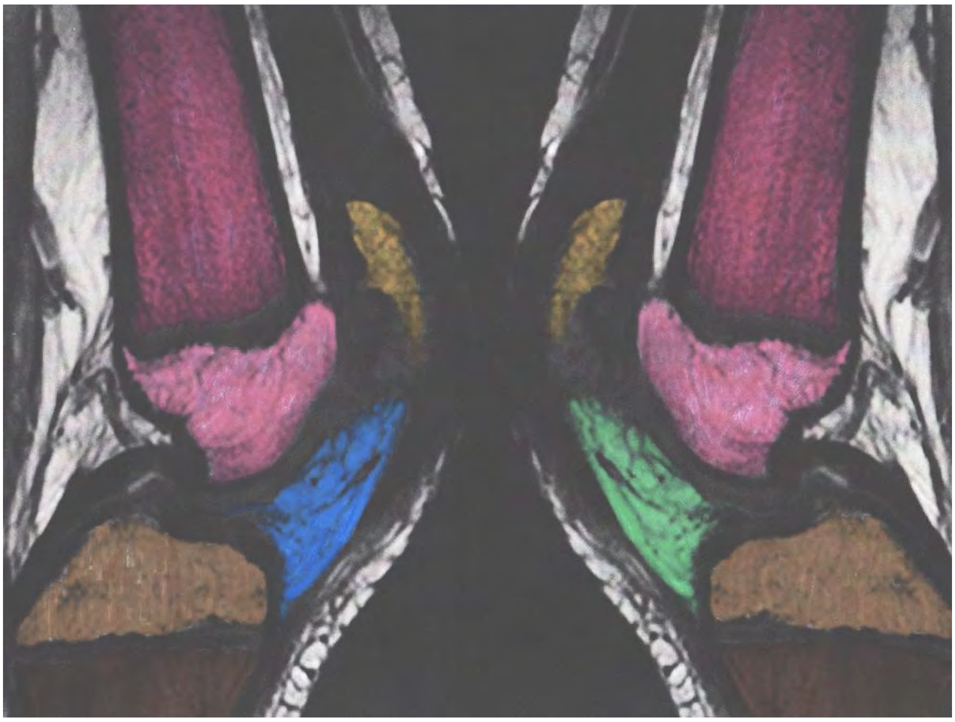

Figure 2. *On the Run,* CC Hart, mixed media, 2015.

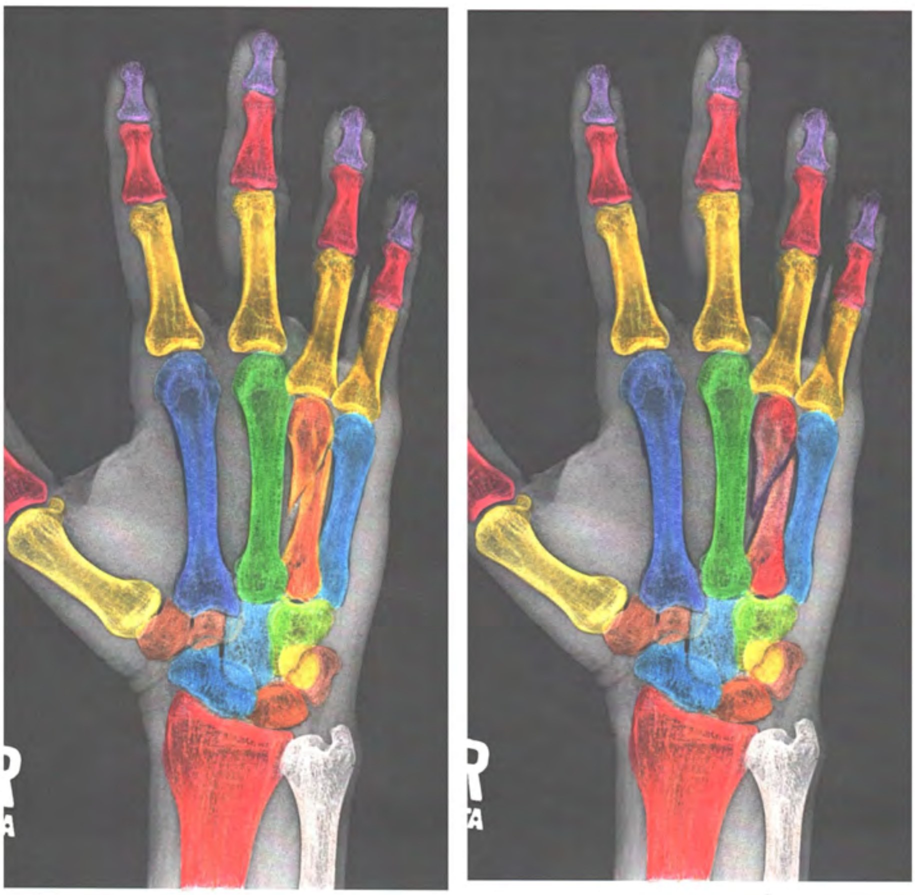

Figure 3. *Sunday Afternoon Distraction,* CC Hart, mixed media, 2018.

Figure 3 is a plain radiograph that has been colored to correspond with five distinct synaesthetic concepts. 1) My colored lexemes for the position of the right hand phalanges. *Proximal*, *medial*, and *distal* all get color from their initial graphemes: goldish-yellow for P, scarlet for M, and purple for D 2) I've colored the metacarpal bones to represent their numerical positions 1 through 5: pale yellow, violet blue, grass green, bright orange, and a medium blue 3) The eight small bones of the wrist colored according to their lexemes 4) The bones of the forearm, the radius and ulna, are colored as per my lexeme synaesthesia, in which every word draws its hue from the first grapheme: reddish-orange for *radius*, and pale silver for *ulna*. 5) The fourth metacarpal bone has an oblique displaced fracture. In the image on the right, the fracture is tinged purple and white to match the way I perceive this orthopedic injury.

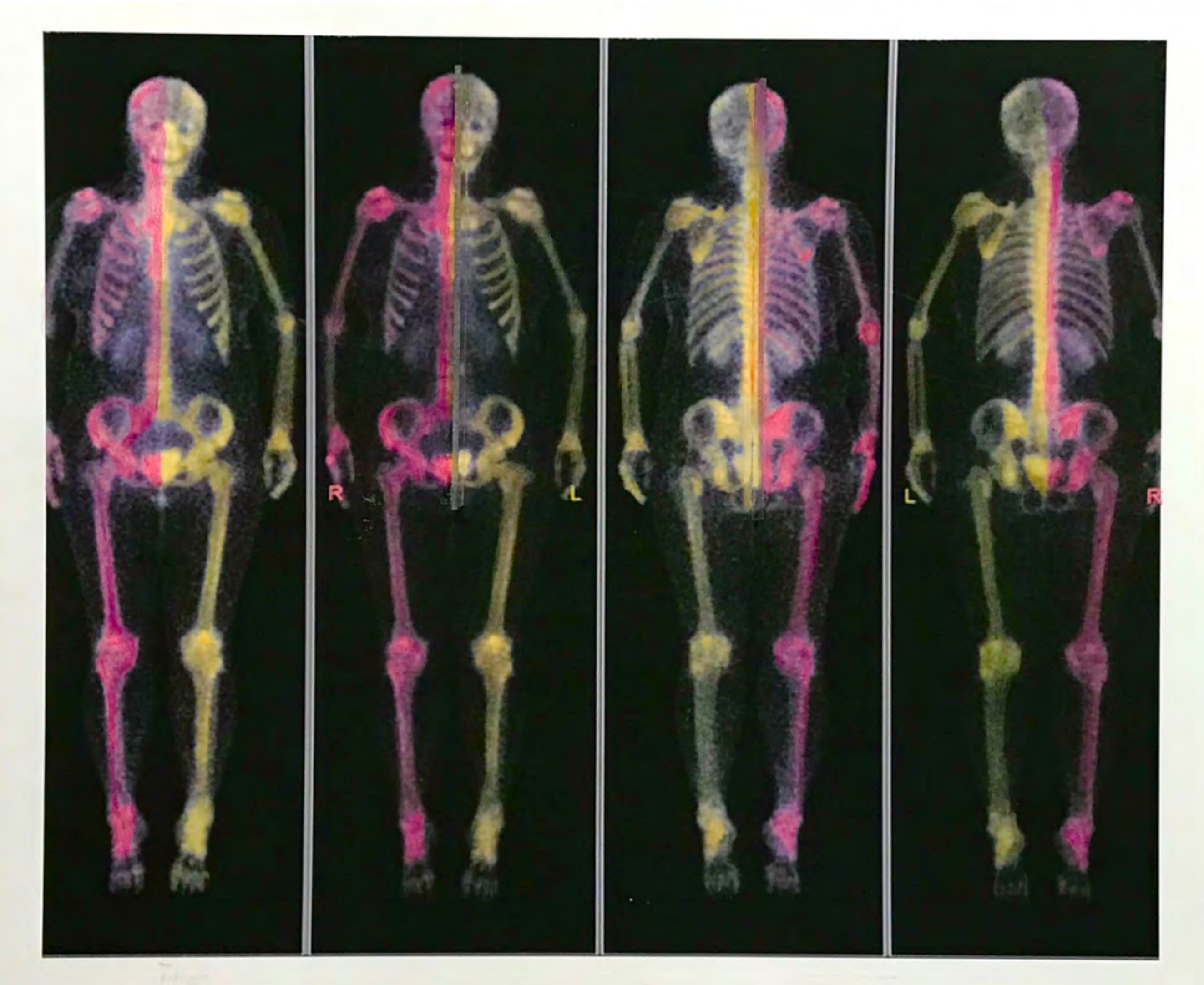

Figure 4: *Right, Left; Left, Right*, CC Hart, mixed media, 2018

Nikolic's 2011 research supports the concept that synaesthetic inducers do not operate solely within the sensorium, but are also anchored in semantic representations where ideas are activated by sensation. In Figure 4, I've colored a scintigraphy (bone scan) to match my sense of bodily proprioception as divided along the sagittal plane. In this configuration, I perceive the right side of the human body as inherently scarlet, and the left side as pale yellow.

In conclusion, for some synaesthetes, novel inducers are noted to provide a color concurrent. Additionally, synaesthesia, as a neurocognitive trait, appears to be more plastic than early studies reported. As researchers continue to expand scientific understanding of synaesthetic phenomena, exploring semantic inducers along with sensory inducers might foster a more detailed map of the synaesthete's interplay between cognition, sensation, and perception.

Acknowledgements

Thank you to Dr. Richard Cytowic, MD, PhD for encouraging me to pursue my interest in novel synaesthetic inducers. Our conversation in 2017 nudged me to reveal my perceptions of colored radiography. For this, I am grateful.

Thank you Dr. Paul Hsieh, MD, board certified musculoskeletal radiologist, for verifying the pathologies and injuries in Figures 2 and 3.

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References

Brang, D. et al. 2013. Impaired acquisition of novel grapheme-color correspondences in synesthesia. *Frontiers in Human Neuroscience* 30 October 2013 https://doi.org/10.3389/fnhum.2013.00717

Dixon, M. et al. 2004. Not all synaesthetes are created equal: Projector versus associator synaesthetes. *Cognitive, Affective, & Behavioral Neuroscience* 4 (3), 335-343

Mroczko, A. et al. 2009. Immediate transfer of synesthesia to a novel inducer. *Vision* 9 (12):25.1-8.

Nikolic, D. et al. 2011. Swimming-style synesthesia. Cortex. 47 (7), 874-879

Simner, J. et al. 2006. Synaesthesia: the prevalence of atypical cross-modal experiences. *Perception* 35, 1024–1033 7

Grey City: Queering chromatic architecture

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Abstract

The legacy of modernism has left contemporary architectural practice with a prevailing chromophobia, which limits the expression of diverse identities in the built environment. This paper originates from a stance that colour can be used as a queer architectural device, and outlines how modernism sought to erase queer colour and promoted the controlled use of 'architectural' colour. It argues that the written and designed work of Le Corbusier actively contributed to this, using his defacement of Eileen Gray's E.1027 as an example of the modernist erasure of queer colour. The concept of queer colour is then explained with reference to drag culture. The discussion is consolidated by linking back to the built environment, using David Batchelor's theory of chromophobia. This argument is concluded with the understanding that the modernist suppression of queer colour directly relates to the monotony of contemporary architectural practice, and that a greater appreciation for aesthetic diversity would be of great benefit to cities and their inhabitants.

Keywords: *Queer Colour, Architectural Design, Modernism, Postmodernism, Diverse Aesthetics, Chromophobia*

Introduction

Queer colour in architecture is a rarely discussed topic, but due to the pervasiveness of architecture in the daily life of almost all people, and the increased diversity of urban populations, the visible representation of diverse cultural aesthetics is important to consider. Owing to the persisting legacy of modernism in the built environment and in architectural discourse, vivid colour is often relegated to a state of inferiority and neglected in favour of white and a muted 'architectural' colour. By rejecting the chromophobic stance of the architectural industry, contemporary architects can begin to inject a visible queer identity through the use of vivid colour in otherwise grey cities. This paper argues for the understanding of queer colour as an architectural device which has been actively suppressed by the dominant modernist voices in mainstream culture, and which can be used as a tool of individual expression in the built environment. The increased visibility of queerness and other cultures has the potential to enhance the beauty in urban areas.

Discussion

In 1938, the modernist architect Le Corbusier painted a series of murals in the home Eileen Gray had built for herself a decade prior. Beyond actively destroying the architectural legacy of Gray, Colomina (1996) argues that this act should be interpreted as an assault on her sexuality by Le Corbusier. Gray was an openly queer woman and E.1027 was a representation of sapphic identity in the built form, from the approach taken to both isolation and disclosure, to its queer use of interior colour in the place of removable decorations. The colours themselves are difficult to determine, partly because there were no coloured photographs of the original piece, but more notably due to the vandalisation of the building by Le Corbusier. Studying the murals helps us understand Le Corbusier's view on Gray's sexuality, as their subject matter "takes on an objectifying male gaze, claiming male ownership of the sexualised sapphic body," according to Hedenskog (2022). Le Corbusier had a complex relationship to the murals, the building, and to colour as an architectural tool. Wigley (1995) recorded that a mural, to Le Corbusier, was an explosive tool with the power to destroy designed spaces. At the same time he valued Gray as a friend, spent much time in E.1027 and even built a small cabin overlooking the building. This is where he spent the last days of his life. The relationship Le Corbusier, as a male modernist architect, had to Eileen Gray, as a female, queer modernist architect, borders on obsessive; there is a need to analyse and evaluate her expression of identity, to both watch over and intervene in her work, in an effort to take control of the narrative. The erasure of colour using a graphic languagewas a way to deconstruct the visible queer traces left by Gray in the building, and this gives insight into the how queerness and colour has been actively erased by the modernist agenda.

Modernist colour

The obsessive need for control permeates Le Corbusier's approach to modern architecture, in particular as it relates to colour. Le Corbusier established his perspective on colour in multiple written works, and this was reinforced by his designs. In *L'art décoratif d'aujourd'hui,* Le Corbusier (1925) expressively denounced a hollow indulgence in colour, enabled by the ease of trade and travel, he had witnessed: "Colour for its own sake has really caught the imagination... What fashionable blacks, what striking vermilions, what silver lamés from Byzantium and the Orient! Enough. Such stuff founders in a narcotic haze." Instead, he argued for a purified, reason-based approach to colour in architecture, one that appreciated the dependability of the white wall. In the book, he outlines the 'Law of Ripolin', the promotion of a whitewashed architecture: "We have in us an unfailing imperative which is the sense of truth which recognises in the smoothness of ripolin and the white of whitewash an object of truth. The object of truth radiates power." Le Corbusier, and modernism, raised the status of white to top the hierarchy of colours, by projecting morality, truth and honesty upon it. In this way white becomes a separate entity, one of authority and control; it is simply *white,* not the *colour* white.

Of course, colour was still present in modernism, but it was carefully selected to enhance the pure appearance of the white wall, and was never indulgent. On the next step below white in the hierarchy of colour were the 'architectural' ones, those earth tones and muted colours endowed with the ability to "construct volume" when displayed alongside the white wall, as discussed by Wigley (1995). What constituted an architectural colour depended upon its physiological and psychological effect, coupled with the informed, controlled desire of the designer. Control was a central requirement among modernists, not to give in to the inebriating effect of vivid, saturated colour. These 'nonarchitectural' colours were given associations with a lower class, lack of sophistication, foreign cultures, femininity, and queerness, according to Batchelor (2000). These colours and their perceived users were relegated to a status of inferiority, consolidating the authority of modernist designers using white. Batchelor suggests that this school of thought still prevails in mainstream culture to this day, but that its associations with subculture is making colour increasingly attractive in higher echelons of society. Gorny and van den Heuvel (2017) observe that architecture, in particular, has been slow to accept visible queer expression in both education and practice, which makes framing the discussion of queer colour in these terms especially important.

Queer colour

Queer culture uses the inferior status of vivid colour relative to the mainstream culture as a tool of empowerment. As a disadvantaged group, queer people have historically used a vivid selection of colour to express a non-conforming identity, primarily in clothing and cosmetics. Architecturally, queer uses of colour have been limited to the safe interiors of the home, as seen in Eileen Gray's E.1027, or the night club, as exemplified by Studio 54. Hedenskog (2022) argues that because these spaces were secluded, out of sight, and inhabited by displaced people, a sense of belonging was found in a collective expression of difference through colourful artifice: neon lights, dramatically painted faces, theatrical ensembles. Artifice is usually considered to lack depth and meaning. It is a performative device with connotations to trickery or theatre, there is a sense of falsity which implies there is a truth being concealed. But in queer culture, artifice does the opposite; it reveals the true identity of its employer by giving a voice to the concealed self in the fundamentally queer act of *coming out*.

Queer colour is a cosmetic—it exists on the surface—but it carries a purpose beyond the perceived shallowness of make-up. Queer colour is an outlet for the expression of identity and culture, and a mechanism for survival. Batchelor (2000) notes that "there is perhaps no-one for whom make-up is more important than the drag queen." In the performance of drag, make-up is exaggerated with the use of bold strokes, contouring and vivid colours. This is similar to how it is used in theatre, but in drag it is often used to enhance masculine or feminine characteristics, as explained by Noniewicz (2020). It is a tool of transformation, of becoming, and of overcoming. Make-up, to the drag queen, is a question of existing or perishing, living or dying, which is perhaps no better exemplified than the fate of Venus Xtravaganza. The story was made visible in Jennie Livingston's documentary about the eighties New York City ball scene, *Paris is Burning* (1990), which concludes with Venus' murder. Venus used colour and artifice to construct a self which she fully owned, but it was also this visibility which made her vulnerable to predators, and ultimately led to her death. It is this vulnerability of visibly queer people which elevates colour (cosmetics, fashion, ornament) to a question of survival. Schweitzer (2016) argues that in queer culture, "fantasy is not an escape, but rather a weapon," and as such colour is used equally to celebrate difference as to defend the group.

Chromophobia

Batchelor speaks of a fear of colour, a *chromophobia,* present in the art and architecture industries, which largely stems from the modernist preference for white alongside a highly selective set of colours. A return to colour "threatens—or promises—to undo all the hard-won achievements of culture," according to Batchelor (2000). In the late 1970s, Postmodernism responded to the white wall with force, but Farrell and Furman (2017) point out that the movement lasted only about a decade. It became known as an architecture of artifice, in stark contrast with the disciplined sophistication of modernism, which has generated a wide range of opinion ranging from disapproving to adoring.

Postmodernism used colour to directly counter the monotonically grey cityscape produced by modernist architecture. It was also a response to a progressively developing world view at the time it emerged, and this aspect of postmodernism remains relevant to this day. It is part of the reason why contemporary architects wishing to tackle exclusion in the built environment may turn to postmodern influences, reinterpreting its stylistic and political devices for the present day. As a 'non-movement', this novel approach can be loosely referred to as *Multiform* design practice, so called because it refuses a common stylistic agenda in favour of taking on multiple, divergent forms of expression, but with a collective goal. This is defined by Hopkins (2021). Multiform resists the notion of conformity and the restrictive, one-dimensional nature of contemporary practice and it aims to produce a truly progressive architecture which allows and enables individual cultural expression. Countering the chromophobe discouragement of aesthetic diversity prevalent in the architectural industry, Multiform makes use of vivid colours and symbolic imagery to convey the rich cultural resources present, but often invisible, in society. The queer use of colour is central to this discourse, and the vibrant marks made by queer designers such as Adam Nathaniel Furman (figure 1) on otherwise concrete-grey cities are important to the increased acceptance of queer colour in planning and practice.

Figure 1. Adam Nathaniel Furman's colourful *Gateways* (2017) installation in Kings Cross injected a moment of joy in a grey public space. Photography by Gareth Gardner.

An aesthetic diversity, including queer colour and other cultural influences, has the potential to increase the sense of belonging felt by people living in urban areas. The Building Better, Building Beautiful Commission (2020) identified that beauty "is not merely a visual characteristic, but it is revealed in the deep harmony between a place and those who settle there." As such, to represent an increased diversity in the population, aesthetic diversity should be central to a contemporary understanding of beauty. Such an approach to urban design takes advantage of a fuller range of aesthetic expression than previously feasible, thus "the result can only be more beauty—an enhanced beauty," according to Ichaba and Akpa (2018). The sense of ownership fostered by creating beautiful urban spaces is of benefit to under and over-represented populations alike as people value and care for beautiful spaces to a greater extent.

Conclusion

Based on the evaluation of the modernist view on colour and the pervasiveness of chromophobia in architecture, it follows that a fear of colour in architecture and planning is part responsible for the erasure of queer identity in urban spaces. Recent efforts by young designers are beginning to counter the status quo by reintroducing Postmodernist influences through their practice. This has been referred to as Multiform design, and it directly responds to Le Corbusier's denouncement of ornament and colour by exploiting classical references, vivid symbolism and bold expression as architectural devices. The aim of this work is to communicate a non-conformity to the dominant culture, while resisting a prescribed stylistic agenda. Progressive architectural thought such as Multiform is relevant today as it is becoming increasingly clear that aesthetic diversity, including queer colour, is required to produce an inclusive and beautiful urban environment.

Acknowledgements

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References

Batchelor, D. 2000. *Chromophobia.* London: Reaktion Books.
Bonnevier, K. 2007. "Behind Straight Curtains: Towards a Queer Feminist Theory of Architecture." PhD diss., KTH Architecture and the Built Environment.
Building Better, Building Beautiful Commission. 2020. *Living with Beauty: Promoting health, well-being and sustainable growth.* London: Ministry of Housing, Communities & Local Government.
Colomina, B. 1996. "Battle Lines: E.1027." In *The Sex of Architecture,* edited by Agrest, D., Conway, P., Weisman, L.K. 167-182. New York: Harry N. Abrams, Inc.
Farrell, T., and A.N. Furman. 2017. *Revisiting Postmodernism.* Newcastle upon Tyne: RIBA Publishing.
Gorny, R., and D. van den Heuvel. 2017. "New Figurations in Architecture Theory: From Queer Performance to Becoming Trans." *Footprint* 11, no. 2: 1-10.
Hedenskog, J. 2022. "The Queer Architect: A tinted affair." *Saturated Space.* https://en.calameo.com/read/005989922d9ff3022071c.
Hopkins, O. 2021. "Introduction: What is Multiform?" *Architectural Design* 91, no. 1 (January/February): 6-11.
Le Corbusier. 1987. *The Decorative Art of Today.* Translated by James I. Dunnett. London: The Architectural Press.
Noniewicz, A. 2020. "The History of Drag and Its Influence on Fashion and Beauty." *The Avenue,* November 3. http://www.theavenuemag.com/beauty/2020/10/18/the-history-of-drag-and-its-influence-on-fashion-and-beauty.
Schweitzer, D. 2016. "Having a Moment and a Dream: *Precious, Paris is Burning,* and the Necessity of Fantasy in Everyday Life." *Quarterly Review of Film and Video* 34, no. 3: 243-258.
Wigley, M. 2005. White Walls, Designer Dresses: The Fashioning of Modern Art.

Colour modelling on a virtual display system- LEDSimulator

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Abstract

An appearance communication system for supply chain management, named LEDSimulator, was introduced in the previous two AIC conferences[1,2]. Some refinements, including hardware and software, were made to greatly improve its colour performance in terms of colorimetric accuracy, repeatability and reproducibility.

Keywords: *Total appearance, spectral tunable LED lighting, LEDSimulator*

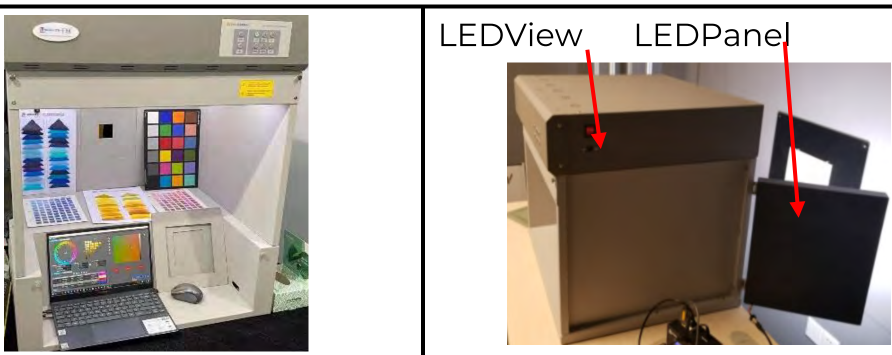
Introduction

LEDSimulator was designed to be an appearance communication tool in the supply chain of the textile industry. Its application included 3 stages: colour exploration, product design and development and manufacturing [1,3]. The journey starts in exploration when designers research trends that translate into fashion concepts. The outcome is colour palette, a collection of colours used for all garments. Colours identified are documented by referencing physical specification systems such as Pantone. Stage 2 is product design and development. Digital images generated in CAD software were used to create garment designs as choices for merchandise plans. As part of an editing process, merchandisers review these images either on displays or on digital prints to determine which designs will be included in the final product line. The final stage is manufacturing. It requires a small size colour standard from the dye lab at the mill together with a production dyeing recipe.

System Hardware

LEDSimulator includes two spectral tunable multiple-LEDs lighting systems. Figures 1a and 1b show the hardware of the system.

The one in front is a viewing cabinet (LEDView), which provides standard viewing conditions like typical viewing in a lab (capable of accurately simulating CIE D65\D50, TL84 and A illuminants) . And two light panels (LEDPanel) are in the back, forming a display system, for which two LEDPanels including red, green and blue lights illuminate a piece of white substrate. Hence, the coloured object (or virtual sample) viewed from an aperture in the back of the LEDView truthfully presented not only the colour but also the texture of a desired product. There is also a dark chamber in the back to avoid the interference of ambient lighting. The display system is based upon the colour mixing theories of additive (mixing coloured lights) and subtractive (reflected colours from surfaces). The system supplies a wide range of desired uncoloured substrates, and different sizes of aperture.



(a) Front view of the system (b) Side view of the system

Figure 1. Two views of the LED Simulator.

Hardware and software refinements

Some hardware and software refinements were made as summarized below. Hardware improvements mainly involve the following three aspects. Firstly, the design in several places was modified that might introduce systematic errors. These included the angle of LED panels, as well as substrate and light aperture positions. Now these variables are all fixed by special mechanical structures. The shading strategy in the darkroom was also modified. The integral, not strictly fixed, difficult to replace the shading cloth to separate, strictly fixed, easy to replace the shading material. Secondly, a standard set of texture substrates were provided for system testing and texture simulation. These substrates were carefully prepared for wet processing to ensure consistency. The resulting five substrates with different texture roughness numbered from 1 to 5 maintain texture consistency. Figure 2 shows ratings of standardized substrates in a psychophysical experiment that grades the roughness of 50 samples assessed by 20 observers.

In addition, some software changes were made to improve the operational efficiency. All exposed wiring was hidden and interfaces were left open, and the substrate backplane was changed so that users can quickly exchange substrates. The 11x11x11 LUT was adopted, replacing the 9x9x9 LUT, to reduce system error.

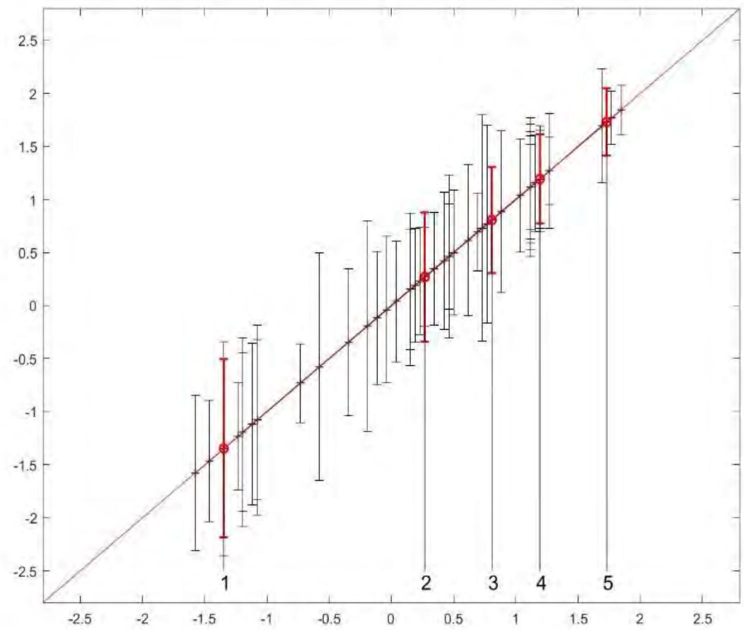


Figure 2. Standardized substrates (red bars) in an experiment that grading roughness of 50 samples.

Performance tests

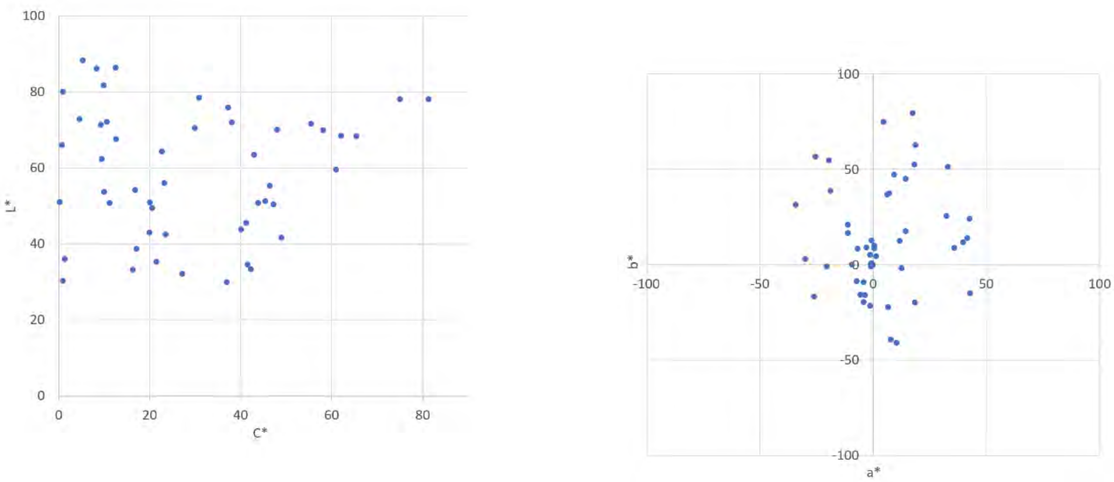


Figure 3. Fifty test samples plotted in (a) L^* C_{ab}^* plane and (b) a^* b^* plane.

In the following tests, two LEDsimulator systems were included. Under the condition of 7.5 cm aperture, all five substrates and light off at LEDview, fifty specially chosen colours were used to perform the tests (Fig.3). They covered a wide colour gamut and lightness range. Three tests were carried out according to 5 different substrates.

Accuracy test

To evaluate the accuracy of the colours of the samples reproduced by the system, the 50 targets in terms of L*, a*, b* values were input to the system and these were then transformed to RGB signals to illuminate the light on to the 5 substrates. These were then measured by a JETI-Specbos 1211 spectroradiometer. The colour difference in terms of CIEDE2000 units (. Eoo) [4] was calculated between the target and the measured. The results are summarized in Table 1. It can be seen the colour differences ranged from 0.26 to 0.35 with an average of 0.29 and a maximum of 0.98. This is a large improvement from the earlier version of 0.84 and the maximum colour difference was 2.03.

Repeatability test

To evaluate the repeatability of the same system used at different times, the 50 targets were measured twice. It can be seen the colour differences ranged from 0.22 to 0.26 with an average of 0.23 and a maximum of 0.73.

Reproducibility test

To evaluate the consistency when colours were transferred between two LEDSimulators, the average colour differences ranged from 0.33 to 0.38 with an average of 0.35 and a maximum of 1.28.

Performance(ΔEoo)	Texture 1	Texture 2	Texture 3	Texture 4	Texture 5	Total	Max
Accuracy	0.26	0.27	0.35	0.29	0.30	0.29	0.98
Repeatability	0.22	0.23	0.23	0.22	0.26	0.23	0.73
Reproducibility	0.33	0.37	0.38	0.33	0.35	0.35	1.28

Table 1. Performance of one LEDSimulator of all five substrates.

Light source effect

However, in real application scenarios, the light in LEDView would inevitably penetrate into the darkroom through the aperture in LEDView, also known as stray light effect. This results in a source of error to reduce accuracy of the system. So, efforts were made to compensate for the stray light. In the previous experiments, this was done under each lighting condition. Each lighting condition includes luminance level, and substrate, a special database. This approach is extremely time consuming. It takes about 30 minutes to complete such a setup. This means that for a typical experimental scenario with a substrate, it would take 270 minutes, i.e. 3 light sources x 3 luminance levels. This is considered to be unacceptable to the users. So, the stray light compensation strategy has been improved. Based on the assumption that the stray light on the substrate surface is linear, we only create a database for each material, and only measure the colour having primaries of [0,0,0] for the panel for different light sources and illuminance. The measured tristimulus values represent the stray light, i.e. for a perfect dark condition, these values should be [0,0,0]. This method greatly reduces the time of equipment calibration. Compared with the previous method, the time required to establish database and calibrate parameters for each substrate was reduced from more than 270 minutes to less than 60 minutes.

The accuracy performance in ΔE_{00} units of the new calibration method under conditions of three illuminants and two illuminance levels (Fig.4). It can be seen that under all conditions, the present calibration method showed much higher accuracy, which is far better than the performance of the previous system (0.8 ΔE_{00} units). Note that the present system's performances are considered to be highly satisfactory even compared with typical displays, having CIEDE2000 difference of about 0.5-0.8 units based on the GOG model [5].

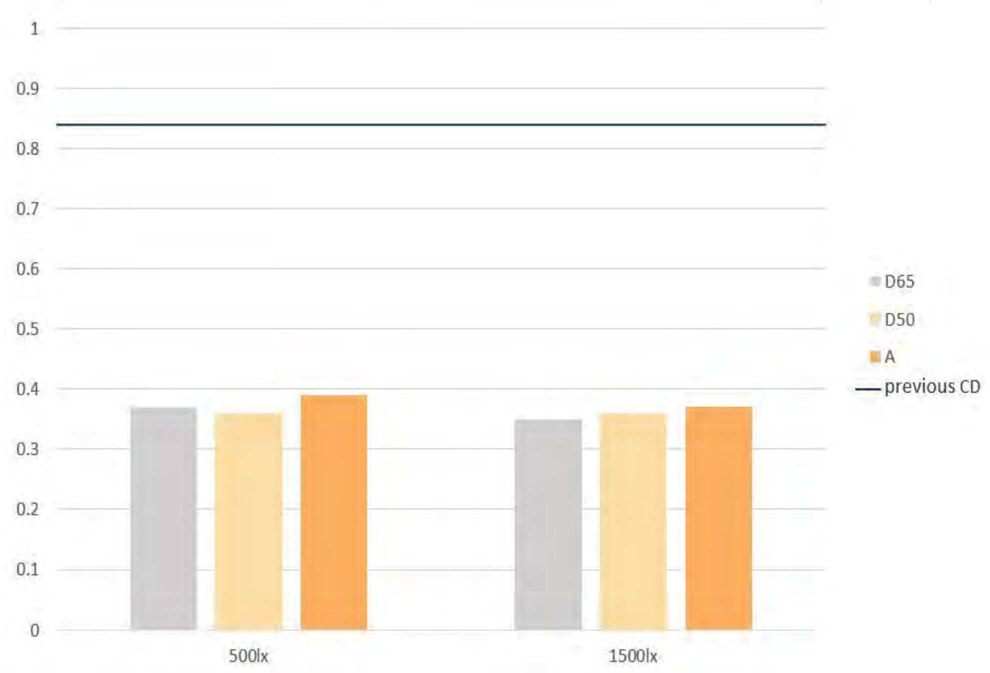


Figure 4. The accuracy of the new calibration method under different light sources, and illumination.

Conclusion

A computer system to achieve appearance reproduction for the supply chain was developed. The system workflow and hardware were first introduced. Then, some refinements made recently were described. Finally, a series of tests was conducted to show the system performance in terms of accuracy, repeatability, reproducibility and light source effect. The results are highly satisfactory to achieve the requirement for such a system.

References

C. He, J. Zhang, M. R. Luo. 2020. A Design Tool: Appearance simulator based on spectrum tunable LED lightings, *AIC2020 proceedings, Avignon, France*

J. Lin, K. Shi, M. R. Luo. 2021. Colour Performance Evaluation for LEDSimulator Technology, *AIC2021, Milan, Italy.*

Luo, M. R., K. Hoover, T. Huang, C. He, X. Zhang, J. Feng and J. Zhang. 2021. A total appearance reproduction for supply chain colour management, *J. Textile Eng. & Fash. Tech.*, 3:46-48.

Luo, M. R., G. Cui and B. Rigg. 2021. The development of the CIE 2000 colour difference formula, *Color Res. and Appl*. 26, 340-350.

Berns, R. S. 1996. Methods for characterizing CRT displays. *Displays* 16. 4:173-182.

Color Preference, Perception, and Its Flavors: Focus on A Snack Package

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Abstract

A product's packaging is an important vehicle to convey product information and branding at the point of purchase. Especially in food packaging, color is one of the critical elements in how people perceive these products and can affect the decision-making process. This study investigates color preference and its flavor and perception of healthier colors on five colors used in the market. Four questions were used to identify color preference when selecting an item to eat in snack food packages; the perception of snack flavors associated with the chosen color; the perception of healthier colors; and whether favorite colors impact the color preference for consumption among adults. The package samples were designed with computer-generated packages as a research method, and the survey was distributed to a Midwest university online. Approximately 800 people participated in the survey. Red was the color most preferred to eat, green is selected as the healthiest color to eat, and blue was selected as the overall favorite color.

Keywords: *Color, Preference, Perception, Flavor, Package Design*

Introduction

In general, a consumer "acts emotionally and compulsively, unconsciously reacting to the ensemble of colors, images, and designs, which in the subconscious are associated with the product" (Cheskin 1957: 62). Especially in food packaging, color is one of critical elements in how people perceive these products and can affect the decision-making process. A consumer makes color associations from the package with its flavor (Ares and Deliza 2010) and color is also known to be an element that influences perceptions and expectations of consumables flavor or how it will taste (Nyman 1983, Clydesdale 1993, Silayoi and Speece 2007, Spence 2015).

This study aims to investigate color preference when selecting an item to eat in the context of snack food packages, the perception of snack flavors associated with the chosen color, perception of healthier colors, and whether favorite colors impact the color preference for consumption among adults.

The survey was approved by the Internal Review Board at Iowa State University. The survey was sent to students, staff, and faculty at Iowa State University through

email. Therefore, the study relied on the participants' computer color calibration and browser settings, which would be one of the limitations of this study. Also, color's flavor can be impacted by culture (Spence 2015), and the majority of participants of this study are based in the Midwest in the USA. Therefore, the data could be limited, reflecting demographic diversity.
Following four questions (Kang et al. 2021) were asked about the five colors and the fourth question is new from the previous study done without packaging context:

1. Rank the color of the snack that you prefer to eat.
2. Identify flavors that you associate with the color.
3. Rank the color of the snack you think is healthier to eat.
4. Rank your favorite colors.

The collection of data and the sample sets of five colors shown in Table 1 are used from previous research done with children (Kang, Satterfield, Ladjahasan 2016).

	GREEN	BLUE:	YELLOW	PINK	RED
Samples					
CMYK	55,0,100,0	100, 95,16,40	0,24,100,0	0,70, 14, 0	2,100,94,0
RGB	127,194,65	42,54,12	255, 196, 11	241,114, 153	233,29,43

Table 1. Packaging showing on the screen and color specifications.

Table 2 shows the sample sets of five colors used to study participants' favorite colors from the previous research (Kang et al. 2021).

	GREEN	BLUE:	YELLOW	PINK	RED
Samples					

Table 2. Color showing on the screen and with the same color specifications in Table 1.

Data Analysis and Discussion

Demographic Information

Data results reflect 795 participants aged 18 and over who responded to the survey, and some participants did not answer some questions. Therefore only valid answers were used for the data analysis. Participation in the study was identified as 39% male and 60% female. Sixty-five percent were between 18 and 22 years old, and about nine percent were 23 to 28 years old. Similarly, 66 % of participants identify as undergraduates and eight percent as graduate students. 16 percent were staff, and about seven percent were faculty. Seventy-nine percent of participants indicated their ethnicity as white, about 11% as Asian / Pacific Islander, six percent as Hispanic or Latino, and about three percent as black or African American.

Healthy Color to Eat

Overall, green (48.6%) is selected as the healthiest color to eat, followed by yellow (23.7%), blue (13.2%), red (9.3%), and pink(5.2%). Also, there are no statistically significant differences in gender and ethnic groups between white and non-white groups in the order of choice.

Color Prefer to Eat

On average, red was the color most preferred to eat at 32.9%, followed by blue (24.6%), green(16.6%), pink(13%), and yellow(12.9%). Table 3 shows the gender differences in colors selected to eat. Females selected blue as the first choice, but the other four color choices were very similar, except yellow. While males chose red as the first choice, followed by blue, yellow, green, and pink, respectively. However, the difference between yellow and green as a first choice is not significant in frequency. Pink was the 5th choice for both genders; however, yellow and pink were tied among female participants.

Color	Green		Blue		Yellow		Pink		Red	
Gender	M	F	M	F	M	F	M	F	M	F
1st Choice	14.1	17.1	30.2	19.6	14.5	13.4	6.9	17.6	34.4	17.6
2nd Choice	17.9	22.7	23.7	23.2	17.6	20.9	8.8	11.3	32.1	11.3
3rd Choice	25.6	21.7	19.8	21.9	19.5	23.2	18.7	17.4	16.4	17.4
4th Choice	26.3	20.9	14.9	19.6	27.5	23.2	21.4	19.6	9.9	19.6
5th Choice	16.0	17.6	11.5	15.6	21.0	19.4	44.3	34.0	7.3	34.0

Table 3. Color selected to prefer to eat by gender (variance= percentage), n=669.

Overall, red was the first choice for all age groups; however, the second choice differed. The 18 to 22 years old group chose blue, pink, green, and yellow, respectively. The age 23 and the older group chose green, blue, yellow, and pink, respectively.

Favorite Color

Overall, blue (41.1%) was selected as the favorite color. Yellow (18.2%) and red(18.2%) were tied as the second choice followed by green (17.9%) and pink (12.4%). However, table 4 shows a difference between genders in the ordering of color choices. Both genders chose blue as the favorite color; however, more males preferred blue compared to females. Red is ranked second by males. Females chose pink as the second, but males selected it as the least favorite color. Yellow was the least favorite color chosen by males.

Color	Green		Blue		Yellow		Pink		Red	
Gender	M	F	M	F	M	F	M	F	M	F
1st Choice	20.5	15.6	46.5	38.0	6.2	13.4	1.9	19.1	24.8	13.9
2nd Choice	19.8	24.7	32.9	25.7	5.4	15.6	8.8	18.7	34.5	15.4
3rd Choice	32.2	22.7	13.6	17.6	22.5	18.4	18.7	19.1	22.5	22.2
4th Choice	19.8	24.9	5.0	12.3	36.0	22.7	21.4	16.1	12.0	23.9
5th Choice	7.8	12.1	1.9	6.3	29.8	30.0	44.3	27.0	6.20	24.7

Table 4. Favorite Color Choice by Gender (variance= percentage), n=661.

Correlations in Color Selection

The data was analyzed using the Pearson correlation (1 as the first choice and 5 as the fifth choice) to see the correlations among preferred color to eat, healthier color, and favorite color. Table 5 shows the significant positive correlations between preferred colors to eat and their favorite colors. For example, when participants selected the blue package as the first choice to eat, they chose blue as their favorite color. This trend is similar to green and pink, matching their second and third choices. However, when participants selected red as the fourth choice to eat, they chose it as the fifth favorite color, while yellow was the fifth choice to eat and the fourth favorite color.

	Green	Blue	Yellow	Pink	Red
Prefer to Eat / Healthy Color	.0.072	.0.052	.173**	.097*	0.069
Prefer to Eat / Favorite Color	.375**	.379**	.367**	.452**	.345**
Favorite Color/ Healthy Color	0.059	-0.017	. 117**	0.014	-0.032

Table 5. Pearson's Correlations in Color Selections.
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Only yellow and pink showed significant correlations between preferred to eat and healthy colors. When participants chose pink as their first preference to eat, they also selected pink as their favorite color. Yellow was the fourth choice for both preferred to eat and healthy color and this showed significant positive correlations.

Correlations between favorite color and healthy color are not strong except yellow. When participants chose yellow as the fourth choice as a healthy color, they also selected it as their favorite color.

Color and Flavor

Most participants perceived colors as a fruit for all five colors. Some participants answered taste rather than flavors even though the survey questions directly asked about flavors.

Forty-one percent of participants recognized green as green apple followed by lime (19.7%), mint (4.4%), salad/vegetables (3.5%), kiwi (2.8%), nuts (2.6%), respectively. Four percent of participants responded that green is sour.

Most participants recognized blue as blueberry (66%) or berries (5.1%). Interestingly, some (7.3%) of participants answered blue as chocolate or dark chocolate. A small number (1.6%) of participants answered blue as salty.
Lemon(39.4%) and banana (22.4%) were the top two flavors for yellow. Some participants answered peanut or peanut butter (5.5%) and honey (4.8%). Also, a small number of participants answered yellow as salty (1.5%) or sour (1.3%).
Pink is recognized as a strawberry (41.8%), followed by watermelon (8.9%), bubble gum (8.3%), raspberry (4.6%), pink lemonade (3.4%), and cotton candy (3.0%). Some participants perceive it as pink as sweet (4.7%).
Cherry (43.9%) and strawberry (15.4%) were the top two flavors for red. Some participants acknowledged red as chocolate(6.7%), apple (4.6%), or raspberry (3.0%). Three percent of participants identify red as spicy.

Conclusion

This study shows that the first ranked flavor matched with the previous research with children (Kang, Satterfield, Ladjahasan 2016). Blue as blueberry, green as apple, red as a cherry, yellow as a lemon, and pink as strawberry were highly identified among participants. A small number of participants answered green and lemon as sour, pink as spicy, and red as spicy. The flavors of four colors, green, blue, red, and pink, also match with the previous study without the context of packaging ((Kang et al. 2021). However, yellow was different from the previous study which recognized banana as the most recognized flavor.

This study showed most participants recognized color as fruits. Also, this study showed significant correlations between preferred colors to eat and their favorite colors. Especially blue, green, and pink showed significant correlations between preferred colors to eat and their favorite colors without the context of packaging (Kang et al. 2021) as well.

References

Ares, G., and R. Deliza. 2010. Studying 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. Online: https://doi.org/10.1016/j.foodqual.2010.03.006.

Cheskin, L. 1957. *How to predict what people will buy*. New York, NY: Liveright.

Clydesdale, F. M. 1993. Color as a factor in food choice. *Critical Reviews in Food Science and Nutrition*, 33:1, 83-101.

Hyman, A. 1983. The influence of color on the taste perception of carbonated water preparations. Bulletin of the Psychonomic Society, volume 21(2), 145-148.

Kang, S.R, D. Satterfield, and N. Ladjahasan. 2016. Color preference study on snack package design to children as a health communication strategy. In: *AIC 2016 Color in Urban Life: Images, Objects, and Spaces, Proceedings of the Interim Meeting of the International Colour Association,* Santiago: Ingrid Calvo Ivanovic, ed. University de Chile, 201-204.

Kang, S.R., C. Faber, N. Ladjahasan, and A. Quam. 2021. Color and Flavor Perception. In: *Proceeding of the Advances in the Human Side of Service Engineering. AHFE 2021. Lecture Notes in Networks and Systems*, Leitner C., Ganz W., Satterfield D., Bassano C. eds. vol 266. Springer, Cham. Online: https://doi.org/10.1007/978-3-030-80840-2_26.

Silayoi, P. and M. Speece. 2007. The importance of packaging attributes: a conjoint analysis approach. *European Journal of Marketing*, vol. 41, No, 11/12, 1495-1517.

Spencer, C. 2015. On the psychological impact of food colour. *Flavour*, 4,21. DOI 10.1186/s13411-015-0031-3.

Improvement of Color Feelings Prediction Formulas for the Estimation of Color Combination Feelings of "Kimono"

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Abstract

We examined the applicability of color feelings prediction formulas to the estimation of color combination feelings of "kimono." As a result, color feelings prediction formulas were found effective in estimating "contrast," "floridness," "warmth," and "pleasantness," but the estimation accuracy of "contrast" and "pleasantness" was lower than that of "floridness" and "warmth." Thus, this study aimed to derive color feelings prediction formulas that are more suitable for estimating color combination feelings of "kimono" by conducting a new evaluation experiment. To improve the color feelings prediction formulas for "contrast" and "pleasantness," we conducted multiple regression analyses using the evaluation results of "contrast" and "pleasantness" obtained in the present experiment as objective variables. We applied the improved formulas to the evaluation results in the previous study and calculated the correlation coefficients between the estimation and evaluation values. Statistical tests indicated that the population correlation coefficients of "contrast" and "pleasantness" were significantly higher after the improvement, and the effect of the improvement was confirmed.

Keywords: *Kimono, Color Feelings, Two-Color Combination, Color Feelings Prediction Formulas*

Introduction

"Kimono" is standardized clothing consisting of *nagagi* (ankle-length garment) and *obi* (sash belt). Therefore, its impression is influenced by elements, such as colors, patterns, and textures, rather than shapes. We have examined the applicability of the color feelings prediction formulas: Nayatani and Sakai (2009) to the estimation of color combination feelings of "kimono" by deeming "kimono" as a two-color combination of *nagagi* and *obi*: Katayama et al. (2022). As a result, the color feelings prediction formulas have been found effective in estimating "contrast," "floridness," "warmth," and "pleasantness," which are the basic emotional factors for two-color combinations: Nayatani et al. (1969), but the estimation accuracy of "contrast" and "pleasantness" is lower than that of "floridness" and "warmth." Thus, this study aimed to derive color feelings prediction formulas that are more suitable for estimating color combination feelings of “kimono” by conducting a new evaluation experiment.

Evaluation experiment of color combination feelings

The evaluation experiment of color combination feelings was conducted using the same equipment and procedure as the experiment done in the previous study: Katayama et al. (2022) in which the applicability of the color feelings prediction formulas to the estimation of color combination feelings was examined. We prepared illustrations of a woman wearing a “kimono” with two-color combinations by painting *nangi* and *obi* with different colors (Figure 1) and showed the illustrations to the observers using the LCD (EV2116W-A; Eizo). The correlated color temperature of the LCD’s white point was set to 6500 K. The distance between the LCD and the observers was ~60 cm. The viewing angle of the displayed illustration was 20°(vertical) × 7°(horizontal). The background of the illustration was an achromatic color equivalent to N5. During the experiment, lights were turned off, and the room was kept in semidarkness. We systematically selected 42 two-color combinations so that each estimation value of “contrast,” “floridness,” “warmth,” and “pleasantness” has an equal interval. The two-color combinations used in this experiment did not overlap with those used in the previous study.

Figure 1. Example of Illustration used In experiment

A total of 84 colors comprising 42 selected patterns of two-color combinations were displayed on the aforementioned LCD to measure colors using a color luminance meter (CS-150; Konica Minolta), and the measured values were converted to Munsell notation values (Figure 2). The two combined colors were connected by a dashed line. In Figure 2, the selected pairs of color combinations are evenly distributed in the Munsell color space. By distinguishing the inverted two-color combinations of *nangi* and *obi*, a total of 84 patterns were displayed. The observers evaluated "contrast," "floridness," "warmth," and "pleasantness" of the displayed stimuli based on a seven-point rating scale. After the observer completed his/her evaluation of all rating scales with respect to a color combination of "kimono," the next color combination was displayed after a 2 s interval (only the N5 background was shown). The color combinations of "kimono" were presented in random order.

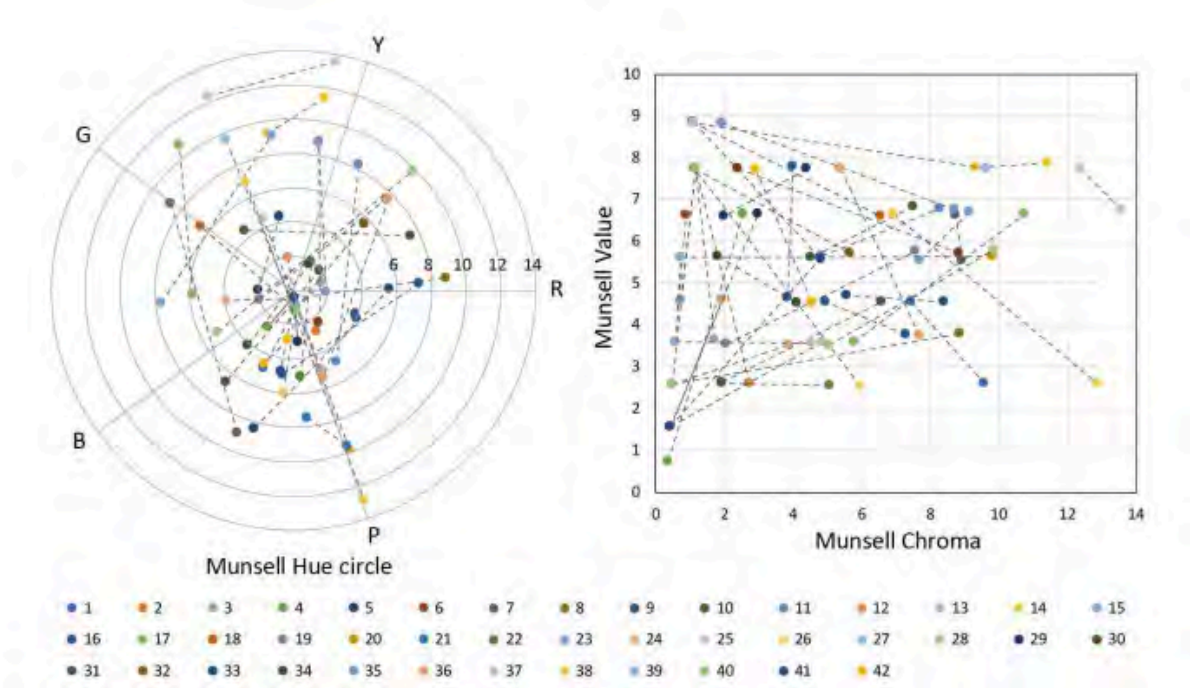

Figure 2. Two-color combinations used in the experiment.

The observers were students and faculty members of a "kimono" vocational school, comprising 44 females and 2 males whose average and median ages were 31.2 and 21 years, respectively. They had normal color vision and visual acuity (including corrected vision). Thirty of these observers also participated in the previous experiment.

Results and discussion

As in the previous study, the results of the evaluation experiment of color combination feelings done in this study reconfirmed that the estimation accuracy of “contrast” and “pleasantness” obtained by the color feelings prediction formulas is lower than that of “floridness” and “warmth,” as shown in Table 1.

		Evaluation results			
		Contrast	Floridness	Warmth	Pleasantness
Estimation values	Contrast	0.685 **	0.593 **	0.200	-0.160
	Floridness	0.740 **	0.854 **	0.549 **	-0.179
	Warmth	0.396 **	0.392 **	0.878 **	-0.223
	Pleasantness	-0.159	-0.061	-0.401 **	0.663 **

significance level **: 1%

Table 1. Correlation matrix for evaluation and estimation values.

To improve the color feelings prediction formulas for “contrast” and “pleasantness,” we conducted multiple regression analyses using the evaluation results (mean evaluation values) of “contrast” and “pleasantness” obtained in the present experiment as objective variables. In doing so, we made sure to follow the basic structure of the existing prediction formulas (explanatory variables).

The improved estimation value of the “contrast” factor is expressed as the sum of the color difference between the component colors, the value of the higher Munsell chroma among them, each Munsell value, each Munsell chroma, and the constant, as shown in Formula (1):

$$x_{c,AB} = a_0 + a_1 \Delta E_{AB} + a_2 C_{max,AB} + a_3 V_{nagagi} + a_4 C_{nagagi} + a_5 V_{obi} + a_6 C_{obi} \qquad (1)$$

where $x_{c,AB}$ is the estimation value of the “contrast” factor, a_0 is the constant, ΔE_{AB} is the color difference between the component colors based on the Godlove color difference formula: Godlove (1951), $C_{max,AB}$ is the value of higher Munsell chroma in component colors, $V_{nagagi\ or\ obi}$ is the Munsell value, and $Ninagagi_{or\ obi}$ is the Munsell chroma, respectively. Each coefficient in Formula (1) is shown in Table 2.

a_n	Value of a_n
a_0	2.55992
a_1	1.46091×10^{-2}
a_2	6.16753×10^{-2}
a_3	3.14791×10^{-2}
a_4	9.95241×10^{-2}
a_5	3.81768×10^{-2}
a_6	5.31982×10^{-2}

Table 2. Coefficients a_n in Formula (1).

The improved estimation value of the "pleasantness" factor is obtained by the multiple regression formula consisting of 11 explanatory variables, as shown in Formula (2):

$$x_{p,AB} = b_0 + \sum_{n=1}^{11} b_n x_{n,AB} \qquad (2)$$

where $x_{p,AB}$ is the estimation value of the "pleasantness" factor, b_0 is the constant, b_n is the partial regression coefficient, and $x_{n,AB}$ is the explanatory variable determined by the locations of the component colors in the Munsell color space and their combinations. The explanatory variables in Formula (2) are the same as the original ones, but the inverted two-color combinations of *nagagi* and *obi* are distinguished. The coefficients bn and the explanatory variables $x_{n,AB}$ are shown in Table 3.

b_n	Value of b_n	x_n	Constitution of $x_{n,AB}$
b_0	4.03187		
b_1	7.36728×10^{-4}	x_1	$Z_{1A}{}^2+Z_{1B}{}^2$
b_2	-2.58902×10^{-3}	x_2	$Z_{2A}{}^2+Z_{2B}{}^2$
b_3	-6.62406×10^{-5}	x_3	$Z_{3A}{}^2+Z_{3B}{}^2$
b_4	-7.97570×10^{-4}	x_4	$Z_{1A}Z_{2A}+Z_{1B}Z_{2B}$
b_5	-4.16145×10^{-4}	x_5	$Z_{1A}Z_{1B}$
b_6	2.59670×10^{-3}	x_6	$Z_{2A}Z_{2B}$
b_7	2.08958×10^{-6}	x_7	$Z_{3A}{}^3+Z_{3B}{}^3$
b_8	-2.17954×10^{-5}	x_8	$Z_{1A}{}^2Z_{3A}+Z_{1B}{}^2Z_{3B}$
b_9	2.15518×10^{-6}	x_9	$Z_{3A}{}^2Z_{1B}+Z_{1A}Z_{3B}{}^2$
b_{10}	-6.10836×10^{-6}	x_{10}	$Z_{3A}{}^2Z_{2B}+Z_{2A}Z_{3B}{}^2$
b_{11}	2.66140×10^{-7}	x_{11}	$Z_{3A}{}^2Z_{3B}+Z_{3A}Z_{3B}{}^2$

$z_{1,i} = C_i\cos\theta_i$

$z_{2,i} = C_i\sin\theta_i$

$z_{3,i} = 8.33V_i$, i = A, B

The subscripts A and B represent *nagagi* and *obi*, respectively.

Table 3. Coefficients bn and explanatory variables xn,AB in Formula (2).

To check the effects of improvements on the prediction formulas, we calculated simple correlation coefficients between the evaluation values obtained from the previous experiment and the estimation values obtained by the modified prediction formulas. Consequently, before and after the improvement, the simple correlation coefficient for “contrast” improved from 0.64 to 0.81, and that for “pleasantness” improved from 0.54 to 0.70. Statistical tests indicated that the population correlation coefficient of “contrast” and that of “pleasantness” were significantly different at the 1% level before and after the improvement.

Then, after normalizing the estimation and evaluation values for the 84 displayed stimuli to mean 0 and variance 1, we calculated the similarities using the multidimensional scaling method and showed the results on a two-dimensional plane (Figure 3). The corresponding estimation and evaluation values for “contrast” and “pleasantness” were connected by arrowed dashed lines, and the correlation coefficients were described in the figure. In Figure 3, the estimation and evaluation values for both “contrast” and “pleasantness” were closer on the two-dimensional plane, and the similarity increased due to the improvement of the prediction formulas.

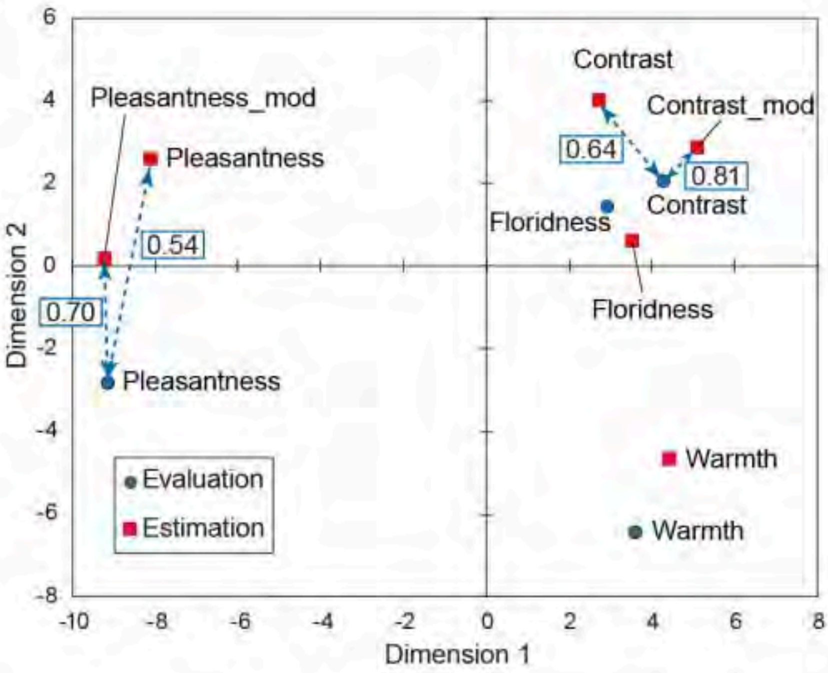

Figure 3. Result of multidimensional analysis.

Conclusion

To improve the color feelings prediction formulas for “contrast” and “pleasantness,” we conducted multiple regression analyses using the evaluation results of “contrast” and “pleasantness” obtained in the present experiment as objective variables. We applied the improved formulas to the evaluation results in the previous study and calculated the correlation coefficients between the estimation and evaluation values. Statistical tests indicated that the population correlation coefficients of “contrast” and “pleasantness” were significantly higher after the improvement, and the effect of the improvement was confirmed.

References

Godlove, I. H. 1951.Improved color-difference formula, with applications to the perceptibility and acceptability of fadings. *Journal of the Optical Society of America* 41: 760-772.

Katayama, I., S. Noguchi, R. Takata, and K. Segawa. 2022. Application of colour feelings prediction formulas to the estimation of two-colour combination feelings of “Kimono”. *Journal of the International Colour Association* 29: 11-21.

Nayatani, Y., and H. Sakai. 2009. Proposal for selecting two-color combinations with various affections. Part 1: Introduction of the method. *Color Research and Application* 34: 128-134.

Nayatani, Y., A. Tsujimoto, C. Asano, S. Machihara, J. Ikeda, S. Namba, H. Sobagaki, and M. Hirata. 1969. An analysis of affective values on three-color harmony by the semantic differential method. *Farbe* 18: 1073-1081.

The Symbolism of Colour for Gen Z. Visual Communication Through Images and Hashtags

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Abstract

Sociologists have identified Generation Z as a group of people born after 1996 who do not know a world without digital devices and virtual communication platforms. Equipped with phones, they document their lives on an ongoing basis, taking photos and sharing them on social networking sites. Today, Generation Z is largely made up of students who divide their time between the real world and the reality of electronic media.

The paper is intended to present the results of an experiment conducted with second-year undergraduate students of the Faculty of Design at the Academy of Fine Arts in Krakow, in the winter semester of the academic year 2021/2022, as part of the colour fundamentals course. The aim was to find out to what extent colours have a semantic value for them, used in interpersonal communication, and how the visual message is complemented by the verbal message. For 2 weeks, students were assigned the task of looking for the particular primary colour - red, yellow, blue or green - in their surroundings. They documented the examples they found by taking photos with a smartphone or camera and then posted them on a specially prepared profile on Instagram, complementing them with hashtags of their choice. Within each colour, a set of hashtags was created and those that were repeated at least three times were used to create basic categories of meaning attributed to the analysed colours.

Keywords: *Colour Symbolism, Colour in Social Media, Colour Education*

Introduction

According to Michel Pastoureau, there is no universal system of colour meaning, it is strictly rooted in the context of a given era and culture. Pastoureau argued strongly with the statement presented by Johannes Itten that 'The laws of colour are eternal, absolute, timeless, as valid in the past as at the present moment', emphasising that the interpretation of colour changes regardless of the fact that the physical characteristics of a phenomenon may remain the same, Pastoreau (2014: 203).

In order to confront this thesis with the audience for whom the use of images is now the primary method of communication, the assignment 'The Symbolism of Colour for Gen Z. Visual Communication Through Images and Hashtags' was started in October 2021. The project involved 25 students (18 females and 7 males). The participants had to deal with one of 4 primary colours: red (7 people), blue (7 people), green (6 people) and yellow (5 people). All students were tested for correct colour vision, using the online version of the test https://www.colorblindnesstest.org/cambridge-color-test/ .

During the project, more than 800 pictures were taken, from which the final selection was made: 213 concerning red colour, 184 blue colour, 190 yellow colour and 280 green colour. The photos were grouped thematically and supplemented with key words marked with hashtags. Some of the photos were published on Instagram on the profiles: colourday_red, colourday_blue, colourday_green and colourday_yellow. Based on the collected material, an attempt was made to determine the map of meanings that the 4 primary colours have for the participants of the experiment.

Selection of colours and gathering of examples

The choice of primary colours - red, blue, green and yellow - was based on the principles used in the Natural Colour System and included four of the six primary colours (W, S, Y, R, B, G), whose selection by the system's authors was derived from the theories of Ewald Hering, Bergström (2008: 11). It was also in line with work on the history and symbolism of colours by Michael Pastoureau. The colours white and black were also considered, but after the initial trials, the scope of the work was limited to the colours of high chromaticity, collected in the area of the colour wheel. The division used by Johannes Itten and Wassily Kandinsky into 3 primary colours (red, blue and yellow) and three secondary colours (green, violet and orange) underestimates, in Pastoureau's opinion, the importance and symbolism of the colour green. The colour ranges corresponding to the names yellow, red, blue and green were determined based on the NCS colour wheel.

Due to the ease of collaboration and communication, the students worked in groups of three or four – there were 8 such groups – two for each colour. The task to collect images was not particularly easy, as primary colours are quite rare in our surroundings. Krakow, like many other European cities, is dominated by shades of beige, white, off-white, grey and brown. The exception is green, which as the natural colour of vegetation appears in many different hues and saturation. Students were asked to collect examples in the format of photographs, which could be either documentary or arranged, or they could use photos they had taken before. Each picture could be tagged with any number of tags, relating to the meaning of the colour and the iconic values of the image. The tags associated with each image were analysed within each colour. To indicate the most popular associations - a set of tags that were repeated at least 3 times was selected.

Blue colour

Figure 1. Blue - examples of images and hashtags collected by team 1 (I. Budzowski, M. Król, G. Kuczyński).

The group working on the blue colour turned largely to photographs taken during holiday trips. During the two-week search, the most common subjects of the photos were elements connected with Krakow's visual identity - the city's colours are blue and white. In other cases, the colour blue is extremely rare in Krakow's landscape. A total of 178 photos were collected and described with 295 hashtags. We have identified 8 major categories of meanings associated with the colour blue:

- **#communication**: #brand #sign #information #mark #logo #bank #business #media
- **#Krakow:** #tram #community #transportation #police #city #together
- **#sustainability:** #bottles #paper #recycling
- **#travel:** #holidays #sea #sky #natural #ice #night #light #clear #cold #winter #cosmos #atmosphere #lake #ocean #river #globe #mountains #UE #Greece #Scandinavia
- **#technology:** #electronics #internet #social media #twitter #facebook #cyberspace
- **#health:** #laboratory #hospital #masks #sterility #dentist #pandemic #cleanliness
- **#feeling:** #sadness #harmony #innocence #melancholy #chill #rest #depression
- **#food:** #chocolate #sugar #mozzarella #feta #fish #milk #dairy #water
- **others:** #ink #porcelain #jeans #suits

Red colour

Figure 2. Red - examples of images and hashtags collected by team 2 (M. Oprych, K. Popiół, M. Piwowarczyk, M. Michałkowska).

Red has proven to be a very rare colour in Krakow, as it is not used in façades nor in architectural details. Reserved for warning signs, advertising and packaging, it also appears in the colours of cars. For this reason, the students decided to carry out a photographic session in the studio, which was supposed to present an area of meaning connected with emotions, beauty and femininity. Also the meaning of red as the colour of food products, turned out to be one of the most important messages. 213 photos were taken and marked with 264 hashtags. Ten main themes were identified:

- **#emotions** #love #passion #heart #courage #care #excitement
- **#beauty** #elegance #femininity
- **#energy** #fire #warmth #heat, #excitement #speed #dynamics
- **#national** #state #Poland #flag #patriotism #communism
- **#luxury** #quality #class #sale #consumerism #buy #buy-me #wealth
- **#celebrations** #festival #Christmas #gift #joy #Santaclaus
- **#food** #spice #wine #peppers #tomatoes #ketchup
- **#attention** #warning #stop #blood #fight #danger #pain #sin #revolution #death #war
- **#nature** #rose #blooming #ripe
- **#east** #China #exotics

Yellow colour

Figure 3. Yellow - examples of images and hashtags collected by team 1 (F. Klechowski, J. Biernacik, R. Baszczyńska).

The group dealing with the colour yellow focused mainly on two categories, which they called 'will get your attention' and 'optimism'. Also this group emphasised that the colour yellow is relatively rare in urban environments and therefore works well in warning and crisis situations. 190 photos were taken and tagged with 218 hashtags. Seven main categories were identified:

- **#attention** #information #warning #gas #coronavirus
- **#liquid** #tasty #juicy #flavour #healthy #sour #liquid #ripe #beer #lemon #fruit #citrus
- **#light** #lamp #energy #warm
- **#nature** #sun #summer #autumn #sunny #vacation
- **#gold** #rich #metallic #precious #art #alchemy
- **#building** #home #family #wood
- **#childhood** #optimism #joy #smile #fun #toy

Green colour

Figure 4. Green - examples of images and hashtags collected by team 2 (J. Kaczmarczyk, Z. Karczewska, K. Dynek).

The groups dealing with greens were very positive about the experience of documenting this colour. The students emphasised the ease of finding green elements, as well as the fact that the objects tended to be stable and static, which made them easier to photograph. At the same time, they fully agreed with Kandinsky's statement 'Absolute green, which is the most restful colour in existence, moves in no direction, has no corresponding appeal, such as joy, sorrow, or passion, demands nothing. This persistent lack of movement is a quality which has a quieting effect on the tired souls of men, though it becomes tiresome after a time.' (Kandinsky, 1977: 65). 280 photos were taken, tagged with 345 hashtags from which 10 categories were identified:

- **#nature** #life #plants #spring #jungle #grass #growth #cells #algae
- **#fruit** vegetable #mint #herbs #vegetable #nuts #freshness #avocado #cumbers
- **#ecology** #ecosystem #veganism #planet #recycling #bio #eco #organic
- **#medicine** #health #healing #hygiene #hospital #cleanliness
- **#publicspace** #architecture #community #pathway #cooperation #fence #transport #trash
- **#safety** #childhood #motherhood #youth #kindness #family #tradition #comfort #home
- **#army** #military #camouflage #defense
- **#money** #hazard #banknotes
- **#rest** #break #holidays
- **#information** #exit #safety #logo #signal #pictogram

Conclusions

After gathering a collection of photographs and analysing the meanings of primary colours, the students' task was to consult Michael Pasteurau's series of books on the history of colours (Pastureau, 2001, 2014, 2017, 2019). A comparison of the students' independently collected meanings and the history of colour symbolism was the subject of a discussion on the system of meanings attributed to colour and how these have changed in successive epochs. The illustrative material collected by the students was published on Instagram and presented in an exhibition at the Academy of Fine Arts in Krakow in November 2021.

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References

Kandinsky., W. 1977. *Concerning the Spiritual in Art*. London: Dover Publications Inc.
Pastureau, M. 2001. *Blue. The History of a Color*. Princeton and Oxford: Princeton University Press.
Pastureau, M. 2014. *Green. The History of a Color*. Princeton and Oxford: Princeton University Press.
Pastureau, M. 2017. *Red. The History of a Color*. Princeton and Oxford: Princeton University Press.
Pastureau, M. 2019. *Yellow. The History of a Color*. Princeton and Oxford: Princeton University Press.

Pixel-based colour image object detection in fashion

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Abstract

An image-to-image Generative Adversarial Network was trained to classify each pixel of an input fashion image according to 5 categories of objects. A total of 1600 images were used as training images and a correctly labelled image was generated manually for each of these training images to use as target output for the network. The network was trained for 100 epochs and this took approximately 200 hours of computation time. Some evidence was produced to show that the trained network was able to generalise by correctly classifying the pixels of images that were not used during the training process. The application of such a network was demonstrated in terms of automatically generating colour palettes that represent garments in an image. This work provides a route to accurately generate colour palettes that represent garments from a huge number of images and this may be a useful tool in colour forecasting processes which are increasingly using large numbers of fashion-related images as inspiration.

Keywords: *fashion, machine learning, colour imaging, colour forecasting*

Introduction

Colour is essential in fashion products. With substantial technological innovations in textile and clothing production, most colour forecasting firms began to expand in the 1960s and 1970s (Cassidy, 2019). Traditional ways of colour forecasting, which depend on intuition and experience, may need to adapt to changes to manufacturing and retail models in Industry 4.0. Forecasters are increasingly looking to derive inspiration from the huge number of fashion images available online. As a result, image analysis for fashion colour forecasting is being explored. For example, EDITED, a fashion forecasting company, applied artificial intelligence to capture colour insights from fashion runway images (DuBreuil and Lu, 2020). Artificial intelligence approaches derived from computer vision have been frequently seen in the literature (Al-Halah *et al*., 2017; Chakraborty *et al*., 2020; Lai and Westland, 2020). However, the actual implementation of using artificial intelligence to fashion colour forecasting still faces challenges.

Even though researchers are increasingly using fashion images in colour forecasting, most studies now primarily focus on fashion catwalk images (Zhao *et al*., 2021). In trickle-down fashion procedures, top fashion designers or authorised fashion brands usually determine colour selections (Holland and Jones, 2017).

Fashion shows are the leading resource of trend insights for mass markets and consumers, but stylists also draw street style inspiration from current fashion markets (Mbonu, 2014). It is also worth considering trends inspired by street fashions found on social media. Street-style images are more varied than catwalk images since they may include complex backgrounds, different model positions, or many models in a single image.

Separating clothing-related information from images is another challenge. In 2015, Vittayakorn *et al*. (2015) proposed an approach for calculating RGB values on pose-dependent garment pixels using the foreground binary mask. Deep learning algorithms have been utilised in more recent experiments to overcome the obstacle of segmented clothing; for example, Mask R CNN object detection (Zhao *et al*., 2021). Han *et al*. (2021) used Macro-Micro Adversarial Network to differentiate garments and models in images and measure only clothing-related pixels. However, the model performs poorly in removing hair-related data. Emerging technologies are being applied to solve challenges in fashion trend forecasting with image data. A pre-trained object detection network (DenseNet) has been combined with unsupervised machine learning to obtain colour insights from fashion runway images (Lai and Westland, 2020). Logistic regression also can be seen in fashion trend research (Chakraborty *et al*., 2020). Convolution deep-learning neural networks may be useful to obtain visual features from fashion runway images (Lin and Yang, 2019).

This study uses a small number of images based on the tag 'street style' as a pilot study to explore a novel way to extract colour insights from images. Designers were hired to perform pixel-based annotations; that is, to classify every pixel in each image with one of five classes (skin, hair, accessories, clothes and null). A Generative Adversarial Network GAN was used to generate the annotated images from the original images. Isola *et al*. (2017) recommended GAN's pix2pix function to tackle the image-to-image challenge.

Methods

A total of 2000 images defined as raw data were collected based on the tag 'streetstyle' online from Google. Data cleansing was applied in the data preparation process. Blurred and irrelevant images were removed from the collection. All images in the annotation task are the same size (512 x 256 pixels) and only a single person per image (see Figure 1). Designers were hired to perform pixel-based annotations. An annotated image was generated from each original image so that each pixel was assigned one of five colours corresponding to one of the five classes: skin, hair, accessories, clothes and null (see Figure 1). A total of 1600 images were randomly selected from the 2000 original images to be used as a training set. The remaining 400 images were retained as a test set.

A MATLAB implementation of the pix2pix image to image translation network was used (Isola *et al*., 2017. The network takes an original image as the input and attempts to generate the paired annotated image as the output. The network was trained using the 1600-image training set for a total of 100 epochs. During each epoch, each of the images in the training set is presented to the network in turn and changes to the network were made so that the output more closely matched the target output. The network was implemented on an Apple MacBook Pro (M1 Pro Chip, 32GM) and took approximately 190 hours.

Figure 1. Example images from the 2000 images used in the study.

Figure 2.
Example of the pixel-based annotations process.

Results

Figure 3 shows an example of the performance of the trained network on one of the images from the training set. Note that the ability of the network to accurately categorise each pixel in the image appears to be quite good (though in this case the network fails to classify the pixels of the glasses correctly and also fails to correctly classify the straps of the handbag).

Figure 3. Example performance of the trained network for one of the training images showing (a) the original image (left), (b) the actual output of the network (centre) and (c) the target output image (right).

Machine learning is useful, however, because of the ability to generalise and perform on previously unseen input. Figure 4 shows an example of the performance of the trained network on one of the images from the test set. Note (Figure 4) that the trained network is able to successfully identify the pixels of the face mask as an accessory (this was the class used by the designers for face masks when generating the annotated images.

Figure 4. Example performance of the trained network for one of the test images showing (a) the original image (left), (b) the actual output of the network (centre) and (c) the target output image (right).

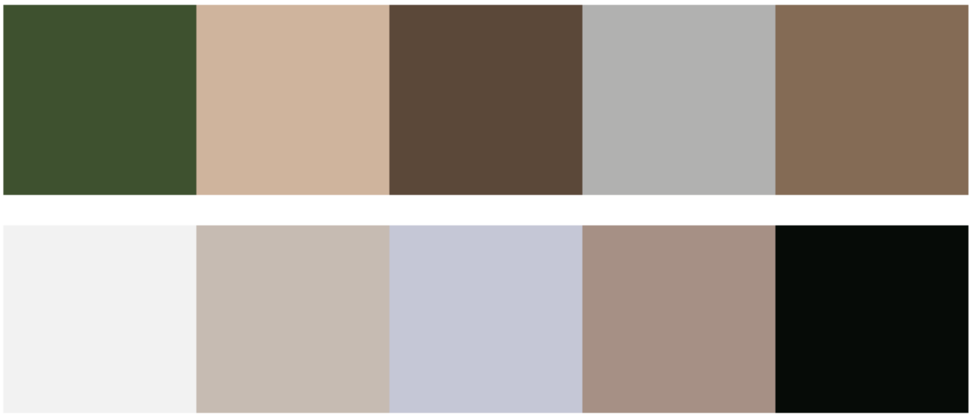

Figure 5. The top row shows the colour palette extracted from the original image (left) in Figure 4 using a k-means clustering algorithm; the bottom row shows the colour palette extracted using the same algorithm but based only on the pixels that are classed as garments according to the network output (Figure 4, centre).

Future work will quantify the proportion of pixels that are correctly classified in the training and test sets and explore how this is affected by the number of epochs for which the network is trained. However, Figure 5 presents an example of how the trained network could be used to extract colours palettes that represent garments in an image.

Discussion

A neural network was trained using 1600 pairs of images and used to classify each pixel of an input image according to 5 object categories. This work provides a potential route to accurately generate colour palettes that represent garments from a huge number of images and this may be a useful tool in colour forecasting processes which are increasingly using large numbers of fashion-related images as inspiration.

References

Al-Halah, Z., R. Stiefelhagen, and K. Grauman. 2017. Fashion Forward: Forecasting Visual Style in Fashion. *Proceedings of the IEEE International Conference on Computer Vision*, 388–397.

Cassidy, T.D., 2019. Colour forecasting. *Textile Progress*, 51 (1): 1-137.

Chakraborty, S., S. A. Hoque, and S. F. Kabir. 2020. Predicting fashion trends using runway images: application of logistic regression in trend forecasting. *International Journal of Fashion Design, Technology and Education*, 13 (3): 376-386.

Han, A., J. Kim, and J. Ahn. 2021. Color Trend Analysis using Machine Learning with Fashion Collection Images. *Clothing and Textiles Research Journal*: p.0887302X21995948.

Holland, G. and R. Jones. 2017. *Fashion Trend Forecasting.* London: Laurence King Publishing.

Isola, P., J. Y. Zhu,T. Zhou, and A.A. Efros. 2017. Image-to-image translation with conditional adversarial networks. In *Proceedings of the IEEE conference on computer vision and pattern recognition*: 1125-1134.

Mbonu, E., 2014. Fashion design research. Hachette UK.

DuBreuil, M. and S. Lu. 2020. Traditional vs. big-data fashion trend forecasting: an examination using WGSN and EDITED, *International Journal of Fashion Design, Technology and Education:* 10.1080/17543266.2020.1732482.

Vittayakorn, S., K. Yamaguchi, A.C. Berg, and T. L. Berg. 2015. Runway to realway: Visual analysis of fashion. In 2015 IEEE *Winter Conference on Applications of Computer Vision*: 951-958.
Lin, Y. and H. Yang. 2019. Predicting Next-Season Designs on High Fashion Runway. In KDD '19: *International Workshop on Fashion and KDD*, August 2019, Anchorage, AK. ACM, New York, NY, USA: doi/10.1145/1122445.1122456.
Zhao, L., M. Li. and P. Sun. 2021. Neo-Fashion: A Data-Driven Fashion Trend Forecasting System Using Catwalk Analysis. *Clothing and Textiles Research Journal*: p.0887302X211004299.

Inhabiting Art

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Abstract

The aim of this paper is to present a conceptual strategy related to the use of colour in architecture, and its practical application. When we speak about "Inhabiting Art", we talk about an approach that depicts the passage from the two-dimensionality of the canvas to what Le Corbusier called the "La promenade architecturale", the experience of space in three dimensions over time.

This journey starts from a new concept of colour that the philosopher Gilles Deuleuze (2007) describes as the "Pictorial Diagram", which emerges on the way to abstraction in art. Theo Van Doesburg, one of the members of the neoplasticism movement, initiates this approach in architecture; from its first steps of the Café Aubette to the "Maison Particulière" models, he develops a true manifesto of "Inhabiting Art". We created a reading tool to be able to "read the unwritten" and the multitude of factors that intervene in its decoding, which we named the *Neoplasticist Tabulae*. Ultimately we performed an intervention in the ceilings of the halls of the Universidad Politécnica de Madrid. Based on the painting "House in Gdansk" by the German expressionist Erich Heckel from the Thyssen-Bornemisza collection, we carried out the intervention "The Expressionist Ceilings at the School of Building Engineering, Universidad Politécnica de Madrid. Finally, we define the "Expressionist keyboards", as a range of beautiful colors extracted from the world of art that can be used in any architectural project.

Keywords: *Colour, Architecture, Painting, Colour Tabulae, Colour Keyboards*.

Introduction

One of the aims of this paper is to shed light on the way in which perception of colour unfolds in architectural spaces, when related to Art. To map out when colour becomes an architectural means, how people can be affected when going from the perception that arises in a two-dimension support, to the fourth dimension of architecture, and thus having a role as a trigger of human experience. Following the enactive tradition started by Merleau-Ponty (1945), perception can be considered as an embodied action and an embodied cognition. Therefore, when we speak of colour in architecture and colour surrounding men, we stop talking about an attribute of things and we start talking about an experience, in which thought, perception and actions are intertwined (Varela et AL, 2011; Noé, 2017).

Our argument starts from a different concept of colour. We have looked in the recent past for the turning point of its meaning, when the traditional role of colour in art lost its role and became an ineffective discourse (Hughes, 2009). This transformation originated at the end of the 19th century during the so-called Modernity period. As a result, colour stopped being used purely for aesthetic and decorative purposes, abandoning its traditional descriptive and symbolic meanings.

The French philosopher Giles Deuleuze (2007) locates this landmark change into the path to abstraction with the appearance of the “Pictorial Diagram”. It’s a moment when both descriptive and narrative aspects are drastically transformed: the faces are not pink any longer, -Matisse, Van Gogh -, the landscapes with defined contours and shapes -Kandinsky, Heckel-, cottony skies -Munch-, and people lose their recognizable features -Kirchner-. Ultimately when what is being said cannot be “read” or “seen”. Thus, a new use of colour in architecture emerges. Regarding the aim and the mode pursued, colour loses its decorative and symbolic conditions, becoming a constructive tool and giving it a key role in the vanguard movements (Hughes, 2009).

From the two-dimensionality of the canvas to the *Promenade Architecturale* in Van Doesburg’s work

In the valley of the Somme, the structure of language was broken. World War I changed the life of words and images in art, radically and forever. The central myth of the traditional Vanguard that, by changing the order of language, art could reform the order of experience and thus alter the conditions of social life, was extraordinarily alive for the next 15 years. The home of the utopian impulse is architecture, social art par excellence, being German expressionism, French purism and Dutch neoplasticism by the hand of their architect-painters, those responsible for the landing of painting in architecture, turning color into a constructive tool, playing a key role in the "the house of Utopia" project (Hughes, 2009).

The De Stilj group manipulates painting as an open plastic element and architecture as a closed plastic element and conceives a new use of color, erasing the limits between both disciplines (Rüegg,1994). They articulate a new purpose in the use of color that we call "Inhabiting Art". At first, architecture is used as a canvas, as in Van Doesburg's Aubette café (fig.1) and Rietveld's Schoeder house. Until the step is taken that goes from the two-dimensionality of the canvas to the fourth dimension of architectural space-time that requires a journey that Le Corbusier called "Promenade Architecturale".

Figure 1. Café Aubette in Strasburg. 1927. Theo Van Doesburg

The Floating Relationships in Van Doesburg's Architecture

In 1918, Van Doesburg had contrasted the capacity of architecture as a "closed plastic element" with its natural counterpoint, modern painting, which according to its own logic was capable of creating an "open plastic element" of colored planes. "Architecture brings together and unites, gives unity; painting dissolves and disunites. And precisely because each fulfills different functions by their nature, they can unite and link harmoniously. This connection or harmonious link is not reached by their characteristics of similarity, but by their characteristics of difference". In any case, the complementarity between form and color was still not achieved, nor the binding relationship between colors functionally and tectonically, says Rüegg (1994).

In May 1923, the architect and painter Van Doesburg moved to Paris to work on a large exhibition on house and space for Leonce Rosenberg, and to prepare the manifesto for the De Stijl exhibition in his galleries in the fall of 1924. At the center of the exhibition, which opened on October 15 at the galleria L' Éffort Moderne, were the models and plans of the three houses made in collaboration with the architect Cornelius Van Esteren. These houses were presented as free plastic entities, creating an abstract effect. The “Maison Particulière” (Fig 2) was an example of the logical collaboration between color and form according to the definition of Neoplasticism, characterized in particular by its orientation towards all sides and the uncompromising union of volumes and space. Color is used with a logic of its own, that of the artist in the form of two dimensional accents, which, however, were carefully related to the form of the house, he points out Rüegg (1994).

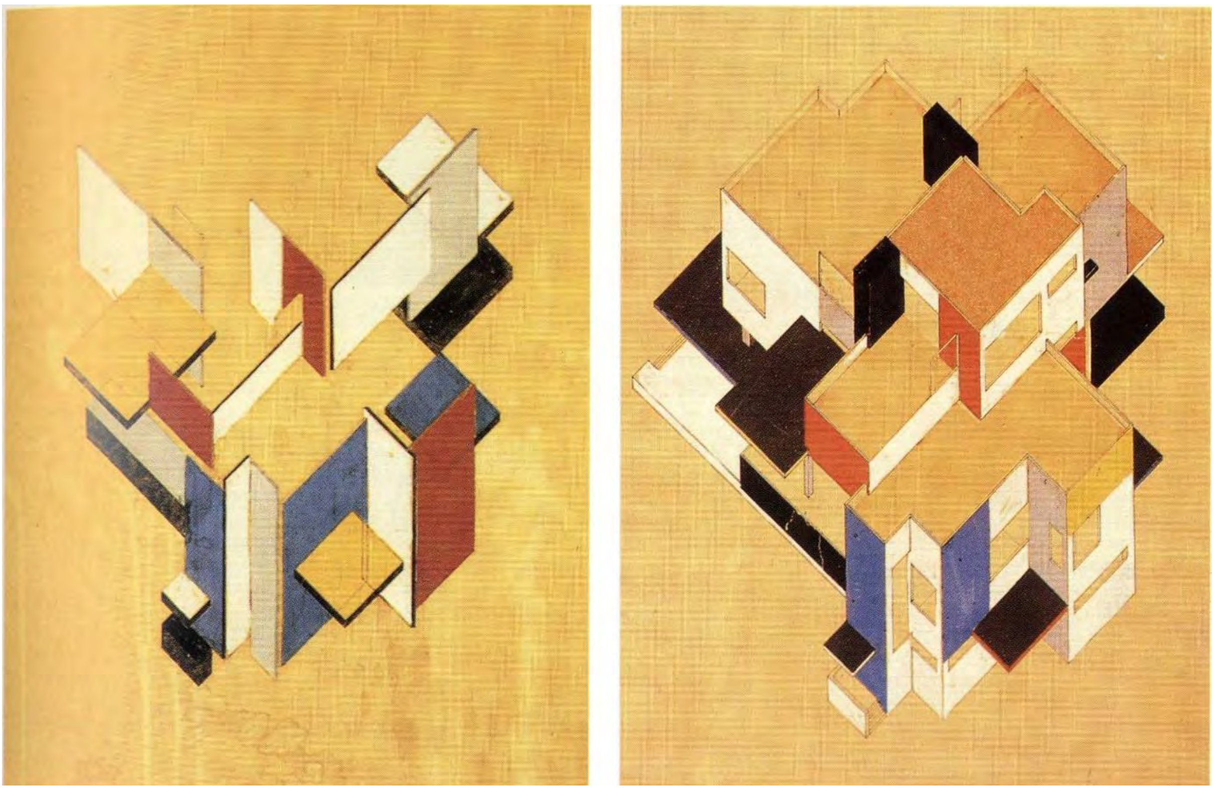

Figure 2. “La Maison Particulière” models. 1923. Theo Van Doesburg and Cornelis Van Eesteren.

On the one hand, the walls are covered with gray, yellow, red and blue, being bordered by a yellow lintel. Only black and white are used to cover structural elements at the corners: the remaining color planes collide with each other at the edges and corners so that the voluminous effect of the structural body is destroyed. The "closed plastic element" that forms the architecture of the piece is visually fragmented, dissolved and hidden by the superimposition of a color system. The colored planes are brought into a floating relationship with each other, as Siegfried Giedion pointed out. The result is a purely visual work that can be related either to a specific location or to a functional regularity. Form and color are understood as equals. As Arthur Ruëgg argued, in De Stilj's architecture, "It was not opposition but the opposite, co-incidence of special plasticity and color; it was not construction, but de-construction, that became an example”.

Van Doesburg, from his de-constructive operations, manages to make color independent in such a way, with a conceptual support, of the architectural form, that he gives it a protagonism never seen before. He manages, from my point of view, to materialize Deuleuze's Pictorial Diagram (2007) in architecture, opening a field in which art and architecture come to relate to each other from a totally new and unexpected place. And this is the core of this article, to present a strategy that, initiated by Van Doesburg in the 1920s, initiates the possibility of a relationship between color from the pictorial and architecture, opening the way to highly complex architectural perceptive experiences of color. The pictorial color acquires an independence from the two-dimensional support, to become a constructive medium in the spatio-temporal dimensions of architecture.

The Neoplasticism Tabulae: "Inhabiting Art"

In the process of researching neoplasticism discourse, in order to develop a new color strategy, we are forced to a double reflection: the relationships between the intervening actors make a direct reading of the chromatin landscape of this period of Modernity difficult. On the other hand, we must establish correspondences with the perceptive experience of color that takes place, that structures and explains it (Lopez-Izquierdo, 2012).

Figure 3. The Colour Neoplasticism Tabulae: "Inhabiting the Art". Dr. Lopez-Izquierdo (2012).

As Walter Benjamin said, we are forced to "read the unwritten", to design a tool that allows us to establish reading fields: we turn to images the data, knowledge, thoughts, places that make up the cultural and social environment of the moment. We borrowed the concept of Tabulae from Aby Warburg, an "operative field of the dissimilar and the mobile" says Georges Didi-Huberman (2010), where everything can always start again and allow a personal reading, as many readings as visitors who look at this device.

We designed the Neoplasticism tabulae (Fig. 3) as a tool for the application of color, based on the purpose of Inhabiting Art. This tabulae or reading device allows us to move from the pictorial experience of the canvas to the perceptive experience in the four dimensions of the "Promenade Architecturale ". spatio-temporal relations - of architecture (Rüegg,1997).

The Expressionists Ceilings at the School of Building Engineering/Universidad Politécnica de Madrid

Finally, we present a project implemented in the lobbies of the School of Building Engineering/Universidad Politécnica of Madrid, which we have entitled "Inhabiting Art". (Fig. 4 and 5).

Figure 4. The Expressionists Ceilings. Color planes and keyboards. Escuela Superior de Edificación. 2021. Dr Pia Lopez-Izquierdo.

We selected Heckel's work for several reasons; one of them is the lively, energetic, and dynamic chromaticity of his painting, which allows us to "transform the reality" of the space as the architect Bruno Taut did in his residential buildings in Berlin in the interwar period. As it was necessary to give life and use to some rather dark school halls, we found the workHouse in Gdansk" very appropriate. We used opposite and complementary schemes, choosing always very saturated colours. On the other hand, the intention of German expressionism to transform social reality through the language of art, only accentuates and justifies the need to change the environment, to encourage meetings and work groups of students studying at school. Finally, another reason is the relationship that the university has with the Thyssen Museum in Madrid, which makes it ideal to base it on one of the paintings in its collection, reinforcing the ties between the two institutions.

Starting with the expressionist painting “House in Gdansk” (1908 by Erich Heckel (Thyssen Museum, Madrid, we began a process of graphic interpretation and volumetric synthesis (fig. 4; we defined the established limits that contain the painting and depicted the central movement and the aerial elements with the blue tones. In short, we made a pictorial experience through color in the lobbies of the School of Building Engineering in Madrid -ETSEM, moving from the two dimensions of the canvas to an architectural experience in the spatial-temporal relationships of architecture, breaking the usual limits of the canvas as a traditional support for art. (Fig. 5)

Figure 5. The Expressionists Ceilings at the ETSEM/UPM. The project. 2021. Dr Pia Lopez-Izquierdo.

Finally, we define the Expressionist color keyboards (Rüegg,1997 formed by the beautiful colors extracted from Heckel's palette, as those that can be used in any architectural project; we standardize and classify this palette referring its sensory characteristics to the nomenclature of the Swedish NCS system (Fig.4.

References

Didi-Huberman, G. 2010. *Atlas, ¿Cómo llevar el Mundo Cuestas?* Madrid: Museo Nacional Centro de Arte Reina Sofía.

Hughes, R. 1991-2009. *The Shock of the new, Art and the Century of Change*. United Kingdom: Thames and Hudson Ltd.

Rüegg, A. 1997. *Le Corbusier -Polychromie Architecturale*. Basel: Birkhauser.

Rüegg, A. 1994. *Colour Concepts and Colour Scales in Modernism*. Dadailos n°51, March: 66-70.

Varela, F. J., E. Thompson, and E. Rosch. 2011. *De cuerpo presente: Las Ciencias Cognitivas y la Experiencia*. Humana. Barcelona: Gedisa.

Intra-observer differences in the perceived colour of colorimetry using tablet devices

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Abstract

To measure the perceived colour of architecture, it is preferable to use an easy-to-carry device. Therefore, in the previous research by Tsuda et al., a method for measuring the perceived colour using a tablet device was proposed. In that study, the inter-observer differences by the colour measurement method in architecture using a tablet device has been examined, whereas intra-observer differences were not confirmed. The purpose of this study is to conduct an experiment to verify the degree of intra-observer differences by letting one observer measure the perceived colour for the same conditions multiple times. We conducted the experiment under the same conditions of correlated colour temperature (CCT) for ambient lighting, display, and spotlighting, all of which had small inter-observer differences in the experiment of Tsuda et al. As a result, the intra-observer differences were smaller under the conditions at CCT of 6500 K than those of 3000 K. Thus we concluded that the colour measurement method using the tablet device is suitable under daylight with a high colour temperature.

Keywords: *Colour Measurement, tablet device, the perceived colour, intra-observer difference*

Introduction

Colour in architecture can be categorized into three types: psychophysical colour, which is the colour under standard illuminant, colour under actual lighting, which is affected by the lighting of the place, and perceived colour, which is the colour that people actually see due to the effects of adaptation and contrast. Tsuda et al. have proposed a measurement method of the perceived colour in architecture using a tablet device and verified its validity in the previous paper (Tsuda et al. (2021)). In order to examine the validity of this colour measurement method, it is necessary to consider and compare both the inter-observer differences and the intra-observer differences. This is because, when multiple observers with different receptors measure the perceived colours, the inter-observer difference should fall within a certain range, and when one observer with the same receptor measures colour, the intra-observer difference is expected to fall within a narrower range than the inter-observer difference. The study by Tsuda et al., confirmed that the inter-observer differences became smaller in the case that correlated colour temperature (CCT) of incident light when entering the experimental room (hereinafter called “ambient CCT”), CCT on the display of the tablet device (hereinafter called “display CCT”), and CCT of incident light when evaluating the target (hereinafter called “spot CCT”) were all the same. The purpose of this study is to confirm the degree of intra-observer differences of the colorimetry method using a tablet device, by letting an identical observer measure the perceived colour for the same conditions multiple times,and to compare the inter-observer and intra-observer differences.

Experimental method

The experimental space was a dark room whose size was 3000 mm in width, 3000 mm in depth, and 2400 mm in height. The interior walls, ceiling, and floor in the room were painted with N9.5. The observers’ eye level was 1450 mm in a sitting position and the distance between the target presented on the wall and the observer's eye was 500 mm. The size of the target was 87 mm in height and 87 mm in width, and it was presented in the center of a square background whose size was 257 mm in height and 257 mm in width. The target was illuminated from an angle of 45° to the wall surface (Figure 1).

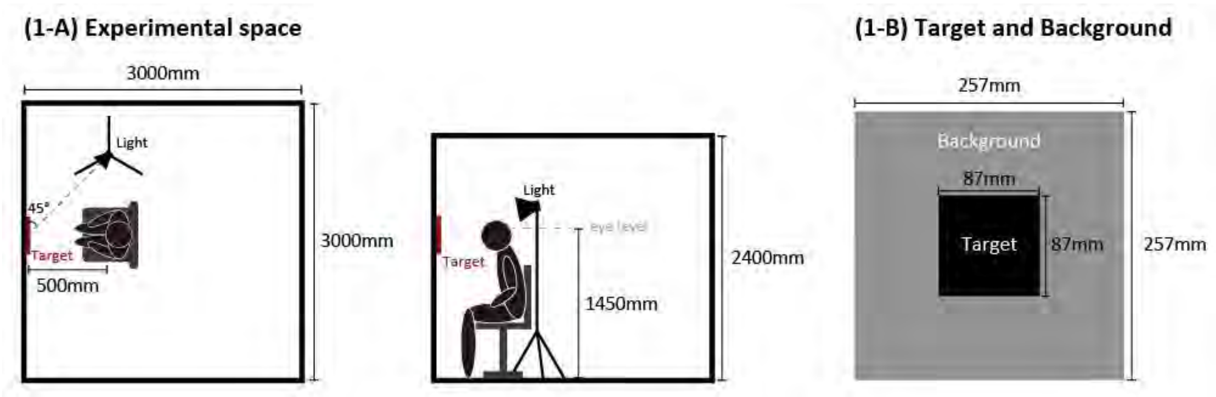

Figure 1. The experimental space (left) and Target and Background (right).

In this experiment, we had the observers evaluate only when the ambient CCT, the display CCT and the spot CCT were the same. The previous experiment conducted by Tsuda et al. confirmed the inter-observer differences under these conditions were small. The experimental factors and their levels were 1) ambient CCT, display CCT and spot CCT (hereinafter called “CCTs”): 3000 K and 6500 K, 2) illuminances on the target: 50 lx and 1000 lx, and 3) the target colour: N9.5, N7, 8YR 9/2, and 9PB 7.5/3 (Figure 2). The background colour of the target was N5. The observer was one person with normal colour vision in her twenties. Since this observer did not participate in the inter-observer experiment of Tsuda et al., the same conditions as those in the Tsuda et al. experiment were also evaluated.

Figure 2. The target colour.

First, the observer adapted to the experimental space for 10 minutes. Secondly, the observer observed the target colour for 20 seconds, then, looking into the black box, adjusted the colour on the screen of the tablet device, whose size was 178.5 mm in width and 125.3 mm in height, to the one that was perceived to be the same as the target colour. They adjusted the colour by manipulating the bars of hue, lightness, and saturation on a colour chart software (flat palette; Tokyo Cartographic CO., LTD.). Then, the experimenter recorded the perceived colour selected by the observer. This process was repeated for a total of 4 conditions that were the combinations of the experimental factor 1) and 2) and each target colour was evaluated 20 times for each condition.

Result and Discussion

Examination of colour difference

Intra-observer differences for each lighting condition were calculated (Figure.3). The vertical axis shows colour difference ΔE (= a*b* Euclidean distance between observers' evaluation) and the boxplots with their maximum, upper quartile, median, lower quartile and minimum values were presented in the graphs.

Figure 3. Intra-observer differences of colour evaluation for each target

As a result, the intra-observer differences were smaller for CCTs at 6500 K than at 3000 K. When these CCTs were at 6500 K, the median ΔE ranged from 0.6 to 3.7, from the colour tolerance classification (Handbook of Color Sciene (2011)), the intra-observer differences for CCTs at 6500 K is within the colour discrimination threshold, so these differences are acceptable. On the other hand, when they were 3000 K, the median ΔE ranged from 5.5 to 12.4, which was a large difference compared to 6500 K.

Comparison of 95% confidence ellipses of the perceived colour distribution between inter-observer and intra-observer

In order to confirm the extent to which the perceived colours evaluated by inter- and intra-observers spread, by referring to the previous paper (Oicherman et al. (2008)), 95% confidence ellipses were created for both the intra-observer experiment conducted in this study and the inter-observer experiment by Tsuda et al. (Figures 4 and 5). Under the conditions of 6500 K for CCTs, the intra-observer 95% confidence ellipses fall within the inter-observer 95% confidence ellipses for both 50lx and 1000 lx on the target. In contrast, under the conditions of 3000 K for CCTs, the intra-observer 95% confidence ellipses fall within the inter-observer 95% confidence ellipses when the target illuminance is 50 lx, however, at 1000 lx, the intra-observer 95% confidence ellipses deviate significantly from the inter-observer ellipses to the blue.

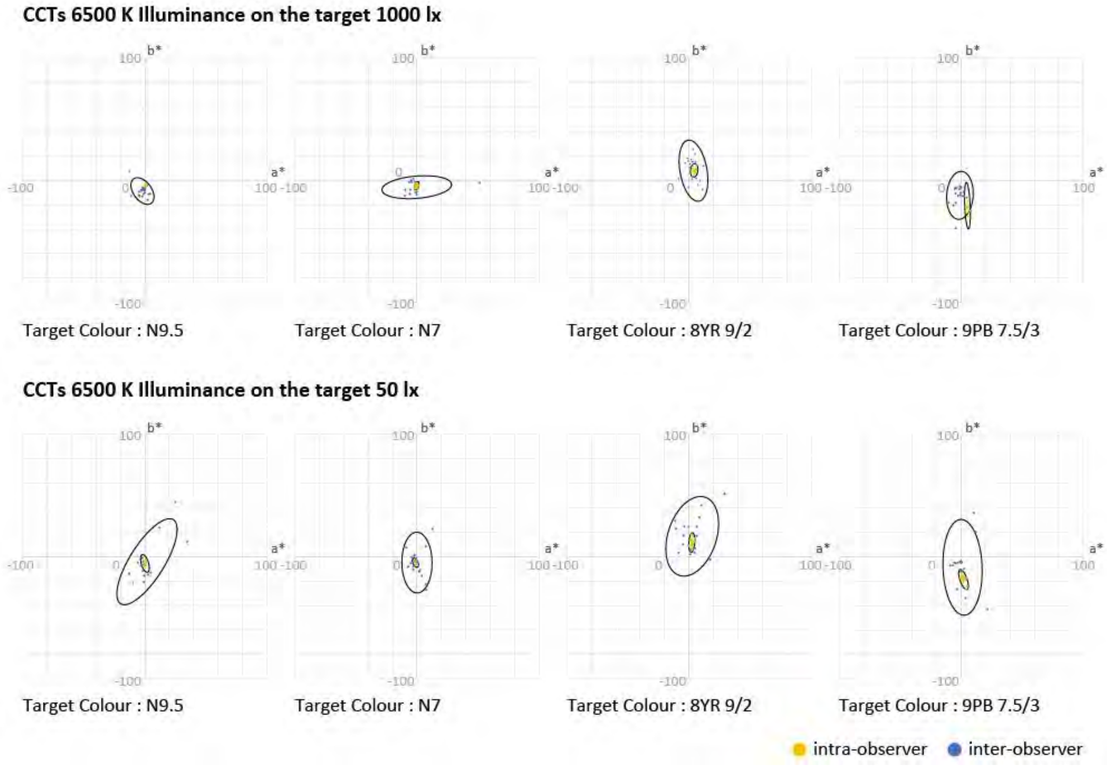

Figure 4. 95% confidence ellipses of the perceived colour distribution at 6500 K for CCTs.

Figure 5. 95% confidence ellipses of the perceived colour distribution at 3000 K for CCTs.

This means that, although there are differences to some extent in the perceived colour evaluated by individual observers due to the differences in individual receptors, the perceived colour measured by one observer is included in a certain small range within that range (6500 K for CCTs, illuminances on the target: 1000 lx and 50 lx, 3000 K for CCTs, illuminances on the target: 50 lx). There is a possibility that the large difference between the two ellipses, when CCTs were 3000 K and illuminance on the target was 1000 lx, was due to the characteristics of this observer's receptors, or some flaw of the experimental data.

Conclusion

When the colorimetry method with a tablet device proposed by Tsuda et al. was used to measure colour by a single observer under conditions of 6500 K for CCTs, the intra-observer difference in perceived colour was within an acceptable range. Thus we conclude that this colorimetry method with a tablet device can be used in bright spaces illuminated by daylight or other lighting with high colour temperature. In this study, the intra-observer experiment was conducted by only one observer, by referring to the paper of Alfvin et al. (1998). However, we would like to conduct further studies with more observers in consideration of individual receptor characteristics.

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References

Alfvin, L. R., and M. D. Fairchild. 1998. Observer Variability in metameric color matches using color reproduction media. *Colour research and application* 22 (3): 174-188.

Oicherman B., M. R. Luo, B. Rigg and A. R. Robertson. 2008. Effect of observer metamerism on colour matching of display and surface colours. *Colour research and application* 33 (5): 346-359.

The Color Science Association of Japan. 2011. *Handbook of Color Science (Third Edition (in Japanese*: 593, Japan: University of Tokyo Press.

Tsuda, H., A. Takei, Y. Oe, K. Kitamura and N. Yoshizawa. 2021. An evaluative study on perceived colour measurement method in architecture using tablet devices. *Journal of the International Colour Association*: 26, 49-58.

Emotional association of colors through participant's delineation of their present state of mind paired with specific color tones

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Introduction

Why is it that when we say someone is sad, they're blue, if they're in love it's reds and pinks? Cultural color associations have been studied thoroughly and well documented. This research aims at understanding if these colour associations also apply when an individual is experiencing a certain emotion. Not only if the association exists but if there is a visual correlation with the intensity of the emotion felt.

Take for example the feeling of being 'anxious.' This emotion can exist in both a negative or positive state of mind. Our methodology allowed participants to rate how energized and pleasant they were feeling in the moment. This allowed us to compare the colors of a single emotion and determine how the intensity of said emotion would compare visually. If a participant was experiencing 'Joy' at its highest rating would it differ visually from another participant's interpretation of 'Joy' at a lower rating?

Numerous studies have been conducted on the connection between colors and emotions. We found the approach to many of these studies to be flawed. In Kaya (2004), they gauged color emotion relationships using written color names rather than paint chips. We believed this methodology to be flawed because any one tester might imagine a different shade or hue from another study participant. Studies (Fugate, 2019) that did offer color chips to choose from would include a variety of tints and shades but the scope of the color swatches was limited. This seemed to be a disservice to the results as there is a wide variety of tints and shades in every color. This insight is what motivated us to include a color picker in the survey that we distributed.

Methods

Given that this study was conducted during the pandemic we determined that a survey distributed digitally would be the best. We distributed the survey digitally in the hope that we would find a greater number of diverse participants. The survey was promoted on several social media channels. Numerous survey platforms were investigated and it was determined that JotForm was the best option for our intended purpose because it had a user-friendly color

After answering questions about their demographic details, participants were shown two slides. The first asked them to self-identify how calm or energized they were from 0 to 10. The second asked them to rate how unpleasant or pleasant they felt in the moment on the same 0 to 10 scale. This was adapted from an approach established by Desmet (2016 pp. 241-268) to map emotions from activated to deactivated, from calm to energized. Other color-emotion studies (Hanada) have incorporated this means of mapping emotions.

Next, we asked participants to identify their feelings. In a pilot study, participants had expressed their difficulty in identifying emotions. Therefore, we used the method described below to assist them in the process. In order to help testers identify their own emotion "The Feeling Wheel" (Willcox) was incorporated into the survey. This classification helps participants to go from well-understood primary feelings to more detailed ones. There are around 34.000 distinct emotions that are impossible to understand for an ordinary person. An inner ring represents the primary feeling (mad, sad, scared, joyful, powerful, and peaceful), while outer rings contain secondary feelings related to the primary ones. This classification helps participants to go from well-understood primary feelings to more detailed ones. This visual and others like it have been developed for people who have difficulties defining their moods. Either because of a language barrier or a deficit in self-reflection.

From the emotions listed in the wheel, we allowed up to three emotions to be chosen per submission. The belief was that emotion like 'anxious' could be attributed to either a positive or negative emotion. We hypothesized that when a positive emotion was paired with 'anxious' either in primary or secondary standing the color would either be more saturated or brighter than its negative emotional counterparts.

Methods: Participants

Our demographic data is composed of gender and the country of origin with which they are most closely identified.

Fifty-seven individuals responded to the survey. Forty-four identified as female and thirteen identified as male. The participants chose the country they most identified with, the most common country was the Netherlands with 20 participants. For 14 participants they identified themselves to have come from a country where English was the most common language spoken.

Results

An unforeseen problem with our methodology was that by asking users to identify one emotion there was a smaller sample of more 'intense' emotions. Only two individuals submitted a response of critical/mad as a primary emotion. In contrast, 15 participants chose 'content' which was the most commonly chosen primary emotion. Assessing the results by emotion we don't have a large enough sample size for all primary emotions.

Results: Primary Emotion

Looking at Figure 1 we can see some trends forming for the emotions of sleepy, anxious, and content. Content is represented by mostly shades of a light green and many of the hues chosen share a similar chroma. The results for the emotion 'anxious' begin to reinforce our hypothesis that a positive or negative corresponding secondary emotion affects the color association.

Secondary emotions that are positive or fall under the joyful category tend to be lighter in tone compared to those with secondary unpleasant emotions.

Primary Emotion	Secondary Emotion	Tertiary Emotion	HEX
"Mad Critical"	"Mad Angry"		#0ce926
"Mad Critical"	"Powerful Important"	"Joyful Energetic"	#fe5b39
"Powerful Respected"	"Joyful Playful"	"Peaceful Thoughtful"	#5add74
"Powerful Proud"	"Peaceful Thoughtful"		#5b35e3
"Powerful Proud"	"Joyful Excited"		#fae475
"Powerful Hopeful"	"Scared Insecure"		#ffab5c
"Powerful Hopeful"	"Scared Rejected"		#88c5fb
"Powerful Appreciated"	"Joyful Aware"	"Powerful Proud"	#000000
"Powerful Appreciated"	"Mad Critical"	"Sad Bored"	#f0b92d
"Scared Anxious"	"Sad Sleepy"	"Sad Bored"	#65c4cd
"Scared Anxious"			#141010
"Scared Anxious"	"Powerful Hopeful"		#365e42
"Scared Anxious"	"Sad Lonely"	"Scared Helpless"	#9d7d4d
"Scared Anxious"	"Powerful Hopeful"	"Sad Sleepy"	#89d196
"Scared Anxious"	"Joyful Excited"		#c6f5e0
"Scared Anxious"	"Sad Lonely"		#199ccc
"Sad Sleepy"			#7025e4
"Sad Sleepy"	"Scared Helpless"		#0f8cd7
"Sad Sleepy"	"Peaceful Thoughtful"	"Powerful Hopeful"	#78c4c9
"Sad Sleepy"	"Scared Anxious"	"Peaceful Thoughtful"	#5e21ba
"Sad Sleepy"	"Peaceful Loving"		#e39a4a
"Sad Bored"			#d4b5c2

Figure 1. Part 1

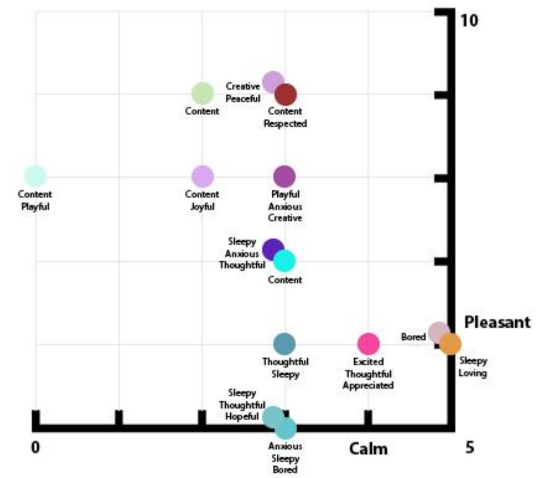
Primary Emotion	Secondary Emotion	Tertiary Emotion	HEX
"Joyful Sexy"	"Peaceful Content"	"Powerful Hopeful"	#f5f33d
"Joyful Playful"	"Scared Anxious"	"Joyful Creative"	#a34da3
"Joyful Playful"	Joyful	Peaceful	#f15f5f
"Joyful Excited"	"Peaceful Thoughtful"	"Powerful Appreciated"	#f5479f
"Joyful Energetic"			#ffcc00
"Joyful Energetic"	"Peaceful Content"		#fce7c0
"Joyful Energetic"	"Joyful Excited"	"Scared Anxious"	#22498c
"Joyful Creative"	Peaceful		#ce9fdb
"Joyful Creative"	"Peaceful Content"		#fab41e
~~"Joyful Creative"~~	~~"Joyful Excited"~~		~~#ffffff~~
"Joyful Aware"	"Scared Anxious"		#46d895
"Joyful Aware"	"Sad Lonely"		#bbddf7
"Joyful Aware"	"Mad Critical"	"Peaceful Thoughtful"	Orange
"Peaceful Thoughtful"	"Mad Angry"	"Sad Bored"	#420b8e
"Peaceful Thoughtful"	"Joyful Creative"		#faa519
"Peaceful Thoughtful"	"Sad Sleepy"		#5b9aae
"Peaceful Nurturing"			#c8c1d1
"Peaceful Nurturing"	"Powerful Proud"		#fd12d2
~~"Peaceful Loving"~~	~~"Joyful Aware"~~		~~#ffffff~~
"Peaceful Content"	"Scared Insecure"		#fdf94e
"Peaceful Content"	"Powerful Proud"		#55f1c1
"Peaceful Content"			#fdf3a0
"Peaceful Content"	"Joyful Playful"		#cdf9f1
~~"Peaceful Content"~~	~~Joyful~~		~~#ffffff~~
~~"Peaceful Content"~~	~~"Sad Sleepy"~~		~~#ffffff~~
"Peaceful Content"	"Peaceful Thoughtful"	"Peaceful Loving"	#29e095
"Peaceful Content"	"Powerful Hopeful"	"Powerful Appreciated"	#079301
"Peaceful Content"			#c6e5b3
"Peaceful Content"	"Powerful Respected"		#9c3032
"Peaceful Content"			#C3E0E5
"Peaceful Content"			#18f2e7
"Peaceful Content"			#cef2d4
"Peaceful Content"	Joyful		#dba8f0

Figure 1. Part 2

Results: Colors as they relate to Energized vs Pleasant scales

Taking the input values from the two sliders we were able to plot the submitted colors onto an x and y graph (Figures 2 - 5). The x-axis represented how testers felt in the moment from calm to energized, and the y-axis represented unpleasant to pleasant. Values found on the calm half of the chart (0 - 3) show a tendency to be of a blue hue and of a similar vibrance (Figures 2, 4). In the Pleasant and Calm quadrant, there is a cluster of pinks with low saturation. The most common emotion between the grouping is 'content' and 'creative'.

The quadrant with the most submissions was Pleasant and Energized (Figure 3). We can begin to see a tendency in highly saturated colors as the value in Energized and Pleasant increases. Although this is not consistent as darker greens, blues, and purples appear in this quadrant as well. The color black, only chosen twice, appears at values 8, 9 which sticks out from the other high saturated colors submitted in that range.



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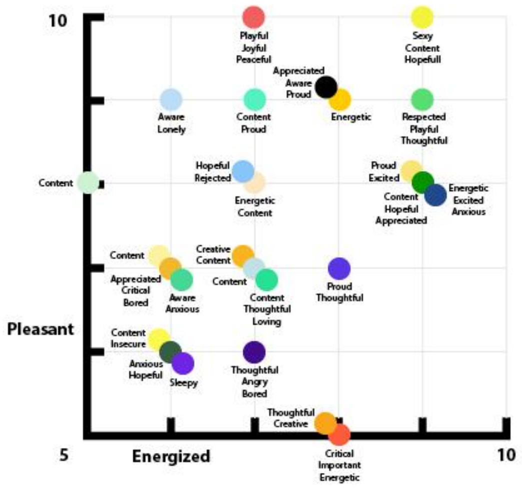

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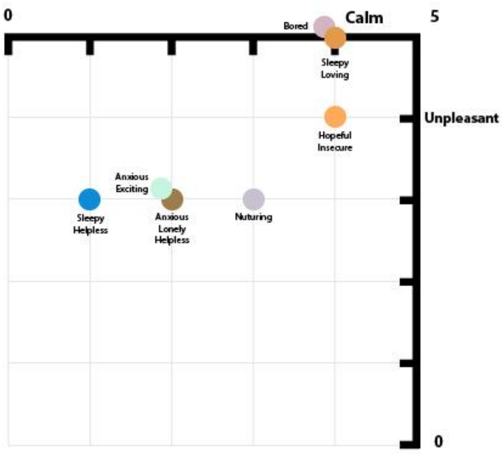

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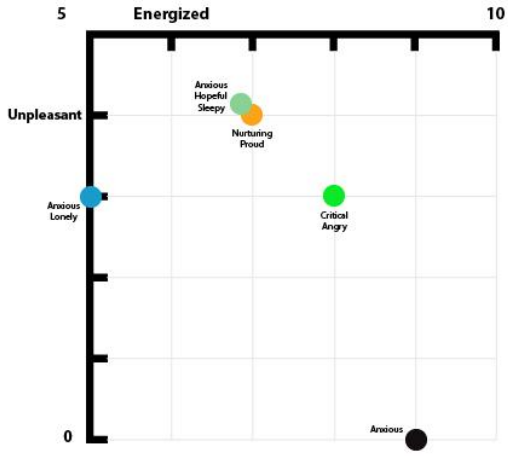

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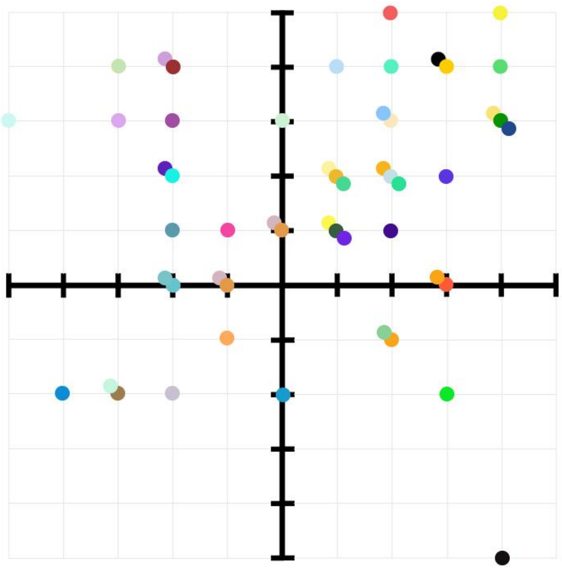

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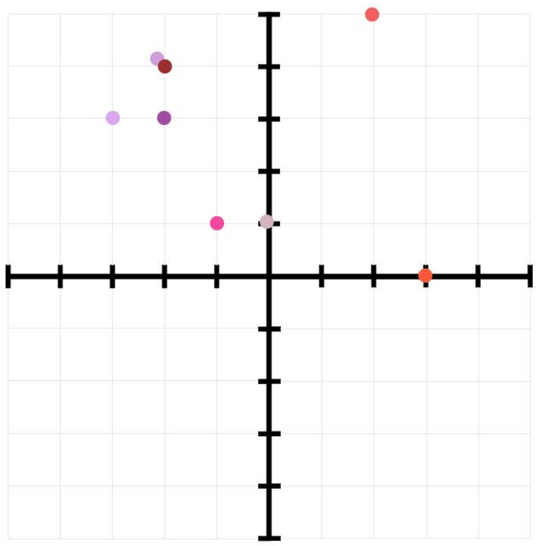

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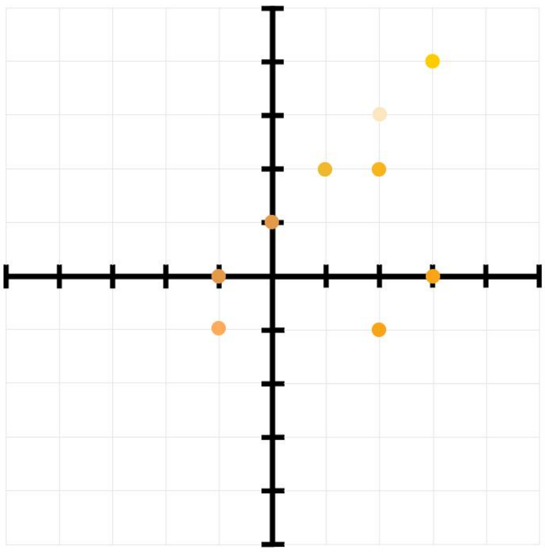
Figures 2-7.

Green is the most common color chosen among participants and appears on the energized half of the chart most frequently and ranges between pleasant and unpleasant values (Figure 10). Blues appear across the spectrum of calm and energized tend to be placed on the pleasant half of the chart (Figure 11). Orange, more than any color, shows a tendency of grouping around the center of the chart (Figure 9).



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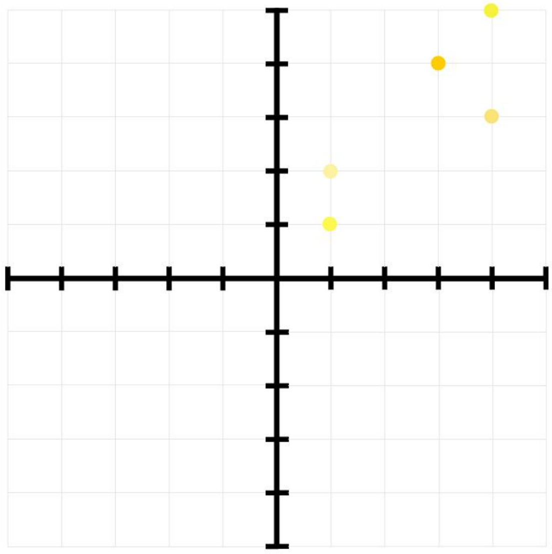

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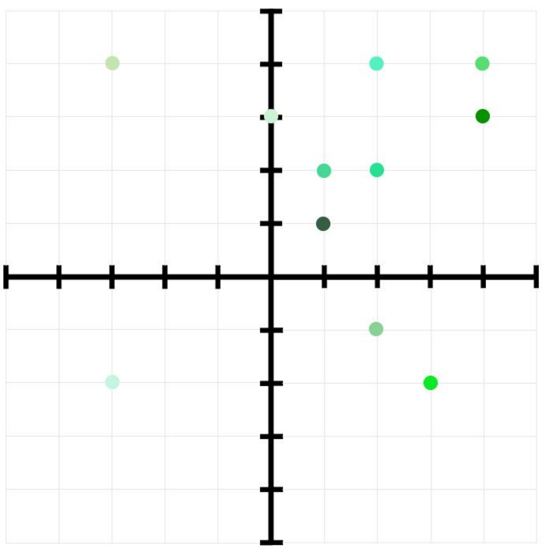

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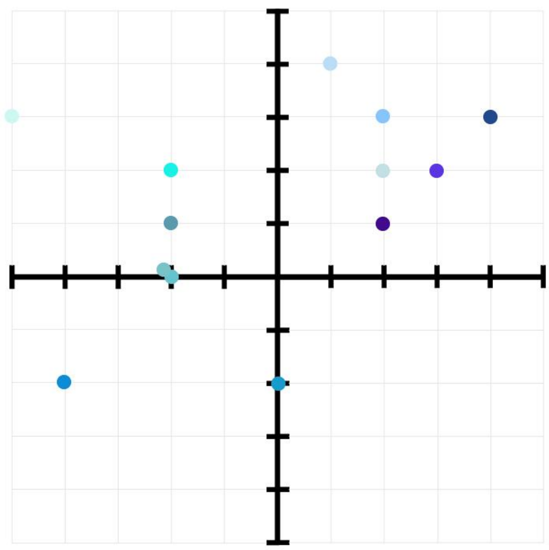

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Figures 8-11.

Results: Color and Emotion Association

Grouping submissions by color shows associations with certain emotions. Green is noteworthy as ‘content’ and ‘anxious’ appear in the greatest number. Looking at results from other studies such as the aforementioned “Relationship between color and emotion: a study of college students” Kaya (2004). Green and Yellow had overwhelming positive emotional associations in their results. Our results showed green and yellow, in their variety of shades, tended to be either pleasant and energetic in rating. A greater sample size is needed to make in-depth conclusions about other color groupings.

Discussion

After the study was concluded there were areas identified for improvement. For one was the concern that colors would appear differently on different devices. We noted that other studies have this concern as well (Fugate, 2019). They compensated by conducting a survey in person that became their control group. Utilizing a control group and prompting for a device type in the initial set of questions would allow us to parse out the submissions more accurately. The survey platform gave us an overall usage by device but we could not parse it by submission. We also received word from a few testers that the color picker was returning an error at submission and the hex code would return as white.

The overlapping of content and anxiousness in green was particularly interesting. Neither of those emotions is traditionally visualized culturally. Given more submissions, it would be curious to see if this trend continues.

The breadth and variety of answers speak to the complexity of human emotions. Trends do appear in our results but never a strict consensus of one emotion to a singular color. The plotting of emotions on the energized vs pleasant chart offers promising insights that begin to correlate with other studies (Valdez, 1994) that indicate saturation and lightness are highly connected emotional associations.

An unforeseen problem with our methodology was that by asking users to identify one emotion there was a smaller sample of more ‘intense’ emotions. Only two individuals submitted a response of critical/mad as a primary emotion. In contrast, 15 participants chose ‘content’ which was the most commonly chosen primary emotion. There is a lack of submissions in our study that fall into the unpleasant category for us to have a complete picture.

Forty-two percent of responses clustered in the energized pleasant category. A larger pool of testers in a follow-up study will be necessary to understand the emotional color associations of an unpleasant state of mind.

References

Branco, R., M. Neves, P. Noriega, and M. Casais . 2020. An Interaction Design Analysis of Mood Trackers. [online]. Available from: https://www.researchgate.net/publication/344902540_An_Interaction_Design_Analysis_of_Mood_Trackers.

Desmet, P.M.A., M. H. Vastenburg, and N. Romero, 2016. 'Mood measurement with Pick-A-Mood: review of current methods and design of a pictorial self-report scale' in J. Design Research, Vol. 14, No. 3. Available at: https://diopd.org/wp-content/uploads/2016/10/JDR140303-DESMET.pdf

Fugate, J. M.B., and C. L. Franco. 2019. "What Color Is Your Anger? Assessing Color-Emotion Pairings in English Speakers." *Frontiers*, Frontiers, 1 Jan. 1AD, https://www.frontiersin.org/articles/10.3389/fpsyg.2019.00206/full.

Gershfeld, Y. 2014. Mood Swings: An application to track, understand and share emotions for people who need to control mood swings. M. Thesis. Tilburg University. Available at: http://arno.uvt.nl/show.cgi?fid=134709

Hollis, V., A. Konrad, A. Springer, M. Antoin, C. Antoin, R. Martin, and S. Whittaker. 2017. *'What Does All This Data Mean for My Future Mood? Actionable Analytics and Targeted Reflection for Emotional Well-Being'* in Human-Computer Interaction, Vol. 32, pp. 208-267. Available at: https://doi.org/10.1080/07370024.2016.1277724

Introducing Mood Self-Tracking at Work: Empirical Insights from Call Centers. [online]. Available from: https://www.know-center.tugraz.at/filemaker/pdf_publikationen/a3-rivera-pelayo.pdf

Kaya, N., and H. Epps. 1970. "Relationship between Color and Emotion: A Study of College Students." *Semantic Scholar*, 1 Jan. 1970, https://www.semanticscholar.org/paper/Relationship-between-color-and-emotion%3A-A-study-of-Kaya-Epps/e227372d80f0d1853894d5eb452c74c8f78a95c2.

Majumdar, N. 2015. Quantifying Emotions: Mood Tracking Methods. [online]. Available at: https://emberify.com/blog/quantifying-emotions-mood-tracking/

Miniukovich, A. & A. Angeli. 2014. Visual impressions of mobile app interfaces. In NordiCHI '14: Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational (p. 31–20). New York, NY: Association for Computing Machinery.

Rivera-Polayo, V., A. Fessl A., L. Müller, and V. Pammer. 2017. Introducing Mood Self-Tracking at Work: Empirical Insights from Call Centers. [online]. Available at: https://www.know-center.tugraz.at/filemaker/pdf_publikationen/a3-rivera-pelayo.pdf

Shneiderman, B., C. Plaisant, M. Cohen, S. Jacobs, N. Elmqvist, & N. Diakopoulos. 2018. Designing the User Interface: Strategies for Effective Human-Computer Interaction, 6th edition. In Society (6th Edition). Essex, England: Pearson Education.

Soegaard, M.and R. F. Dam. 2018. The Basics of User Experience Design. The Basics of User Experience Design, 73 . Retrieved from interaction-design.org

Swan, M. 2013. *'The Quantified Self: Fundamental Disruption'* in Big Data Science and Biological Discovery. [online]. Available at: https://www.researchgate.net/publication/274428630_The_Quantified_Self_Fundamental_Disruption_in_Big_Data_Science_and_Biological_Discovery

Unknown (n.d.). 2015. MoodTracker: Monitoring Collective Emotions in the Workplace. [online] Available at: https://www.microsoft.com/en-us/research/wp-content/uploads/2016/04/MoodTrackerACII_2015.pdf

Valdez, P., and A. Mehrabian. 1994. Effects of color on emotions. *J. Exp. Psychol.* 123, 394–409. doi: 10.1037/0096-3445.123.4.394

Willcox, G. 1982. "The Feeling Wheel." *Transactional Analysis Journal*, vol. 12, no. 4, pp. 274–276., https://doi.org/10.1177/036215378201200411.

Psychological effects of white- and coloured-LED lighting for older people

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Abstract

The purpose of this study is to clarify physiological and psychological stress of white and primary colour lights on older people. In this paper, firstly, we examined the psychological effects on the light colours with the older subjects. In the evaluation items relating the impressions of the lighting environment, the white lights have been significantly more positive evaluations than the red light. Secondly, we confirmed the evaluations among the lighting conditions for each age group using the results of our previous study. For the greater part of the evaluation items, the differences between light colours in the young were not found in the older subjects. One reason for this can be reduction in colour discrimination ability with ageing. Thirdly, the comparison of the evaluative tendencies between age groups showed that the evaluations of "eye strain" and "anxiety" for the red and the blue light on the older subjects have been more negative than on the younger subjects.

Keywords: *psychological effects, chromatic light, older people, LED lighting*

Background and purpose

In recent years, as the developed countries, especially Japan, face an aging population, it is increasingly important to design lighting environments that are comfortable not only for the young but also for the older people. As one of the proposals, the lights that deviate significantly from the vicinity of the Planckian locus (hereinafter referred to as "coloured light") are being used in restaurants and medical facilities such as operating and maternity rooms.

The report of CIE (2017) has revealed that while visual properties are reduced by aging, a chromatic mechanism is renormalized by a compensation of visual changes in a brain and colour vision remains relatively constant. However, there is currently not enough research with coloured light that takes into account the visual characteristics of older people, it has not been grasped the effects of coloured lights on them and the differences between age groups. Therefore, in order to clarify physiological and psychological effects of lighting for older people, the experiment was conducted to expose them to white lights and the primary colour lights. In this paper, it is examined the psychological effects of light colour on older subjects. In addition, the results of our prior study with the younger subjects were used to compare and discuss the changes in the psychological effects of aging.

Experimental method

The content of this experiment was approved by the Ethics Committee of Tokyo University of Science. The experiment was conducted in a space assumed to be a living room (3370mm in width, 2400mm in depth and 2700mm in height) as shown in Figure 1. The sofas, the table and the floor lights which were turned on only during the explanation were placed. The light source (LED luminaire) was installed on the wall. The sofas were set diagonally toward the light source so that the subjects could be exposed to the light sufficiently and did not look directly at the light source. The subjects were required to be over 65 years old with normal colour vision (confirmed using the Ishihara test). There were 19 subjects (17 males and 2 females) with a mean age of 73.7 years. One or two subjects participated per experiment.

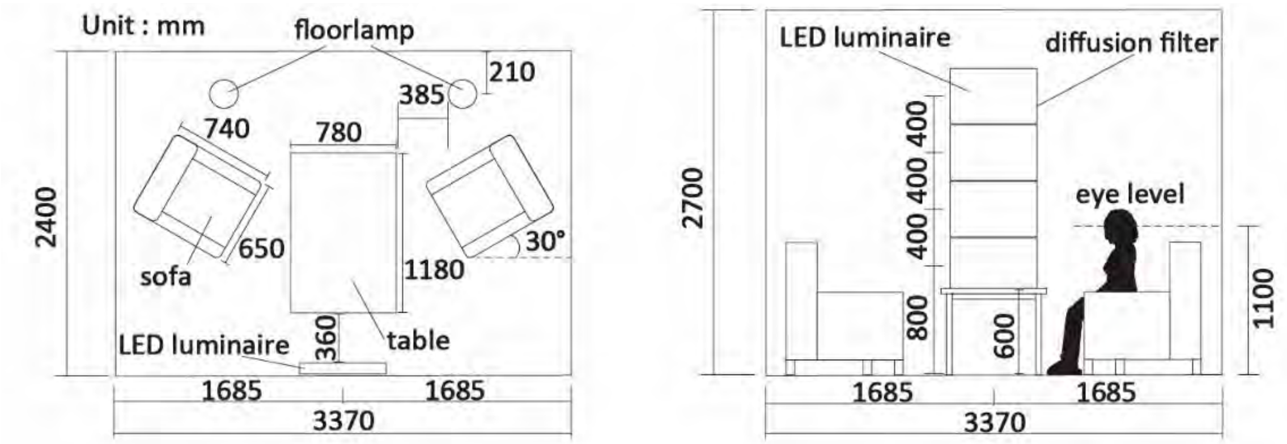

Figure 1. Experimental room (left: plan view, right: sectional view)

Lighting condition

A total of 6 lighting conditions were used: white lights with correlated colour temperature of 2700K, 4000K and 6500K, red, green and blue light at 53 lux of vertical eye illuminance. In this paper, the names of white conditions are expressed by correlated colour temperature, and the names of the coloured lights are expressed by the first letter of each light colour name (red: R, green: G, blue: B). Figure 2 shows the relative spectral distributions for each condition (a:2700K, b:4000K, c: 6500K, d: coloured lights). Also, Figure 3 shows the pictures of the experimental room when the light sources were turned on, taken from the right-hand seat towards the light source.

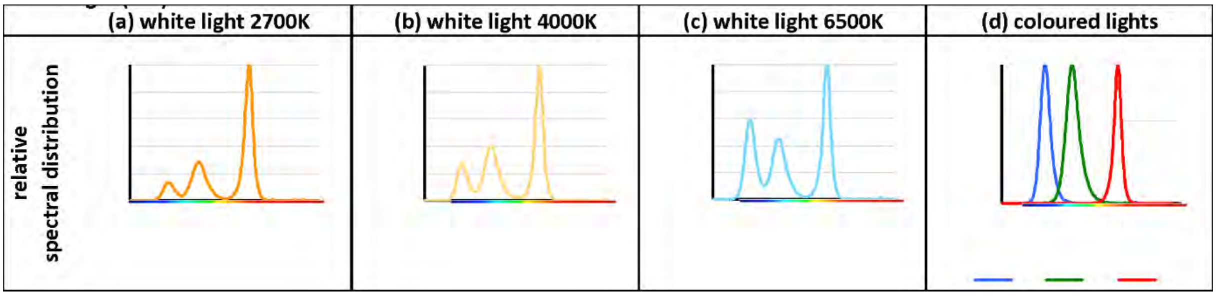

Figure 2. Relative spectral distributions.

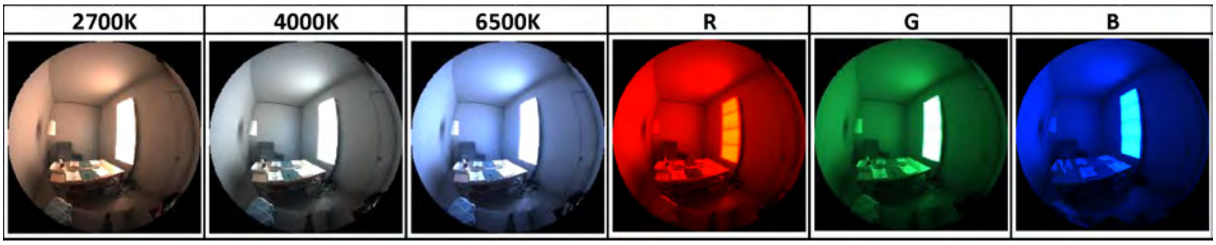

Figure 3. Pictures of the experimental room when the light source is turned on. (Taken from the right-hand seat towards the light source.)

Experimental procedure

Figure 4 shows the experimental protocol. Two lighting conditions were presented in one experiment, and the order of the lighting conditions was random. It took about 120 minutes for each experiment. The experiment consisted of five phases. Phase1: 8 minutes of the dark adaptation, Phase2: KAPLA (French building blocks), Sudoku (number puzzle), and sketching work for 8 minutes each under the first lighting condition, Phase3: 8 minutes of the dark adaptation, Phase4: Same contents as Phase2 under the second lighting condition, Phase 5: 6 minutes of the dark adaptation.

For each lighting condition, the psychological evaluation was performed twice: beginning (Q1) and end (Q2) of Phase 2 or Phase 4. In Q1, the subjects answered after adapting to the lighting condition for one minute after the light was turned on. There were nine evaluation items: "stress", "preference", "comfortability", "visibility", "sleepiness", "motivation", "concentration", "eye strain", and "anxiety". They were carried out by the 9-point Likert scale.

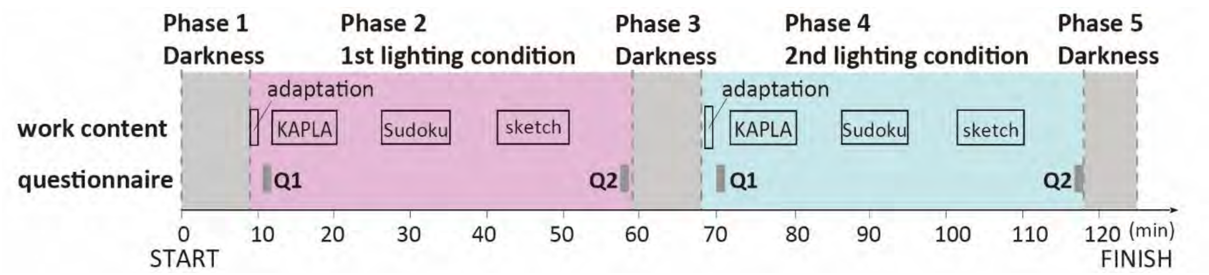

Figure 4. Experimental protocol.

Results and discussion

In comparing the evaluative tendencies between age groups, the results of previous studies with the younger subjects (N=28 – 41) whose mean age is 21.8 years were used, conducted by Miura et al. (2021). The results of Q1, which is considered to be the most sensitive to light, were used in this paper.

Examination of the evaluations for lighting environment in the older subjects

The statistically significant differences between lighting conditions were examined for each of the evaluation items. Figure 5 shows the evaluated mean values on the older subjects of the evaluation items for which tendencies were observed.

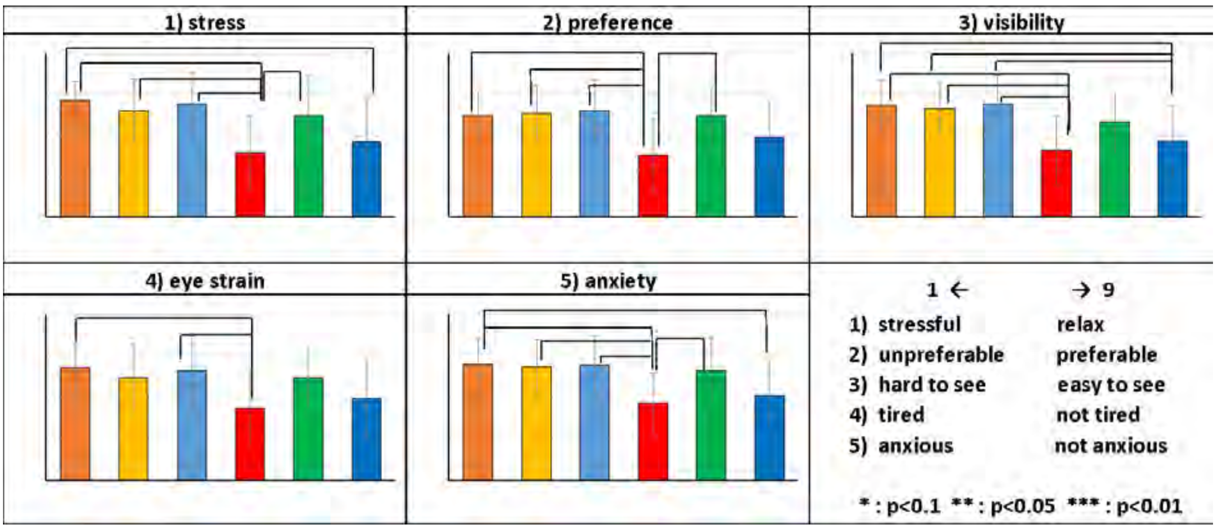

Figure 5. Evaluated values (Q1) of the older subjects (mean ± SD)

In all items, all white lights on the older subjects have been more positive than the red and the blue light. In the coloured light conditions, the green light on the older subjects has a significantly more positive evaluation than the red light in terms of "stress", "preference" and "anxiety" ($p<0.05$). In terms of "stress" and "preference", the younger subjects showed similar tendencies to these.

Then, comparing the evaluations among the lighting conditions for each age group, some characteristics of the evaluation on the younger were not found on the older subjects. The detailed results of the young subjects are the following four points: 1) In terms of "stress", the green light has a significantly more positive evaluation than the red light. 2) In terms of "preference" and "visibility", the three white lights have significantly more positive evaluations than the green or the blue light. 3) In terms of "eye strain", the red and the blue light have significantly more positive evaluations than the green light. 4) In terms of "anxiety", the blue light has a significantly more positive evaluation than the green light. One reason for these results may be that colour discrimination ability declines with ageing.

Comparison between age groups for each lighting condition

The statistically significant differences between age groups were examined for each evaluation item. Figure 6 shows the evaluated mean values for each age group by the evaluation item.

In all items, the evaluations of the white lights on the older subjects were more negative. In terms of "visibility", the evaluation of the green light on the older subjects was significantly more positive. In terms of "eye strain" and "anxiety", the evaluations of the red and the blue light on the older subjects were significantly more negative. There were no significant differences in the green light between age groups.

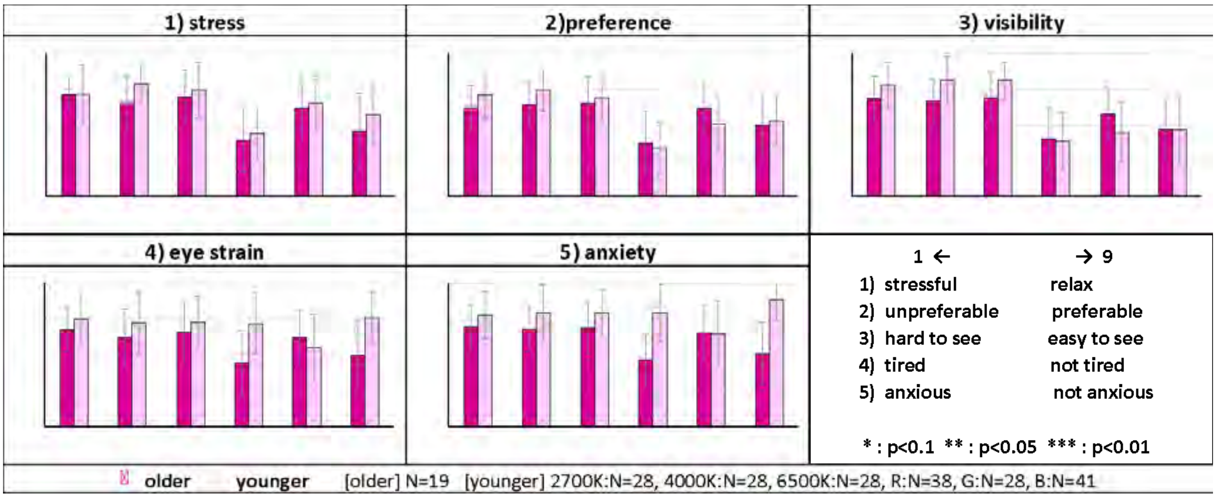

Figure 6. Evaluated values (Q1) for each subject group by lighting condition (mean ± SD).

Examination of the correlations between evaluations in both age groups

Correlation analyses were conducted to examine the factors affecting "stress" in each age group. Figure 7 shows the correlations between a part of the evaluation items in each age group. There were moderate correlations between "stress-preference", and between "eye strain-anxiety" in both age groups. The differences between age groups were clearly found in "stress-anxiety" and "stress-eye strain", and these correlations were high only for the older subjects. Confirming for the partial correlations in the older subjects, there were moderate partial correlations between "eye strain-anxiety" (0.29) and between "stress-anxiety" (0.55), while the partial correlation between "stress-eye strain" was weaker (0.16). It is thought that eye strain increased anxiety, and anxiety led to stress on the lighting environment.

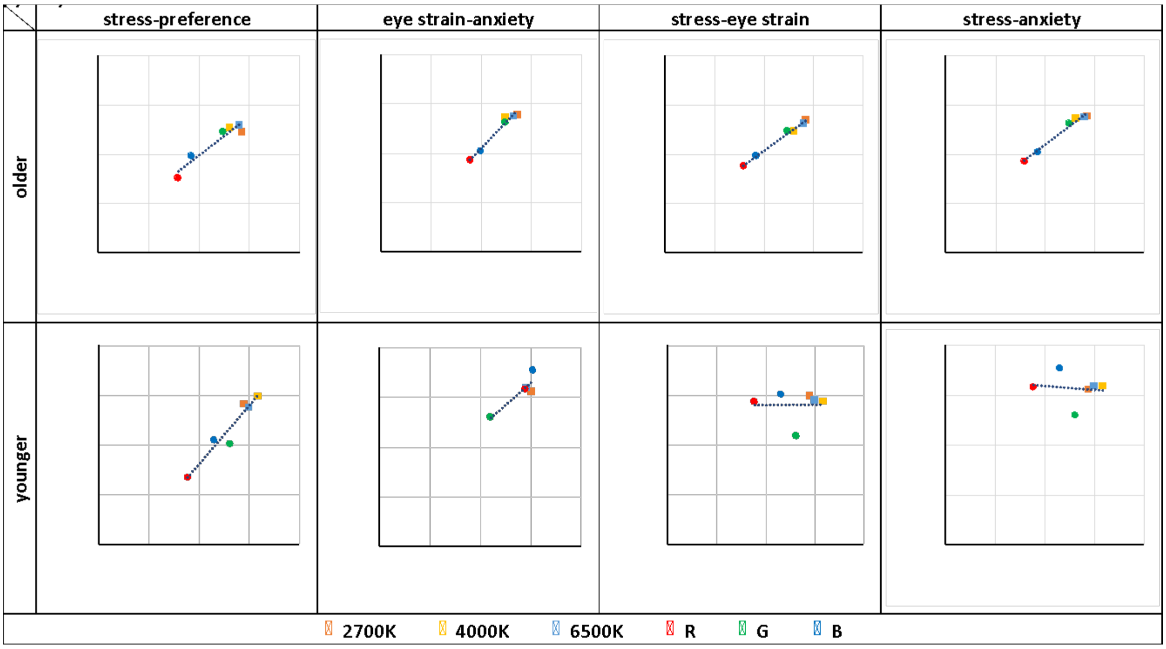

Figure 7. Correlations between a part of the evaluation items in each age group.

Conclusion

In this study, there were no significant differences between the older and younger subjects in the stress by primary colour lights. On the other hand, the older subjects were more likely to feel "eye strain" and "anxiety"" with the red and the blue light than the younger subjects. As the stimulus purity of the coloured lights in this study were so high at 85.9-99.9%, it is possible that in actual lighting environment design, reducing the saturations or using indirect lighting would reduce eye strain and improve the evaluation of the lighting space.

In the future, the main effects of illuminance and the interaction between light colour and illuminance should be analysed at several illuminance levels. When applying to real spaces, workability and physiological stress must also be considered, so they need to be investigated in further studies. It is also useful to confirm subjects' preference for light colours in advance, as Takahashi (2005) suggested that subjects' preference for light colours may have an influence on their psychological state and work performance.

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References

CIE (Commission Internationale de L'Eclairage). 2017. Lighting for Older People and People with Visual Impairment in Buildings. *CIE technical report,* 227:1-10.

Laufer.L, E. Lang, L. Izso, E. Nemeth. 2009. Psychophysiological effects of coloured lighting on older adults. *Lighting Research and Technology,* 41:371-378.

Miura, Y., Y. Oe, N. Yoshizawa. 2021. Examination of Psychological Effects and the Additivity Assumption in the Stress evaluation of Chromatic LED Lightings. In: CIE Midterm Meeting, *Proceedings of the Conference CIE 2021,* 73-79.

Takahashi, S. 2005. Psychological Study of Environmental Colors (1) -Effects of Color Lighting on the Performance of Simple Tasks-. *Journal of Human Environmental Studies,* 3(1): 41-46

Wang, Y., H. Huang, G. Chen. 2020. Effects of Lighting on ECG, Visual Performance and Psychology of the Elderly. *Optik*, 207:1-9.

The study of color in cities as a component of urban cultural constructions

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Abstract

The study of the phenomenon of color in the city is proposed as an element of experience and urban cultural construction. This work starts from the studies of urban color. It is proposed to link between the methodologies of analysis of tangible color with the studies of urban anthropology and urban imaginaries, to relate the objective and the subjective of color in the city, from reality and the cultural construction of the protagonists of it. The approach to the study of color in this article starts from the objective and the subjective and is related to the study of the colors of the city from the material and immaterial perspective. From here, the relationships between the subjective aspects of color that come from images, experiences, or visual stimuli and the perceived material reality are considered. This materiality of objective color becomes the starting point for the study of subjective colors as a product of the urban cultural construction of a city. The proposed methodology is developed from the generation of objective color palettes, which include the analysis of the colors of the urban image, made up of the facades, the urban furniture, and the landscape context, as a particular setting for each city, to the study of the subjective chromatic perceptions, also expressed in palettes that reveal the urban cultural constructions developed by the inhabitants, visitors, migrants, etc. depending on the cultural dynamics of each city.

Keywords: *Urban Colour , Colour and Culture, Color Identification*

Introduction

The study of color in the city can be approached from different approaches. When we ask ourselves about the characteristics of the colors of a city, multiple factors can be analyzed, however, the result involves a set of perceptions and meanings that are built from the urban experience of its inhabitants and visitors. The chromatic study of a city deals with the construction and perception of its colors as elements that make it unique and directly relate it to its cultural and historical heritage. This perception contributes to the reconstruction of a sense of belonging and local identity, but at the same time reflects the multiplicity of its inhabitants and the elements of the collective culture. (Odetti 2019) This article presents a theoretical reflection and a methodological proposal for the study of urban color, understood as an element of experience and cultural construction. For the study of the colors of a city, the analysis of the relationships between its objective colors together with the subjective perceptions about color, developed by its inhabitants, is proposed.

The proposed methodological approach supports how the color palette of a city includes objective and subjective aspects. The physical aspects of colors in the city form the objective dimension and their psychological effects constitute the subjective dimension.

The proposal is to develop a generation of objective color palettes, which include analyzes of the colors of the urban image (facades, urban furniture, and the landscape context) together with the study of the subjective perceptions of color, also expressed in chromatic palettes, that demonstrate the urban cultural constructions developed by the inhabitants.

To do this, studies from urban anthropology and urban imaginaries are taken as a theoretical framework.

The approach to the study of color in this work starts from the objective and the subjective and is related to the study of the colors of the city from the material and immaterial perspective. This materiality of objective color becomes the starting point for the study of subjective colors as a product of urban cultural construction.

From the study of these relations between the objective materiality and the constructed subjectivity of color, an approach to the multiple looks, experiences, and perceptions as a result of the urban experience is proposed.

Theoretical reflection

The theoretical anchoring of the work is built around three axes: authors who define and frame the reading of urban perceptual color are taken up, from the objective approach to color, from the disciplines of urban design and architecture, on the other hand, a conceptual and methodological crossing for the subjective aspects of color from the studies of social and urban imaginaries together with the contributions of urban anthropology. This complexity ends up linking with a third aspect that investigates urban color from the objective and subjective with the particularity of studies on tourist cities.

It is argued that the study of color maintains a relationship with urban morphology, the environment, and the construction of identity “color is a carrier of meanings that build collective identity. At the same time, it can mark our sense of sight, and give meaning to our visual environment, through a semantic function” (Collete and Nguyen 2006). From here, the numerous works that start from a visual-perceptive approach are linked, such as Jean Philippe Lenclos (1999), which introduces the concept of the 'geography of color', where not only the so-called permanent colors that have a relatively visual character are included stable and objectively detectable (for example the colors of the material construction) but also the non-permanent variable colors, which constitute a feature of the landscape (such as light, sky, vegetation) that contribute to the ever-changing vitality of a place. For this reason, “Each habitat has a color, whether it is earth, like the skyscrapers in the city of Shibam in Yemen, or white, like the houses of the white villages of Andalusia.” (Lenclos and Lenclos 1999, 9)

The Italian researcher Cristina Boeri (2010) adds another degree of complexity by warning about the need for an analysis that is capable of relating the chromatic component with the cultural, temporal, and spatial context and, later, with the more complex system of variables (light, material) that determines our perceptual experience of places. Color thus represents an invaluable element of recognition, belonging, legibility and city. In this context, it is noteworthy to point out that it is color, with its significant, evocative, and emotional force, that plays a crucial role not only due to the need to preserve the identity of the city, but also to initiate a process of social revaluation.

And it is at this point where the studies that delve into the subjective aspect of color in a city intersect and link, thus referring to the theory of imaginaries based on (Castoriadis 2013) whose work revolves around the definition of the social imaginaries, together with García Canclini (García Canclini 1997) and Armando Silva (2006) , to take the construction of these imaginaries in the urban context. For Castoriadis (2013), societies exist in the symbolic since they form their symbolic network and their network of meanings over time. At first, society creates collective meanings that can be called imaginary insofar as it does not correspond to the real or the rational.

In this sense, Armando Silva (2006), also mentioning Castoriadis, emphasizes that, in the history of humanity, the origin of social organizations is found in fundamental imaginations. Silva agrees with Castoriadis in that the imaginary "affects the ways of symbolizing what we know as reality and this activity permeates all instances of our social life." (Silva, 2006, p. 96). For his part, García Canclini (1997) addresses the visual image as a possible document to read and as a carrier of meanings from the construction of urban imaginaries. For the author, the city becomes a place to live and to be imagined. Thus, he emphasizes: "cities are built with houses and parks, highway streets and traffic signs, but cities are also configured with images" (García Canclini, 1997, p. 109).

From here the new contributions made by urban anthropology are added, from which the experience of living the city as a cultural construction is highlighted. Signorelli (1999) thus defines a field within anthropology as the need to "... deal with conceptions of the world and life, of cognitive-value systems elaborated in and by urban contexts... as active elements of cultural dynamics, of syncretisms and hybridizations, transformations, refunctionalization, resemantization and revaluations that are interwoven in every process of cultural production” (p. 10).

From this perspective, the concept of the city is specified, which Wirth Louis (2011) defines from urban sociology as a relatively large, dense, and permanent settlement of socially heterogeneous individuals, taking three variables for this conceptual precision: number, density, and space. degree of heterogeneity, to characterize urban life and differentiate between different sizes and different types of cities. Thus, Wirth Louis (2011) explains how the city can be "read" from different configurations that imply conceiving urban planning as a characteristic way of life. For Capel (2010) the city is also an idea, a concept, a perception, and an image. And it is through its spaces, objects, and architecture that it produces culture and meaning, and develops its symbols that organize, and define it.
Finally, Figure 1 shows a synthesis of the approach and theoretical reflection developed.

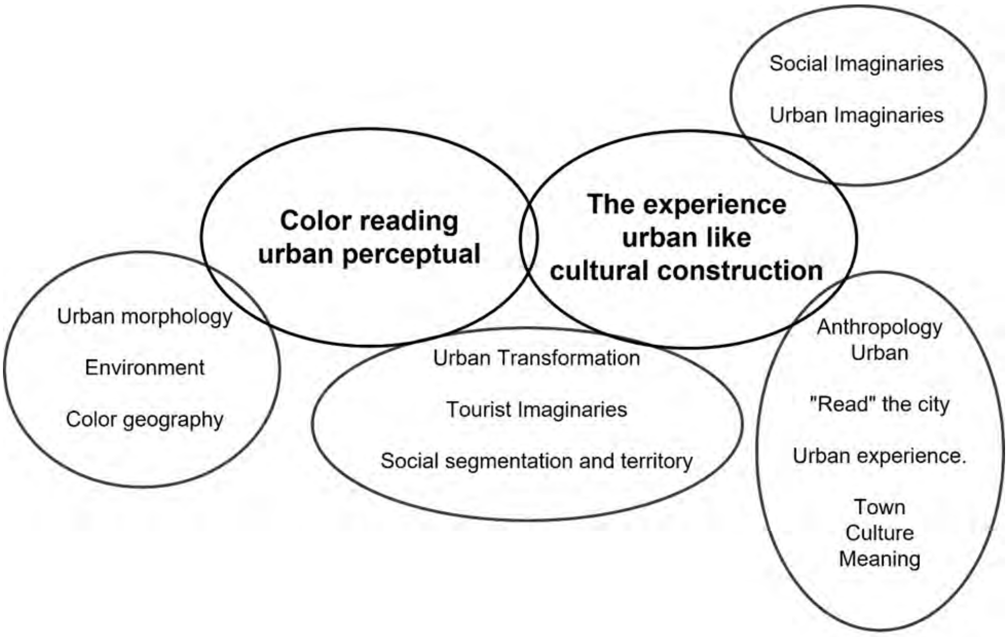

Figure 1. Theoretical Framework. Own elaboration source.

Methodological proposal

It is proposed for the chromatic studies of the city, from this theoretical perspective, explained above, a research design that corresponds to a qualitative study, with an interpretive perspective, which focuses on the analysis of the meanings attributed by the research subjects to the case study, seeking to interpret what is being captured through the application of the various selected instruments.

Therefore, the use of data collection techniques such as direct observation, photography, color scanning, qualitative surveys, in-depth interviews, and visual ethnography is proposed.

To define the main units of analysis, it is proposed to consider the socio-demographic profile of the city to be analyzed, as well as the subjects that intervene in the urban experience and the main objective of the research.

The dimensions of analysis should be related to the specific research objectives planned, it is proposed to divide them into two conceptual categories: the analysis of the objective and subjective color of the city, to identify: Objective colors: Palette of tangible colors of the city, identified by representative places. Temporary color palette (morning – afternoon – night). Seasonal color palette (spring-summer-autumn-winter). Subjective colors: Perception of the chromatic identity of the city. Feelings associated with the color of the city. Color perception is associated with the different places in the city Color perception is associated with the temporality (morning – afternoon – night) of the city. Chromatic perception is associated with the temporality (seasons of the year) of the city. Color perception is associated with celebrations and/or events in the city Color perception is associated with the natural landscapes of the city. Chromatic perception is associated with the architecture of the city. All these perceptions will be identified from the interviews carried out with the inhabitants and/or visitors of each city studied.

Proposed Instruments

To apply this methodology, it is proposed to structure the different phases of the project from the objective analysis of color to the analysis of the subjective perception developed by the inhabitants of the city.

For the objective analysis of the color of the city, the approach is proposed with direct observation techniques such as photographic registration and color scanning, which can be registered in dominant palettes where the chromatic measurement is carried out with the Natural Color System color ordering system.

For the analysis of the subjective perception of color, an approach based on interviews with stakeholders and interview-survey forms is proposed.

For form surveys, it is suggested to take the methodology proposed by Armando Silva as a guide, in which a conversation questionnaire is formulated, where the respondent is invited to freely answer the questions, some of which are left open for later interpretation. The different answers must be framed within the associations and construction of meanings according to the concepts specified in the theoretical framework of this work.
Figure number 2 summarizes the proposed methodological route.

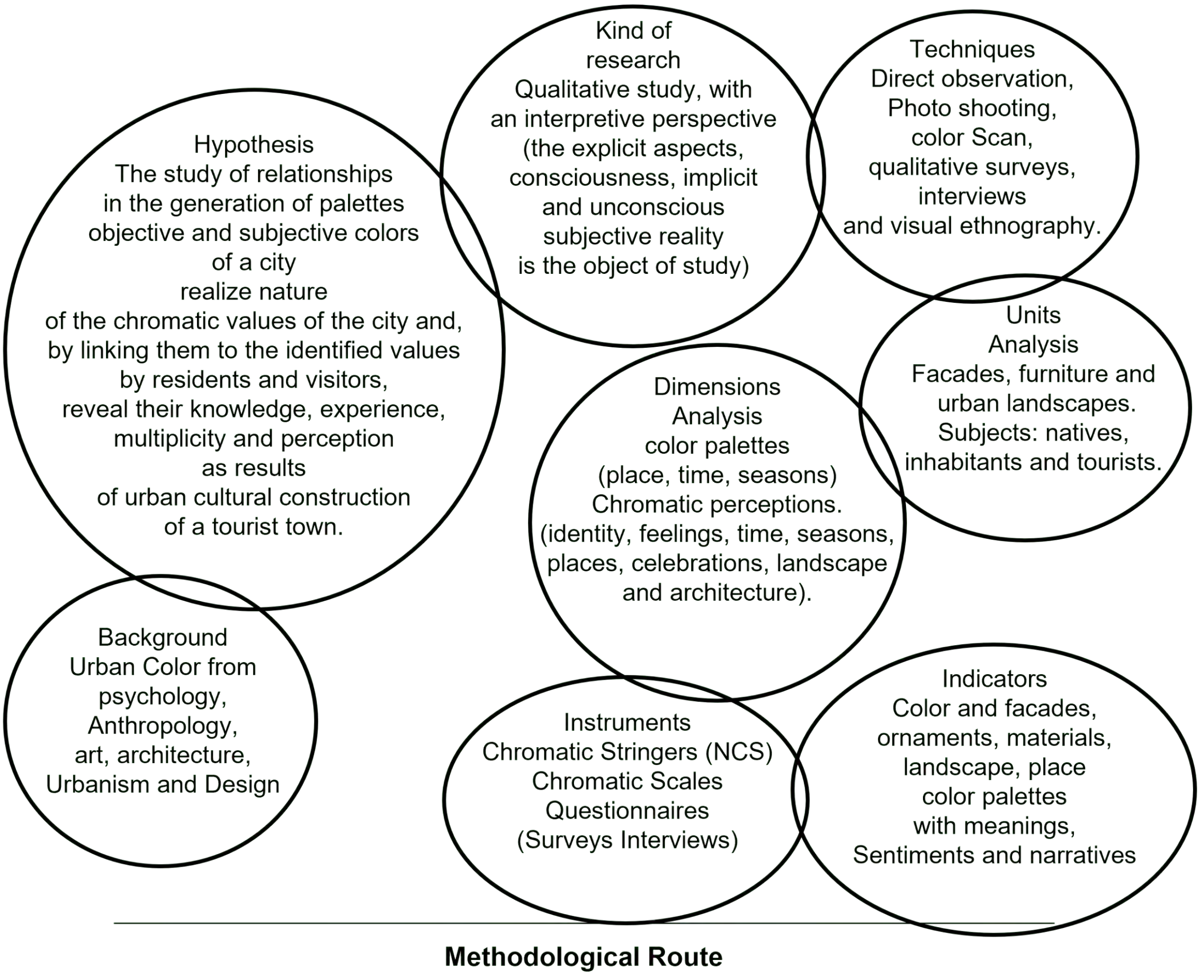

Figure 2. Methodological proposal. Own elaboration source.

Conclusion

Proposing the study of a city from the chromatic aspect supposes a combination of variables and elements to be analyzed that make the task extremely complex. In addition, when we open or cross our gaze even more on the city and we position ourselves in the subjects that inhabit it, or visit it, in this sense color becomes an evocative element of innumerable meanings, with which it is possible to narrate a city.

Added to the analysis are aspects that have to do with the cultural dynamics that this implies and with the multiplicity of senses and meanings that the inhabitants and visitors contribute from color and their experiences, finding ourselves at a crossroads of perceptions that make each city a particular place.

The challenge that arises is to generate enough interpretative and illustrative crosses that account for all the multiple chromatic visions with which the city is identified and show us its dynamic route and the objective and subjective characterizations that its protagonists generate every day, from their experiences.

and symbolic constructions, which make color dialogue with the experience and cultural construction of the city.

In this sense, the study of the city from its colors implies an urban perception and cultural construction, which arises from the symbolic, is psychically constructed and allows its expression through colors as language, to create modes of communication and interaction. setting the color. as a significant element in the cultural construction of the city.

A chromatic reading of the city in this sense allows an approach and an understanding of it, which is built from the voice and the experience of living in the city for all the subjects that travel, visit and inhabit it every day.

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References

Boeri, C. 2010. A Perceptual Approach to Urban Colour Reading. *Colour Light in Architecture_First International Conference 2010_Proceeedings* . Venezia: Università Luav Di Venezia. 459-463.

Capel, H. 2010. Diálogo y participación para profundizar la democracia y dar nuevas perspectivas a la ordenación urbana y del territorio Discurso inaugural del XI Coloquio Internacional de Geocrítica. *Scripta Nova. Revista Electrónica de Geografía y Ciencias Sociales*. 14. http://www.ub.es/geocrit/sn/sn331/sn-331-1.htm.

Castoriadis, C. 2013. La institución imaginaria de la sociedad. México: Fábula TusQuets. México: Fábula TusQuets.

Colette, J P, and L Nguyen. 2006. Couleurs et pratiques urbanistiques. *Les Cahiers de l`Urbanisme* 70-75.

García, Canclini, N. 1997. *Imaginarios Urbanos.* Buenos Aires: Eudeba.

Lenclos, J P, and D. Lenclos. 1999. *Colors of the world.* New York: Norton.

Odetti, J. V. 2019. Los colores de Puerto Vallarta, en la construcción cultural urbana de una ciudad turística. 1990 – 2016. *Tesis Doctoral.* Buenos Aires: Universidad de Palermo, Marzo 19.

Signorelli, A. 1999. *Antropología Urbana.* . México: Anthropos Editorial.

Silva, A. 2006. *Imaginarios Urbanos.* Bogotá: Arango.

Wirth, L. 2011. Leer la ciudad. Ensayos de antropología urbana. El urbanismo como forma de vida. *Revista de estudios sociales* 110-115.

Medical illumination and geographic issues at circumpolar areas may cause changes in colour perception

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Abstract

Polar T3 syndrome is a change in thyroid hormone T3 related to prolonged residence in polar circles. Polar T3 syndrome may also include colour vision perception changes. In some areas of the world colours green and blue are perceived in a similar way so the perception is called or expressed under the term "grue". Grue is seen also in polar circle areas. There are also studies showing that there are clinically measurable colour perception differences in Norway when a comparison is made between the inhabitants living inside and outside the polar circle. Colour perception changes are experienced also in prolonged day and night times. At the pole areas of the world daylight is there for 6 months uninterruptedly followed by a night of 6 months uninterruptedly. Night vision changes colour perception. In addition artificial illumination is needed for normal illumination and to overcome the biologic clock changes at the polar night. Night vision changes also have an effect on colour perception. On the other hand there are no high incidences in depression found in Iceland as expected due to long night episodes. So in the polar regions of the world medical, illumination and geographic issues and changes may cause colour perception changes.

Keywords: *Circumpolar areas, Colour perception, Illumination, Geography, Medicine.*

Introduction

Circumpolar areas are areas inside both polar circles of the earth. In the circumpolar area around the north pole, there are resident people living around the year and mostly all their life through. In the circumpolar area around the south pole, there is Antarctica, where there are non-residents for normal living. The crew in the stations in Antarctica live there mostly for research reasons and mostly only for 6-12 months uninterruptedly. Circumpolar areas are of special interest in science. Because there are 6 month day and 6 months night intervals. Due to these changes the natural illumination is unique. In winter months artificial illumination is needed all day long.

Living in circumpolar areas has many impacts on human life and health. These special environmental conditions may also cause changes in human colour perception. The reasons may be reviewed in three sections: 1. Medical issues. 2. Illumination issues. 3. Geographic issues.

Medical issues

The first study is about the Polar T3 Syndrome. Humans who live in Antarctica for greater than 5 continuous months demonstrate alterations in the hypothalamic-pituitary-thyroid axis. These changes are characterized by increased pituitary release of TSH in response to iv TRH, increased serum clearance of orally administered T3, and normal serum total, free T4, and unstimulated TSH levels. To clarify the mechanism responsible for these findings, serum kinetic studies of 125I-labeled T4 and T3 were carried out in a group of normal men, first in California, then after 20 and 42 weeks of continuous Antarctic residence. The marked increase in T3 TVd and the small increase in MRT are associated with increased T3 production and clearance and only minor changes in T4 kinetics. This was the first description of a mechanism for the change in thyroid hormone economy occurring with extended residence in Antarctica. Polar T3 syndrome may also cause color vision perception disturbances (Reed 1990: 70(4):965-7).

Polar expeditions include treks and stays at summer camps or year-round research stations. People on such expeditions generally undergo psychological changes resulting from exposure to long periods of isolation and confinement, and the extreme physical environment. Symptoms include disturbed sleep, impaired cognitive ability, negative affect, and interpersonal tension and conflict. Seasonal occurrence of these symptoms suggests the existence of three overlapping syndromes: the winter-over syndrome, the polar T3 syndrome, and subsyndromal seasonal affective disorder. All these medical issues may also cause color vision perception disturbances (Palinkas LA and Suedfeld P. 2008. 371(9607):153-63.).

The medical mediated colour vision changes mentioned in the studies about Polar T3 Syndrome are important because they show the side effect results of a disease which has systemic effects making also changes in colour vision.

Illumination issues

In circumpolar areas low levels of natural illumination may change human colour perception. Several studies document rudimentary color vision under dim illumination. Here, hue perceptions of paper color samples were determined for a wide range of light levels, including very low light levels where rods alone mediate vision. The appearances of 24 paper color samples from the OSA Uniform Color Scales were gauged under successively dimmer illuminations from 10-0.0003 Lux. Triads of samples were chosen representing each of eight basic color categories; red, pink, orange, yellow, green, blue, purple, and gray. Samples within each triad varied in lightness. Observers sorted samples into groups that they could categorize with specific color names. Above 0.32 Lux, observers sorted the samples into the originally chosen color groups with few exceptions. For 0.1-0.01 Lux, the red and orange samples were usually correctly identified as either red or orange.

The remaining samples tended to be grouped into two categories, associated with the scotopic sample reflectance.

The lowest reflectance samples were below threshold and were named black. The higher reflectance group was named predominantly as green or blue-green (three observers; the fourth observer used blue or achromatic). At the three dimmest levels (< or = 0.0032 Lux) there continued to be conspicuous color percepts. Color categories were reliably assigned based on relative sample scotopic lightness. Of the samples above threshold, those with lower reflectance were classified as red or orange (all observers) and the higher reflectance samples as green or blue-green (three observers) or achromatic or blue (the fourth observer). Rods and L-cones presumably mediated color percepts at the intermediate light levels used in the study. (Pokorny J et al. 23(3-4):525-30).

At Arctic and Antarctic latitudes, personnel are deprived of natural sunlight in winter and have continuous daylight in summer: light of sufficient intensity and suitable spectral composition is the main factor that maintains the 24-h period of human circadian rhythms. Thus, the status of the circadian system is of interest. Moreover, the relatively controlled artificial light conditions in winter are conducive to experimentation with different types of light treatment. The hormone melatonin and/or its metabolite 6-sulfatoxymelatonin (aMT6s) provide probably the best index of circadian (and seasonal) timing. A frequent observation has been a delay of the circadian system in winter. A skeleton photoperiod (2 × 1-h, bright white light, morning and evening) can restore summer timing. A single 1-h pulse of light in the morning may be sufficient. Increasing the intensity of ambient light exposure throughout the day advanced the circadian phase and was associated with benefits for sleep: blue-enriched light was slightly more effective than standard white light. A few people desynchronize from the 24-h day (free-run) and show their intrinsic circadian period, usually ti24 h. With regard to general health in polar regions, intermittent reports describe abnormalities in various physiological processes from the point of view of daily and seasonal rhythms, but positive health outcomes are also published. True winter depression (SAD) appears to be rare, although subsyndromal SAD is reported. In all these changes colour perception changes also occur .(Arendt J. 29(4):379-94.)

The variations of illumination in the circumpolar areas seasonally are scientifically extraordinary. The creatures living in these variations have to adapt to them in order to survive. Human beings are not living directly in nature, but for the time spans being in nature they have to adapt to the variations in illumination or colour perception.

Geographic issues

Many languages express 'blue' and 'green' under an umbrella term 'grue'. To explain this variation, it has been suggested that changes in eye physiology, due to UV-light incidence, can lead to abnormalities in blue-green color perception which causes the color lexicon to adapt. In the study advanced statistics were applied on a set of 142 populations to model how different factors shape the presence of a specific term for blue. In addition, they examined if the ontogenetic effect of UV-light on color perception generates a negative selection pressure against inherited abnormal red-green perception. They found the presence of a specific term for blue was influenced by UV incidence as well as several additional factors, including cultural complexity. Moreover, there was evidence that UV incidence was negatively related to abnormal red-green color perception. These results demonstrate that variation in languages can only be understood in the context of their cultural, biological, and physical environments. UV-B incidence difference between the equator and poles of the earth seem to be one the reasons for the perception of grue. (Josserand M et al. (1):19095.)

Geographical changes in the circumpolar areas change the visual and color perception of animals which live in nature. One study about them shows that light plays a fundamental role in the ecology of organisms in nearly all habitats on Earth and is central for processes such as vision and the entrainment of the circadian clock. The poles represent extreme light regimes with an annual light cycle including periods of Midnight Sun and Polar Night. The Arctic Ocean extends to the North Pole, and marine light extremes reach their maximum extent in this habitat. During the Polar Night, traditional definitions of day and night and seasonal photoperiod become irrelevant since there are only "twilight" periods defined by the sun's elevation below the horizon at midday; we term this "midday twilight." Here, we characterize light across a latitudinal gradient (76.5° N to 81° N) during Polar Night in January. Our light measurements demonstrate that the classical solar diel light cycle dominant at lower latitudes is modulated during Arctic Polar Night by lunar and auroral components. We therefore question whether this particular ambient light environment is relevant to behavioral and visual processes. We reveal from acoustic field observations that the zooplankton community is undergoing diel vertical migration (DVM) behavior. Furthermore, using electroretinogram (ERG) recording under constant darkness, we show that the main migratory species, Arctic krill (Thysanoessa inermis) show endogenous increases in visual sensitivity during the subjective night. This change in sensitivity is comparable to that under exogenous dim light acclimations, although differences in speed of vision suggest separate mechanisms. It is concluded that the extremely weak midday twilight experienced by krill at high latitudes during the darkest parts of the year has physiological and ecological relevance. (Cohen JH et al. 19(10):e3001413).

Extreme natural ambient light reduction, in both energy and range of wavelength spectrum, occurs during the winter season at very high latitudes (above the Arctic Circle or 66 degrees 32' North) that in turn results in increased exposure to artificial lighting. In contrast, during the summer months, the sun remains above the horizon and there is no darkness or night. Little is known about these extreme changes in light exposure on human visual perception. Measuring color discriminations with the FM100 Test revealed that Norwegians born above the Arctic Circle were less sensitive to yellow-green, green, and green-blue spectrum differences whereas they were more sensitive to hue variations in the purple range than individuals born below the Arctic Circle. Additionally, it was found that the Norwegian individuals born above the Arctic Circle and during autumn showed an overall decrease in color sensitivity, whereas those born in the summer showed a relative increase. All participants were adults and their color vision was tested in the same location (i.e., in Tromsø at 69.7 degrees North). These findings are consistent with the idea that there is a measurable impact on colour vision as adults of the photic environment that individuals born above the Arctic Circle and in the autumn experienced during infancy, namely a reduction in exposure to direct sunlight and an increase in exposure to twilight and artificial lighting. (Laeng B et al. 47(12):1595-607).

Geographic circumstances determine how life has to be for creatures, so that they can survive. On the other hand they change the natural and social life of humans. The latitude in which humans live seems to change their colour perception also.

Conclusion

Colour perception is multifactorial in normal human life. The factors can be differentiated from each other but they also coincide in human life. The medical, illumination and geographic issues at circumpolar areas are a challenge for humans, so that sometimes the colour perception has to change also. All three issues also have effects on each other so that the effect on colour perception is also multifactorial in circumpolar areas.

References

Arendt, J. 2012. Biological rhythms during residence in polar regions. *Chronobiol Int*. 29(4):379-94.

Cohen, J.H. et al. 2021. Photophysiological cycles in Arctic krill are entrained by weak midday twilight during the Polar Night. *PLoS Biol*. 19(10):e3001413.

Josserand, M. et al. 2021. Environment and culture shape both the colour lexicon and the genetics of colour perception. *Sci Rep*.11(1):19095.

Laeng, B. et al. 2007. Latitude-of-birth and season-of-birth effects on human color vision in the Arctic. *Vision Res*. 47(12):1595-607.

Palinkas, L. A. and P. Suedfeld. 2008. Psychological effects of polar expeditions. *Lancet*. 371(9607):153-63.

Pokorny, J. et al. 2006. The color of night: Surface color perception under dim illuminations. *Vis Neurosci*. 23(3-4):525-30.

Reed, H.L. et al. 1990. Changes in serum triiodothyronine (T3) kinetics after prolonged Antarctic residence: the polar T3 syndrome. *J Clin Endocrinol Metab*. 70(4):965-7.

Color, Materiality, and Authenticity: The Cathedral of Portalegre Rehabilitation

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Abstract

The goal of this article is to relate the color and the materiality to the authenticity arising from the methods employed in the work. The restoration of the cathedral of Portalegre was done in such a way as to avoid further building degradation, to give the building an updated infrastructure, improve the space of worship, and restore the altarpieces and chapel paintings that embody a rich and unique historic heritage dating back to the sixteenth century. Both in the project plan and in the works, fundamental importance was given to materiality, the way light played off the colors, and the materials. The whole project and works respected the principles of cultural heritage. The key concepts employed were: reversibility of the interventions, above all the use of whitewashing to cover up paintings, for economic reasons; versatility to allow future restoration work to reveal these paintings; simplicity, which is present in the whole philosophy of the project and the moderation of resources used; sustainability, from the way the program was conceived and implemented.

Keywords: *Color, Materiality, Authenticity, Glazed Tile (Azulejo), Mortar*

Introduction

The Cathedral of Portalegre was built in the sixteenth century (1556-1575) and classified as a National Monument in 1910. The castle wall that is partially integrated within the cathedral was classified in its own right as a National Monument in 1922 in recognition of the historical importance of this fusion, the site, and its cultural significance.

This article describes the restoration of the Cathedral of Portalegre, the cloister, and annex spaces. The introduction of a cultural program focused on the religiously significant architectural heritage of the site was intentional, in order to breathe life into this part of the city, highlighting its historical, spiritual and social importance (Figure 1).

Figure 1. Rehabilitation of the Cathedral of Portalegre, its cloister and annex spaces: 1st prize in a competition by invitation. Architects: RBD.APP, 2014. Photo: João Morgado, 2020.

While the project plan was completed and approved in 2016, it was only put forward to the Alentejo 2020 Financial Program in 2019. Just 70% of the estimated budget was secured, and this was restricted exclusively to the areas for worship. This required a series of alterations to the project design and its management, since the project to restore the cathedral building, its cloister and associated spaces had been conceived holistically, without making a distinction between the areas of worship and the museum. The sustainability of the whole project was called into question, since the cultural activities of the site underpinned its economic sustainability and future maintenance. Both in the project plan and in the works, fundamental importance was given to materiality, meaning texture and the way light played off the colors and the materials. "The whole intervention has as key concepts: reversibility, versatility, simplicity and sustainability with respect for Cultural Heritage principles" (Pinheiro, 2019).

Facades

The granite stones on the facades of the cathedral display two different tones – gray and brown (Figure 2 – right). The collective effect, however, which can be read as a counterpoint to the white borders of the facades, possesses a unity without any distortion. The mortars used where the stone joins are ultimately about filling the gaps and waterproofing the walls and floors. They were put to various kinds of tests, with color being the determining factor in choosing the composition of the mixture. Sands that were washed and certified as salt-free by Airport were used in the mortar tests, as well as sand from the local river of Barros Alexandre in Portalegre. Different lime-based and quicklime binding agents were used from a variety of suppliers: hydrated lime from Calcidrata, natural quicklime NHL-3.5 from Secil, and lime putty from Lacrilar (Oliveira, 2021).

The cathedral facades were painted in the original white color, using a water-based paint with a mineral look from modified polysiloxane resins. This kind of white matte paint allows great permeability to water vapor while repelling liquid water.

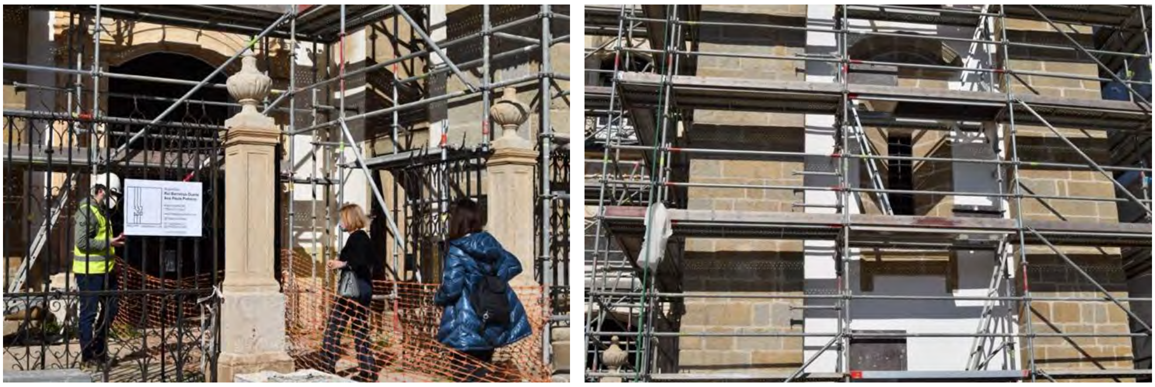

Figure 2. The cathedral entrance under construction (left). North tower, partially restored (right). Photo: RBD.APP, 2022.

Consideration had to be given to maintaining the artificial coatings, whether those beneath the lime wash or those that remain visible. Many of these visible coatings that duplicate the brown color of the granite are in fact pigmented mortar: Aguiar (2002) and have a lime and sand base (Figure 2 – left).

Spire (s)

The 8m tall octagonal, pyramid spire(s) were originally decorated with Portuguese glazed tiles ('*azulejos*') and are currently plastered (Figure 3 – left). This decoration will be renewed through the use of white tiles specifically made for this purpose. A white tile originating from the cloister was used as a reference point to ensure the authenticity of the color. Several trials were made before similarity of form, size, color and brilliance was achieved.

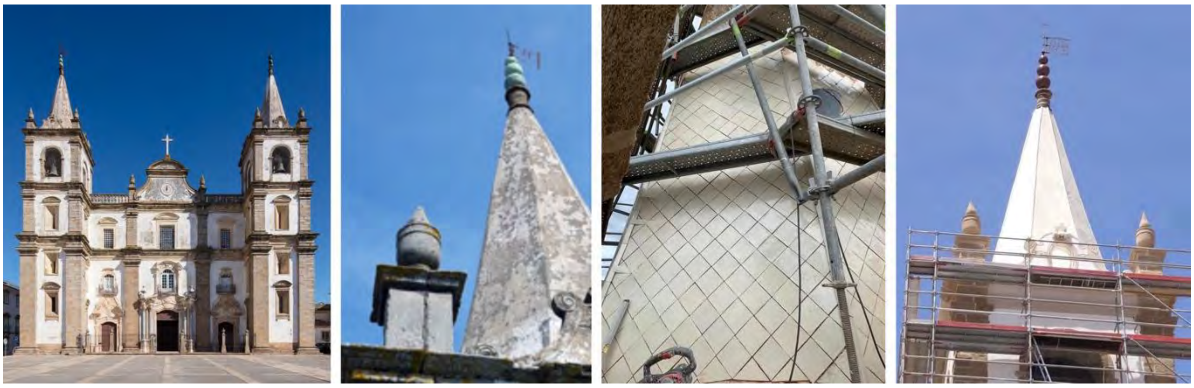

Figure 3. Before the intervention. Photo: João Morgado, 2020 (left). Plastered spire. Photo: RBD.APP, 2016 (center-left). Tiled spire, under construction. Photo: João Pires, 2022 (center-right). Tiled spire. Photo: Paula Batista, 2022 (right).

The tiles are 10mm thick and were made traditionally in a 14cm x 14cm size using hand-built molds and red slip. To achieve the glaze color a matte white base was used. Toasted yellow and ochre-brown colorants were used to give tonality to the color. The tiles were placed diagonally (chequered pattern), and a piece was fashioned for the edge finishes. These pieces, in a 30cm-long V shape, have a rounded edge to disguise the lack of precision resulting from imperfections in manufacture and height, as the irregularity of the base makes it impossible to achieve perfect symmetry (Figure 3 – right).

Cloister

The galleries of the cloister are cladded in Estremoz white marble with seams only in the north wing and the west corner (Figure 4 – center). With the change of bishop during its construction, the remaining wings remained plastered or painted with an artificial overlay to imitate the marble.

The white color where the stones in the walls and floors meet was the result of various selections and chromatic experiments with mortar, with consideration given to its leak-proofing quality, adhesion and weather resistance. We were unable to restore the mortars and artificial coatings in the eastern, southern, and western galleries due to budget constraints. These coatings were therefore painted with a lime-based paint in a color matching the cleaned mortar.

Figure 4. Rooftop (left). Cloister (center). North gallery of the cloister (right). Photo: RBD.APP, 2022.

The remaining glazed tiles, which were arranged in panels of heights varying between 50cm and 59cm, were removed from the interiors of three of the cloister's galleries. This was because of their deterioration (gaps, broken pieces, looseness from the wall, poor manufacture.) These tiles were used to rebuild and restore some panels within the cathedral, allowing for the completion and consistent quality of what remained of the originals.

These cloister panels were replaced with white marble without veins, so as to create a white marble background approximately 1.4 m high, thus conforming to the height relationship of the glazed tile panels in the stair antechamber (Figure 4 – right). In the staircase giving access to the cloister rooftop and its antechamber the panels of glazed tiles form an incomplete pattern, although a dominant theme can be seen. The project redefined the patterns using existing tiles to complete them, thus creating a design with two elements expressed with each other. On the rooftop the granite coexists with mortar of the same color, which completes the design of the architectural style elements (Figure 4 – left).

Openings, railings and metallic elements

The colors chosen for the location restore the traditional reddish tone of the colors of doors, where iron oxide is a color determinant. Today, use of RAL colors allows for the identification of the most appropriate color, with a mind to the continuity of its application over time, without entering into dissonance with the existing color.

So, the doors of floors 0 and -1 will be painted with the color Oxide Red RAL 3009 and all of the entrances of the upper floors will be painted in white, with the color RAL 9016. The exterior ironwork will be painted to match the openings. The interior ironwork will be painted in black color Y764 using an anticorrosive glazed gel for iron metals. The cloister's drainage grills will be treated with a commercial iron converter suitable for exterior application, with the goal of creating a black-colored, protective coating for the metal.

The south facade's window panes are a yellow color. The windows of the north facade were replaced over a long period and currently present various shades of colors. So, their replacement was proposed to bring them back to how they were before the alterations. Spatially, the natural afternoon light introduces a tone that creates a golden ambiance. The glass in the frames, for the most part broken or missing, was replaced by identical, transparent glass panes.

Restoration

The restorative work in respect of the traditional furnishings and painting restoration follows cultural principles and techniques in keeping with the authentic tone of the building.

The restoration of the altarpieces is an essential and sensitive intervention carried out by the conservation and restoration team. As such, appropriate restoration methods and techniques were used. The techniques of cleaning and the restoration refreshed the colors and brought back the authenticity of the altarpieces so that their artistic and cultural qualities might be appreciated. The work used all relevant technical and legitimate instruments to ensure the authenticity of the process. The colors of the space must be maintained, and the liturgical elements restored. This also applies to the ceilings, especially in the space that defines the main altar's chapel (Figure 5, left). The quality and type of material finish has a strong impact on the color one hopes to achieve and its durability. The clarification of the authenticity of the niche paintings, comprising various layers of paint, led to the choice to do that which best exalts the saints' images. The restoration of the color of the mortars and the artificial coatings, just as with the visual elements of the paintings where the original colors of the altarpieces from the sixteenth century painting style were recaptured, ensures overall authenticity.

Figure 5. Chancel (left). Chancel vault (center). North chapels (right). Photo: RBD.APP, 2022.

Gold paint replaced the intended gold-leaf gilding given the high cost. While this does not achieve the same effect in relation to expression, durability, and nobility, it captures the symbolism. Areas where there was originally gilded carving were documented so that gilding can be applied in the future, under more favorable economic conditions (Figure 5 – center). The reduced budget did not allow, either, for the colorful motifs of the vaults, walls and chapels to be made visible. Some 'openings' were created in the plaster to allow the record of the underlying paintings to be visualized, and to give a sense of what exists beneath the whitewash (Figure 5 – right).

In spatial terms, we can reference the Santiago Chapel, where principally blue painting graces the surfaces (Figure 6 – left).
However, the colors are degraded, mainly due to the humidity and to leaks, making it necessary to ensure the solidity of the surfaces so that they can function over the long term.

In architectural style terms, besides the painting, one has to consider the importance of the artificial coatings and frescoes, since the mortar color for all of them must be the same. There is always a break in authenticity when one paints the mortar, because it is altering the conditions of the material's existence and its color. Therefore, mortar should be tested so it conforms to the texture, consistency, coverage, and color of the original. One has to verify if there is wicking within the walls and if there are breaks in the piping in the walls that is destroying, or that could come to destroy, the painting and artificial coatings, as is happening in the Santa Catarina Chapel (Figure 6 – center).

Figure 6. Santiago Chapel (left). Santa Catarina Chapel (center). Ancient sacristy (right). Photo: RBD.APP, in progress, 2021.

The ancient eighteenth century sacristy is accessible through a transitional space containing panels of glazed tiles that were restored, and it is itself completely covered in tiles. These are organized in a figurative design of blue and white, creating a spatial unity that exalts the space (Figure 6 – right).

Conclusion

The project used all relevant technical and legitimate instruments to ensure the authenticity of the process, and the works were monitored by DRCALEN and DGPC (heritage institutions). The results obtained, and in progress, are in line with the anticipated objectives. The assurance of this comes through the methodology used, the materials, the technical means and techniques used, the onsite assessments, and the trials done throughout the process in various atmospheric and lighting conditions. In this way, after the trials it was concluded:

In the marble seams, to use a measure of lime, half a measure of hydrated lime from *Calcidrata*, half a measure of natural quicklime NHL-3.5 from *Secil*, three measures of sand (1 APAS 12 from *Airport*, 1 APAS 20 from *Airport* and 1 APA 60 from *Airport*). Where the gap to be filled is very large a stony granitic material is to be used to fill in structure in a way that does not alter the mechanical properties of the joints.

In filling up the joints in the marble, use a measure of lime, half a measure of hydrated lime from *Calcidrata*, half a measure of natural quicklime NHL 3.5 from *Secil*, three measures of sand (1 of FPS 120 *Airport*, 1 of APB 60 *Airport*, half of APAS 60 and half of calcium carbonate).

There are technical and chromatic procedures that assure the color and authenticity of the whole, and which should be documented. The concepts used in the project—reversibility, versatility, simplicity, and sustainability—were applied as planned throughout the whole project and works.

References

Aguiar, J. 2002. *A intervenção no Património. Práticas de Conservação e Reabilitação*. 1st ed. Porto: Faculdade de Engenharia da Universidade do Porto: 246-247.

Duarte, R. and Pinheiro, A. P. 2016. Relatório prévio - Reabilitação da Sé Catedral de Portalegre, claustros e espaços anexos. *Architectural report for the General Directorate of Cultural Heritage (DGPC)*, Portugal. Portalegre: Diocese de Portalegre e Castelo Branco: 29.

Oliveira, A. R. 2021. Relatório de testes realizados em materiais pétreos - Reabilitação da Sé Catedral de Portalegre, claustro e espaços anexos. *RESTART conservação e restauro*: 11.

Pinheiro, A. P. 2016. *Proceedings of the 10th EAAE/ARCC International Conference*. 1st ed. London: Taylor & Francis Group: 16-17.

Pinheiro, A. P. and R. Barreiros Duarte. 2020. Reabilitação arquitetónica e Património: Catedral de Portalegre. *al.madan*, (2nd series | November 2020): 96-105.

Pinheiro, A. P. 2019. *Proceedings of the First Russian Congress on Color*. 1st ed. Smolensk: The Scientific Notes of the Color Society of Russia: 61-66.

The Effect of Colours and Textures of Interior Materials on the Thermal Comfort of Libraries in Hot and Humid Climates

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Abstract

To provide a comfortable place for readers and researchers and to attract visitors to the library, it must be taken into consideration with equal importance both the appropriate temperature to preserve the library's materials and people's thermal comfort. This study aims to develop thermal comfort in libraries by using the colours and textures of materials inside the library to improve thermal comfort, maintain the appropriate temperature to preserve books. This study also aims to understand the effect of colour on the visual and psychological perception of heat to enable the development of design approaches in response to these findings. The methodologies used in the research compare the materials used in global libraries in different regions, temperature measurements, and interviews with library users. The results showed that colours and materials are selected in libraries regardless of the climatic zone's thermal comfort requirements. The temperature of the library is too cold, it affects the comfort of users, while warm colours give the physical feeling of warmth.

Keywords: *Worm colour, cold colour, thermal comfort, hot and humid Climates*

Introduction

Libraries contain books, manuscripts, and other library materials that must be preserved from damage by providing a suitable atmosphere of temperature and humidity. Not only do the library materials need to be maintained at an appropriate temperature, people in the library, such as employees and visitors, also need a comfortable temperature. Thermal comfort is important to encourage library attendance. One of the basic design elements of building a library is to consider air temperature. ASHRAE Standard 55 (2020) indicates that 24°C, plus or minus a degree, is the most comfortable temperature in hot and humid areas. Therefore, the comfortable temperature for humans in hot and humid areas ranges between 23°C and 25°C where the average comfortable temperature in these areas is 24 ° C.

Increasing the temperature raises the rate of chemical degradation in conventional library and archival materials (Adcock et al., 1999). The basic guidelines established by Ogden (1999) for the preservation of library and archival materials recommended that the temperature in the internal space of libraries not exceed 21°C while humidity should not exceed 50%. Also, the International Federation of Library Associations (IFLA) indicates that the temperature for the care and handling of library materials should be around 20–22°C (68–72°F) in reading areas (Adcock et al., 1999). The difference between the highest temperature for preserving books in reading areas and the lowest temperature for human thermal comfort in hot and humid regions is one degree. In contrast, the difference between the average temperature for thermal comfort and the average temperature for keeping books is three degrees.

Interior design, through the choice of colours and materials, could play an important role in bridging the difference between the appropriate temperatures for thermal comfort and keeping books in reading places. People's sense of vision highly impacts how cold and warm they feel (Wastiels et al., 2012). Thus, retailers use textures and the colours of decorative materials to stimulate feelings of warmth so that they do not have to adjust the temperature mechanically (Baek et al., 2018).

The Reflection of Temperature Sense in Materials' Colours and Texture

Wastiels et al. (2012) proved that glossy surfaces (e.g., metal and glass) provide a cooler perception of temperature than textured surfaces (e.g., fabric and wood). Moreover, colour has a greater influence on perceived warmth.

Balcer (2014) confirmed that colours have a clear effect on temperature perception by conducting a test on the effects of the colours red and blue on eleven women and three men. Hot colours, such as red, can reduce how cold people feel, whereas cool colours, such as blue, can reduce feelings of warmth (Ziat et al., 2016). The appropriate choice of colours in interior spaces depends on many factors, such as human activity in the space, the orientation of the space, and the climate outside of the space. For example, in spaces in the northward direction, the use of warm colours is preferable. Warm colours are preferable in cold climates, whereas cool colours are preferable in hot climates (Ćurčić et al.,2019). In interior design, choosing suitable colours can increase energy efficiency and visual comfort (Goodarzisoroush & Mostafavi, 2018).

Virtual Reality

Kuliga et al. 's (2015) study examined the coincidence of building users' experiences in a real building and a virtual model of the same building, and they proved that virtual reality has high potential as an experimental research tool in psychology and architectural study.

The results of the simulation by Zhang et al. (2019) suggested that 3D virtual reality technology could enhance the realistic effect of interior design by increasing interior design logic and assisting interior decorating and graphic design. Also, Zhang et al. (2019) indicated that 3D virtual vision technology provides greater direction for interior design, visual effects, and other applications.

Methodologies

Comparison of Colours and Materials Used in Global Libraries

The first comparison was between the materials and colours for the interior design of three sustainable libraries located in different climatic regions around the world: Temple University's Charles Library in Pennsylvania in the United States, which has a cold climate; the King Abdullah University of Science and Technology (KAUST) Library in Saudi Arabia, which has a hot and humid climate; and the Library of Alexandria in Egypt, which has a Mediterranean climate. As shown in Table 1 below, the colours used on these libraries' ceiling, handrail stairs, and columns are brown, blue, white, and gray. The materials are white-painted wood and metal with reflective surfaces.

Library	Location	Climate	Colour Palette	Materials
Charles Library	USA	cold		wood, painted, and metal
KAUST Library	KSA	Hot and Humid		wood, painted, and metal
Alexandrina Library	Egypt	Mediterranean		wood, painted, and metal

Table 1. Comparison of three sustainable libraries in different climates,

Library	Location	Climate	Colour Palette	Materials
Green Library	Thailand	Hot and Humid		light wood, vinyl, and light paint
King Fahd Library	KSA			orange-painted wood, carpets, metal, and plastic
Qatar National Library	Qatar			marble, acrylic, and wood

Table 2. Comparison of three libraries in hot and humid regions.

The second comparison was between materials and colours for the interior design of three libraries located in hot and humid climate regions around the world as follows: the Green Library in Thailand, the King Fahd Library in Saudi Arabia, and the Qatar National Library in Qatar. As indicated below in Table 2, most of the colours used in the Green Library and Qatar National Library are cool, such as white, green, blue, and beige, while the colours used in the King Fahd Library are warm, such as orange, gray, and light yellow. The materials used in the Green Library include light wood for the bookshelves and reading desks, vinyl for the floor, and light paint for the walls and ceilings. The King Fahd Library has orange-painted wood, carpets for the floor, metal for the bookshelves, and plastic for the reading tables, while the Qatar National Library has marble for the floors on the reading zone, acrylic for the bookshelves, and wood for the reading desks.

Temperature Measurements

To determine the temperature of the library and its suitability for thermal comfort and preservation of books in hot and humid areas, the King Fahd Library in Jeddah in the Kingdom of Saudi Arabia was used as a case study. Temperatures were measured in different reading areas of the King Fahd Library, which is located in hot and humid areas. The King Fahd Library contains two sections: a section for men and a section for women. The temperatures ranged between 19.3℃ and 21.6℃ during the day, while they ranged between 17.4℃ and 19.1℃ at night, as shown in Table 3 below.

Library		Section	Zone 1 reading area between book shelfs	Zone 2 book shelfs	Zone 3 reading area open space	Zone 4 reading area study room	Zone 5 reading next widows
King Fahd	Day	Male	20.8 °C	20.5 °C	20 °C	21.6 °C	21 °C
	Night	Male	19 °C	18.8 °C	17.9 °C	17.5 °C	19 °C
	Day	Female	19.7 °C	19.3 °C	18.7 °C	20.6 °C	19.7 °C
	Night	Female	19.1 °C	18.7 °C	18.6 °C	17.4 °C	19 °C

Table 3. Temperature measurements for different zones in the reading area of King Fahd Library.

Semi-structured Interviews

Interviews were conducted with six users of the King Fahd Library, and a virtual reality (VR) headset device was used during the interviews. Two 3D images were shown to them that simulate an interior design for the reading area of King Fahd Library which could be rotated 360 degrees. The wearer of the VR headset could feel like they were inside the place and experiencing the impression of its colours (Figure 1).

Figure 1. Two simulations of interior design for the reading area of the King Fahd Library that could rotate 360 degrees.

The first picture uses cool colours and soft and reflective materials, such as leather, as shown in Figure 2.

Figure 2. First simulation.

The second picture is a simulation of the same place but with warm colours and somewhat rough materials, such as fabric and wood, as shown in Figure 3 below.

Figure 3. Second simulation.

The first interview question was about the user's experience in the library and the library's thermal comfort; every interviewee answered that the library is always cold. The second question was about their willingness to go to the library; they all mentioned that they took a jacket or thicker clothing with them to wear in the library so that they could achieve thermal comfort and stay for a longer time. One library user mentioned that he often leaves the library early because he feels cold. All interviewers indicated that they changed locations in the library to find a warmer place. The third question in the interview was about the participants' impressions of the image they see through the VR headset, which is the image referred to in Figure 2. The six interviewees said that the picture has comfortable colours, but they did not feel a difference in temperature and still felt the library's coldness. When the image was changed in the VR device to the image shown in

Figure 3, the participants all stated that they felt warmer when looking at the place with warm colours and lighting. All of them reported that they preferred to sit on the fabric more than the leather because it made them feel warm, and they preferred the wooden desk over seating made of plastic and other materials that reflect the cold.

Results

By comparing three sustainable libraries in the world located in regions with different climates and three libraries in hot and humid areas, significant results were found. Building design rarely considers the textures and colours of materials in public buildings. The design of public libraries throughout the world incorporates similar materials and colours regardless of the region's climate. For example, similar materials and colours are found in the interior design of Libraries in the United States, Egypt, and Saudi Arabia, as shown in the examples in Table 1.

On the other hand, libraries located in the same Kind of region use significantly different materials and colours, such as the Green Library in Thailand, the Qatar National Library in Qatar, and the KAUST Library in Saudi Arabia, which are all located in hot and humid regions, as shown in Table 2.

The results of measuring temperatures for a library located in a hot and humid area (the King Fahd Library) showed that the reading area's temperatures in the daytime and nighttime are lower than the temperature that achieves thermal comfort according to ASHRAE Standard 55 (2020), although the temperatures are suitable for keeping books on the shelves located in the reading area according to the IFLA (1999).

The interviews, which took place in a library located in hot and humid areas, showed important results that the following points illustrate:

- First, visitors feel cold, which affects their comfort, the length of time they spend in the library, and the desired benefit of visiting the library.
- Second, warm colours greatly affect their feeling of physical warmth and, thus, their feeling of thermal comfort.
- Third, visitors prefer rough and textured materials that do not reflect the coldness in the library's reading area.

Conclusions and Future Work

The temperature of libraries in hot and humid areas is lower than the temperature required for thermal comfort in these areas, although the temperature is appropriate for preserving books. The results of this research show that the use of warm colours and woven and rough materials helps visitors obtain thermal comfort. In order to obtain results that can be generalized for libraries in hot and humid areas, future studies can send questionnaires to a large population located in this climate. This research can test the reading places in libraries by using rough materials and paints with warm colours. Researchers can then observe the behaviour of visitors, their choice of seating, and how much time they spend in the library.

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References

Adcock, E. P., M-T. Varlamoff, and V. Kremp, eds. 1999. *IFLA principles for the care and handling of library material*. International Federation of Library Associations and Institutions, Core Programme on Preservation and Conservation.

American Society of Heating, Refrigerating, Air-Conditioning Engineers, & American National Standards Institute. 2020. *Thermal environmental conditions for human occupancy*.

Baek, E., H. J. Choo, and S. H. M. Lee. 2018. Using warmth as the visual design of a store: Intimacy, relational needs, and approach intentions. *Journal of Business Research* 88: 91-101.

Balcer, C. A. 2014. Visual cues effects on temperature perception. Thesis. Northern Michigan University.

Ćurĉić, A., A. Kekovic, D. Ranđelović, and A. Momcilovic-Petronijevic. 2019. Effects of color in interior design. *Zbornik radova Građevinskog fakulteta* 35: 867-877.

Goodarzisoroush, M., and A. Mostafavi. 2018. Promotion of efficiency in low-carbon architecture through explaining the principles of optimal distribution of light and definition of interior reflector materials (in educational applications). *Islamic Azad University*, 5-17.

Kuliga, S. F., T. Thrash, R. C. Dalton, and C. Hölscher. 2015. Virtual reality as an empirical research tool—Exploring user experience in a real building and a corresponding virtual model. *Computers, Environment and Urban Systems* 54: 363-375.

Ogden, S. 1999. Temperature, relative humidity, light, and air quality: Basic guidelines for preservation. *Northeast Document Conservation Center*.

Wastiels, L., H., N. J. Schifferstein, A. Heylighen, and I. Wouters. 2012. Red or rough, what makes materials warmer? *Materials & Design* 42: 441-449.

Zhang, Y., L. Li, and B. Liu. 2019. The discussion on interior design mode based on 3D virtual vision technology. *Journal of Advanced Computational Intelligence and Intelligent Informatics* 23: 390-395.

Ziat, M., C. A. Balcer, A. Shirtz, and T. Rolison. 2016. A century later, the hue-heat hypothesis: Does color really affect temperature perception? *In International Conference on Human Haptic Sensing and Touch Enabled Computer Applications,* pp.273-280.

Reconstructing a history of colour in Mexican women's fashion 1900-1910

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Abstract

To reconstruct a history of women's clothing in Mexico from 1900 to 1910, based on the periodical publications of the time, a history of colours can be unravelled. Each historical context has framed specifications in colour & design. For this investigation, we start from the last year of the 19th century, emphasizing in each garment their textile design, trends, silhouettes, cuts, materials, textures and volumes. First, it starts from the raw material. In other words, the types of fibres used were mostly due to natural fibres. Secondly, the manual and industrial processes for the colouring of manufactured textile materials will be analysed. In the same way, the finishes and final details are addressed. As a third section, the representation and distribution of women's clothing designs emphasize prices providing a colour palette that reflects the preference of the female public, their social, economic and cultural position. Therefore, it is possible to contribute to understanding the designs of a specific decade in Mexico, without omitting the influence it received from Europe. It seeks to provide a conceptual solution that can be used by clothing design students interested in looking at the history of colour, through the looks and chromatic traces preserved in archives.

Keywords: *History, Colour, Mexico, Fashion, Women*

Introduction

From the beginning of the Porfiriato, an admiration for European fashion became evident, to which only the wealthy classes could access, beginning with Díaz himself and his wife. The national identity of textile and apparel design were expressed in subtle associations with the transatlantic world. Mexico showed artistic and cultural influence by France and England, due to their investments. In the case of the United States, the influence of this neighbouring country was due to its geographical proximity, as well as its economic interest. The codes of clothing and the way of dressing quickly positioned these three nations as an aesthetic reference for the female silhouette, textile materials, shapes and colours, based on political ideology and social events.

By the beginning of the twentieth century, Paris reigned as the capital of art and fashion, with great extravagance and opulence, French haute-couture predominated over English fashion. Art Nouveau was the artistic avant-garde that ornamented curved shapes, floral prints and ornaments in pastel tones. Women wore corsets, in addition to beautiful dresses, two piece sets were introduced, which consisted of a skirt and blouse. Garments often featured high necks for the day and low necklines for the night. Lace dresses were popular for the outdoors. Pale colours and fabrics in monochromatic tones accompanied by embroidery, they were bathed in this style. By the end of the first decade of this century, elaborate hats of great size and decorated with feathers of birds, were indispensable for the upper-class Mexican women, since much of the European fashions permeated the daily life of the nation.

Women's Fashion Colours in the Press

Slippers & Boots: colours, material and price

On May 10th 1900, the letter of the writer Margarita was published in the Ecos de la Moda Parisien section, in which she outlined the general lines of fashion. In the note it was possible to read that the "beginning of the use of grey kid shoes adorned with borders and stitched arabesques; they were accompanied by black silk stockings embroidered on the sides. Also announce the appearance of beautiful Louis XV style shoes, black morocco with openwork, drawings and red silk heels, which will be accompanied by stockings the colour of the heels."[1]

In accordance with the fashion of the time, the material of the slippers was white satin fabric, in pastel colours, varied like pink, blue and black. Qualifications such as fantasy buckles, bows and beads added to this type of footwear. They are also made in suede material in red, blue, green and white colour variants. In addition, the companies offered the option of ordering them in the way you wanted: in canvas, leather and kid material. As an alternative to the slipper, there were shoes that used elegant buckles to be able to open and adjust to the size of each foot. For those who wanted to cover the foot even more, they could buy a pair of glacé boots, which were open to allow the foot to air; they used to have buttons or laces, for opening and closing. Like the shoes, they were in suede in various colours such as red, blue, green, pink and white. Another option was corn with a bow, with buttons, with balls and ribbons, in a variety of colours. Felt and leather slippers. Patent leathers showed an option in tanneries for the construction of footwear, furniture and harnesses due to their resistance, flexibility, firmness and colour tones equality. They were also made of patent leather with a thin or thick sole and with a military or French heel.

[1] *El Popular,* México City, 29th May 1900, p. 1

Figura 1. El Tiempo, October 31st, 1900, p. 3.

As for its production, both industrially and massively, it was difficult for the national workshops and artisans, since the permanent tension between the importation of shoes of American origin and the exportation of footwear produced in Mexico was inevitable. The registry of the newspaper *El Imparcial* dated October 16, 1910, allows us to note the design of satin slippers in pink, white and blue, black with fantasy buckles, kid with bow, beads and suede. According to this announcement, the Port of Veracruz located at the corner 2nd of the Fifth of February and 3rd Capuchinas, they sold the shoes at prices ranging from $8.95, $9.95, $11.50, to $12.50 Mexican pesos.[2]

White as a witness of the time

The beauty canon for 1900 was highly related to the colour white. [3] In all its ranges this colour, since then, referred to the hygienic, the pure and the clean. This aesthetic permeated not only the tissues and fibres, but also the pores of the skin. While natural skin with facial hair was rejected, a pale complexion was validated as synonymous with beauty. Those who wanted to achieve this state of the skin had to have the cosmetic help of pharmaceutical companies with the use of creams, powders and waxes.

In the newspaper *El Tiempo Ilustrado* of 11th August 1907,[4] It stated that the trend was increasingly towards white in all kinds of garments, in all its gradations from the purest, crudest white, to creamy white bordering on white and yellow. The fondness for this colour in the social sphere was not accidental, and it is that it carried from the interior of the toilet. The use of white colour was abundant as it detonated luxury and elegance. For the example of the above, the peinador was a transcendent piece of underwear, indispensable for the careful damask. Its design changed with wide sleeves that abandoned the elegance that had marked it, with the application of lace ornaments, ruffles and ribbons. It was created in white, with satin folds adorned with lace on the neck and tulle on the sleeves. The hairstyle was the simile of what we know today as a robe. It was a gallant and sumptuous shot.

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[2] *El Imparcial*, México City, 16th October 1910, p.4

[3] The association of this colour prevails until these first decades of the 21st century, with the clear distinction that currently, underwear is dying in a wide variety of colours. In consequence, it is offered in fluorescent, phosphorescent or iridescent versions. By 1900, the options were limited to neutral, pastel and white tones, so the use of extravagant colours or black were unimaginable, which today denotes elegance, sophistication and luxury.

[4] *El Tiempo Ilustrado*, México City, 11th August 1907, p. 19.

Figure 2. *The Mexican Herald*, 16 de mayo de 1907, p.7. **Figure 3**. Peinador, *El Diario*, February 19th 1907, p.3.

At the beginning of the 20th century, the practice of sports as part of the concern for health lightened textile fabrics and discovered the parts of the body that were previously hidden, in order to provide comfort (Sohn, 2006: 102). Little by little, appearance, which had paid more attention to clothing over valuing the skin and the body, turned towards health. The technology that was glimpsed at the beginning of the century, granted longevity, although for the female world it was a total metamorphosis, since it gave them "greater social participation" by reducing the demand in the space of private property destined for the upbringing of children (Duby & Perrot, 2000: 31).

By 1905, lingerie dresses in flowing white colors with lace detailing were a popular choice for warm weather indoors. In 1910, black velvet for dresses and underwear gained strength as part of fashion trends.[5] Regarding this issue, he considers that "cleanliness in the 17th century was essentially concerned with clothing and immediate appearance, while later the preservation of the body or the defense of the population would be taken into account" (Vigarello, 1985: 2). The above,

[5] *Zig Zag*, 23th January 1910, p. 17

because it is immediately visible, even above the body. The author suggests us to discover the changes that both garments and cleaning practices are taking place in increasingly complex ways. Without forgetting the place where they manifest. To clarify this, the cleaning practices that we know today are not the same as those of 1900 to 1910. Shaking a garment was enough to consider it "clean".

And the hats, as natural as possible

If it was desired to go outdoors, a pretty hat accompanied the lady who was about to take a walk. Elaborate hats, often large, decorated with bird feathers, enjoyed great popularity. According to the fashion of 1910, the last fashionable word for high life hats was "Nouveauté a la Napoleon", which had to be "straw straw in the natural color, with a round crown and high up to the height of the crown", from the wing, which carries the Napoleon from behind and from the front. A wide black velvet ribbon, 8 to 10 centimeters, surrounds the cup and passes over the brim, in a section of 15 centimeters, as seen in the engraving. An arrow passes through the entire length of the exposed section of the ribbon, in an oblique direction, and while the point of the arrow is fire-gilded, the simulated feathers at the opposite end are shaded in strong colors. The hat is simple and of great effect.``[6]

On August 1st 1908, it was published that due to the monetary crisis that fell on the United States, a severe law was voted to repress the exaggeration of feminine elegance: "<<No woman, married or single, may wear in the hat more feathers than those from turkeys, roosters, geese and other poultry. >>;<<Gold and silver earrings and bracelets are prohibited.>> <<All seamstresses must record the hats sold, prices and people who bought them in a book.>>"[7]

Epilogue

Based on the periodic press, this work makes a contribution by locating some garments from the Porfiriato events in Mexico, based on primary sources based on news that described the colors, materials, and prices of women's designs . In the case of color, it is important to point out that there is a bias due to the lack of images to be able to map the color palette of the time, however, this opens a new path in my research.

We can appreciate that in this decade, the representation of an extremely feminine woman became present in the fashion trends designated elegance, flowing lines, eccentric curves, drooping shapes, and pastel colors characterized the dress of the time. Tailor-made suits were as expensive as they were popular, but many women chose the lingerie dress, especially the younger ones, who did not dress to show the last layer of fabric, but the first: the underwear. In the case of delicate gowns, those were be sewn with lightweight fabrics like: chiffon, organdie,

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[6] La Gaceta de Guadalajara, 17th April 1910, p. 10

[7] La Patria, 1st August 1908, p. 3

or cambric, in white and pale pastel shades, all woven flat, resulting in wide pleats with delicate material such as lace, embroidery, and trims with a touch Romantic.

Although large cities were the center of consumption for textile creations, women outside this center can choose to follow trends from the comfort of their home. Thanks to the efficiency of the postal service, you can request textile supplies from the empires for the clothing of the city. If the woman did not have the resources or simply decided to make the garment herself, she could follow the visual references of the time in fabrics, colors and silhouette. Due to the above, the sewing machine took a primordial place in the lives of women; it was an essential tool to build the second skin not only of her, but also of the members of her family.

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References

Duby, G., and M. Perrot. 2000. *Historia de las mujeres en occidente*, V. Madrid: Taurus.
Sohn, A. 2006. 2003. El cuerpo sexuado In: Jean-Jacques, Courtine (Comp.), 2006, *Las mutaciones de la mirada*, Madrid: Siglo XX & Taurus.
Vigarello, G. 1991. Lo limpio y lo sucio, la higiene del cuerpo desde la Edad Media. Madrid: Alianza.
National Newspaper Library of Mexico (Hemeroteca Nacional de México):
El Imparcial, México City, 16th October 1910, p.4.
El Popular, México City, 29th May 1900, p. 1.
El Tiempo Ilustrado, México City, 11th August 1907, p. 19.
La Gaceta de Guadalajara, 17th April 1910, p. 10.
La Patria, 1st August 1908, p. 3.
Zig Zag, 23th January 1910, p. 17.

Sensing Colors Through Smart Lighting Based on Multisensory Experience of Poetry

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Abstract

As the hierarchy of living needs has increased, people are looking for products that not only meet their needs but also create positive experiences for them. In a multi-sensory design approach, the designer intentionally considers the role of every sensory modality. Intangible sources like poetry can also be a source of design inspiration. With the emergence of modern lifestyles, although there are still signs of poetry in people's lives, compared to the past, poetry has moved away from everyday life. A renaissance for old poetry is needed because these poems are full of human concepts that should not be forgotten. The aim of this study is to design a multisensory experience around Hafez's poetry and explore the role of sensing colored lights related to his poems that evoke positive emotions. The design thinking method includes the literature studies, holding generative sessions, making the product simulation, and testing it using the “prEmo” method. The results showed that the use of colored lights could significantly increase the expression of positive emotions in users. As a result, engaging the user's different senses in interacting with a product based on poetry can enrich the experience.

Keywords: *Multisensory Experience, Colour, Poetry, Sensing, Smart Lighting*

Introduction

There is an imagery sense in poetry which can be experienced when it is read or listened to. The use of figurative language evokes a sensory experience in the reader by "reading" or "listening" to a poem that is often full of different emotions. It provides the sights, tastes, smell, sounds, internal and external feeling, and even internal emotions. Although unique regional cultures have always been an amazing source of inspiration for designers, this inspiration has been limited to tangible cultural sources such as historical buildings or cultural artifacts. Therefore, the fact that intangible sources like poetry can also be a source of design inspiration is somewhat ignored (Zhu & Yu, 2015). However, in recent years, with the emergence of modern lifestyles, although there are still signs of their poetry in people's lives (for example many people still keep Hafez's book in their homes), compared to the past, it has moved away from everyday life. In this context, design can play an important role in designing novel everyday products based on poetry. When the subject of a product design project is based on poetry, the emotional nature of poetry becomes a good reason to design in such a way that the different senses of the body are involved to give users a deeper and more pleasurable perception of a poem. The first part of this article is a literature review on topics such as multisensory product experience, multisensory experience of poetry, as well as the relationship between poetry and colored lights, and a look at Hafez and his poems, as an example of poets who have dealt with immaterial concepts in their poetry. The second part of this study is based on a practical project for designing a smart device in order to create a multi-sensory experience of Hafez's poetry. The next sections are dedicated to testing and evaluating this product with the users.

Multisensory Product Experience

As a human being, we are all created with a "Sensing Body" and with the help of our senses, we can deeply gather information and perceive the world around us - on large and small scales. It is traditionally identified that there are five basic senses: sight, smell, touch, taste, and hearing. However, in recent years, it is accepted among the scientific community that we have more than those five senses; for example, the sense of proprioception, which makes awareness of the body in space (Bjorklund, 2010), Interoception, which recognize internal body cues, or even the ability to sense Earth's magnetic field (Velasco and Obrist, 2020). But what role does this sensing body play in our relationship with products? The field of "Product Experience" seeks to understand the subjective experiences of individuals that result from human-product interactions. To interact with products, we always use our senses to perceive them, then we process the perceived information and as a consequence, we may experience one or more emotions. All our senses work together to form our overall product experience, which is important to pay attention to each of them in the design process. (Hekkert and Schifferstein, 2008). On this basis, although in a way, all experiences are multisensory. The concept of "Multi-Sensory Product Experience" is different from "product experience". In designing a multisensory experience, the human senses are central to understanding how the experience is understood. In addition, the multisensory experience is intentionally designed to be multisensory, meaning that the designer applies sensory elements to his design in order to make a particular impression on the user. (Velasco and Obrist, 2020). In this way the greater the number of sensory modalities that are stimulated at any one time, the richer our experiences will be. (Hekkert and Schifferstein, 2008).

Multi-Sensory Experience of Poetry

The word "Poetry" may refer to different things, such as different ways of writing, ways of seeing the world, or states of mind. But commonly, we consider "poetry" as the art or work of a poet. By the use of distinctive style and rhythm, poets make compositions in verses or patterned arrangements of language, so that they express their feelings and ideas (O'Donoghue , 2019). Poets have the abilities of thoughtfulness and observation. They transform existing images into a language of meaning and emotion. They use words to create authentic experiences for people

(Marti, 2015). Therefore, what designers do have similarities with what poets do. Designers are expected to design experiences that give people a positive emotion and sublime meaning by carefully observing and thinking through their design process. A product designer designs experiences for people with his product, while a poet does that with his poetry. The nature of poetry is multi-sensory and it excites our senses; as Kurkjian et al (2004) pointed out in their article that the poetry can be experienced in multiple modalities, and as new technologies emerge, it can be also experienced through multimedia formats like picture books, multimedia poetry, or cinepoetry (Kurkjian et al., 2004). However, it should be considered that the focus is on improving image and/or sound in audiovisual (AV) systems when it comes to multimedia applications. This causes the stimuli to be mainly limited to the sense of sight and/or hearing, and therefore a level of disconnection between the user and the represented scene happens because of the lack of stimuli for other senses like tactile, olfactory, or taste (Covaci et al., 2018). Although poetry is inherently emotional, poems are obviously different and can be classified using many different evaluation metrics, such as subject, historical period, author, school, place of origin, etc. (Lou et al., 2015).

Sensing Colored Lights

Our vision is a type of energy receptor just like our other senses. Light, as a transmitter of energy, is the stimulus for vision. Our sense of sight of course does not collect this energy for its own sake, but for informing our brain about the environment and products we experience (Mayo, 2015). One of the reasons that light is so important for us, is its role in colorimetry. Without light, there is normally no color. Colors can be self-luminous and, in that case, the light source itself is the color. On the other hand, more colors are not self-luminous, but they are associated with objects that reflect or transmit the light emitted by light sources (Ibid). With the help of colors, we can make communications in a non-verbal form and influence people's attention, learning, and certain moods. Also, when we want to present complex information to audiences, colors can make it easier (Asarkar and phatak, 2020). Today It is clear for us that colors affect a person's psycho-emotional state and are associated with certain moods (Hussain, 2021). Accordingly, "Colored Light " is among the important stimuli for the human sense of sight and can affect both the perception and the feeling during the experience of poetry. Depending on the designer's decision and the characteristics of the selected poems, the inclusion of colored lights in a multi-sensory experience of poetry can take many different forms.

Methodology

This study describes the role of sensing colored light in a multi-Sensory experience of poetry. The general direction of the research was the use of "Design Thinking" which consists of three main steps: "Inspiration", "Ideation" and "Implementation" (IDEO, 2015). The first part of the research focused on library studies. In addition, there have been observations and communication with users to receive more in-depth information (Inspiration phase in Design Thinking). The second part of the research is dedicated to ideation and application of what was learned in the first phase through a practical project. In this section, a smart device was designed that offers a multi-sensory experience around poetry, with a performance of colored lights as a key role in it; In this step, the initial prototype and simulation were considered. In the third part, the simulated version of the product was tested and evaluated with ten users, using the PrEmo (Product Emotion Measurement Instrument) tool (Ideation and implementation phase in Design Thinking).

Designing The “Hafiz” Smart Poem Reader

“Hafiz” is one of the greatest Iranian poets. He lost his life in the city of Shiraz in Iran and has rested in a place called “Hafezieh”. Many poem lovers travel to Shiraz every year to visit his magnificent and beautiful tomb (Jafri, 2000). The motivation of these visitors has both physical and mental aspects. From the physical point of view, the atmosphere of the site has its unique features, and from the mental point of view, the mental and affective connection with the poet and his poems creates attraction. Combining these two aspects, the main level of experience for visitors is obtained which is the cognitive perception and learning experience (Azizi et al., 2020). Hafez's tomb has a special importance in terms of its architecture and aesthetics. It has symbolic significance in Iranian culture. “Hafezieh” is not limited to this tomb and has other elements such as orange trees, flower gardens, paths, and a stream. (Yarshater et al., 2011). Hafiz used to write his poems when he was divinely inspired. “Divan of Hafiz” is his famous book and its poems are mainly about spirituality, love, and objectivity. Hafez believed in his poems that human love is a prerequisite to divinity or mysticism. This love, which has been inherent in mankind since the beginning of his creation- can lead him to prosperity and perfection (Li et al., 2021). One of the interesting traditions about Hafez's poetry is that his divan is used for practicing divination and this bibliomancy is called “Fâl-é Hafiz”. When a querent is in a dilemma and seeks an answer to his question, he holds the Divan in his hands while it is closed. Then he prays for Hafiz’s soul to rest in peace, concentrates on the question with closed eyes, and finally opens the book to a random page. The poem on that page in which his eyes fall is the answer to his question.

Sometimes modern querents use an e-book of Hafiz’s Divan for that purpose. But however it is done, the main point is that the queen reaches the poem purely randomly (Aghamohammadi, 2019). These data, along with previous observations and interviews, were analyzed to determine which features of Hafez, his resting place, and his poems could be applied to the design of a smart device and help to create a multisensory experience around his poetry. This process is briefly shown in Table 1. The final smart device (Shown in figure 1) was designed based on engaging the senses of sight, hearing, and smell, as well as the sense of touch at a lower level. In this multi-sensory experience, for each poem, according to its concept, a performance of colored lights is considered.

The human Sense	Type of Experience	Feature in Product	Details
HEARING	Acoustic Experience	The Recorded Voice of Reading a Poem	By Each time pressing the "Play" button, the recorded human voice of reading a Hafez's poem is played *randomly*. This form of poetry is not only inspired by the tradition of divination but also is a sensory representation of listening to someone reading a poem in "Hafeziya".
SIGHT	Visual Experience	The Form, Size, and Color of The Device + Performance of Colored Lights	The form and the color of the designed product is a modern inspiration from the tomb of Hafez in "Hafeziya". **Colored lights** are synced with the concept of each poem to make the experience more pleasurable and help them better understand the poem.
SMELL	Olfactory Experience	The scent of Natural Incense	One of the main elements of "Hafeziya" is its smell of orange blossoms. In the designed device, by placing the natural orange blossom incense, that space is associated.
TOUCH	Tactile Experience	The Device Texture, Indentations, and protrusions	The designed device is like a small tomb of Hafez in hand. Users can feel the device by holding it in their hand, and also by touching its recesses to turn its light on and off.

Table 1. The brief process of creating a multi-sensory experience for Hafez's poetry.

Tests and Evaluating

"prEmo" tool is a set of fourteen cards showing a cartoon character that uses her/his face, body, and voice to express fourteen different emotions. Half of these are positive, and the other half are negative. With "prEmo", people can report their feelings about products by simply pointing out one or more cartoons. Since it does not rely on words, it makes the measurement of feelings simple and reliable (Desmet, 2019). This tool is used to understand how people feel about the designed product. The test was taken with 10 volunteers and its method was as follows: 1- In the first step, the image of the product was shown to the participants in its OFF state (without colored lights), the sound of reading the poem was played, and also the smell of fragrant incense was spread in the space. 2- In the second step, the sound of reading the poem was played along with showing the video of the product simulation in its ON state (with the performance of colored lights synced with the poem) and the smell of fragrant incense was spread in the space.

Figure 1. The designed “Hafez” smart poem reader

In fact, in the first case, involvement of the sense of sight, hearing, and smell was considered. The second case was actually similar to the first one, except that the involvement of the sense of sight was enhanced by colored lights. Finally, the data gained from the two steps were compared and analyzed (shown in figure 2). The results showed that people experienced different positive emotions while using the product. In this context, colored lights enhanced the experience of five positive senses compared to the off state (joy, admiration, pride, satisfaction, and fascination). The total score of positive emotions was 143 in the ON state; While this number was 109 in the OFF state. Also, during generative sessions and interviews with users, it was found that the experience of these feelings depend on the momentary mood of people, their backgrounds, and their interest in Persian poetry.

Figure 2. Left: taking prEmo test with users. Right: Results of prEmo tests.

Conclusion

We perceive the world around us with the help of our senses. Different stimuli around us can engage one or more of these senses in different ways and eventually lead to different positive or negative emotions. Research has shown that by increasing the number of senses involved in a product experience, the experience becomes richer for users. Meanwhile, colors can play an important role in affecting our sight senses. In this research, by using colored lights and other elements, a multi-sensory experience around Hafez's poetry was designed. The results of the product test showed that the presence of colored lights in this product experience can significantly increase the expression of positive emotions in users. It is suggested that in future supplementary research, the effects of colored lights other than increasing positive emotions, can be studied and the process of designing pleasurable experiences for the poetry of other poets can be continued.

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References

Aghamohammadi, M. 2019. The Divining Reader: A Construct Based on the Bibliomantic Approach to Hafez's Divan. *Journal of Applied Linguistics and Applied Literature: Dynamics and Advances*, 7(1): 119-140.
Asarkar, S. V., & M. V. Phatak. 2020. Effects of Color on Visual Aesthetics Sense. *In Proceeding of International Conference on Computational Science and Applications* .Springer, Singapore: 181-194.
Azizi, F., F. Shekari, and Z. Mohammadi. 2020. Literary Visitors' Motivations and Experiences: The Case of Hafez Tomb in Shiraz, Iran. *In Culture, People and Technology: The Driving Forces for Tourism Cities Proceedings of 8th ITSA Biennial Conference 2020*. 49-51.
Bjorklund, R. 2010. *The Senses*. Marshall Cavendish.
Covaci, A., L. Zou, I. Tal, G.M. Muntean, and G. Ghinea. 2018. Is multimedia multisensorial?-a review of multimedia systems. *ACM Computing Surveys (CSUR)*, *51* (5): 1-35.
De Mayo. 2015. *The everyday physics of hearing and vision*. Morgan & Claypool Publishers.
Desmet, P.M.A. 2019. *PrEmo (Emotion Measurement Instrument) card set: Male version*. Delft, Delft University of Technology.
Hekkert, P., and H. N. Schifferstein (Eds.). 2008. *Product experience*. Elsevier.
Hunt, R. W. G., & M.R. Pointer. 2011. *Measuring colour*. John Wiley & Sons.
Hussain, A. R. 2021. Colour Psychology in Art: How Colour Impacts Mood. *Art and Design Review*: 9(4), 301-308.
IDEO (Firm). 2015. The Field Guide to Human-centered Design: Design Kit. Ideo.
Jafri, S. 2000. Hafiz Shirazi (1312-1387-89). Social Scientist: 12-31.
Kurkjian, C., N. N. Livingston, T. Young, and L. B. Hopkins. 2004. Poetry: a feast for the senses. *The Reading Teacher*, 57(7): 694-793.
Li, M., Z. Mansor, & S. Band. 2021. Data visualization technique to study the conceptual metaphors in Divan of Hafiz and Bustan of Sa'adi. *Digital Scholarship in the Humanities*, 36(4): 971-979.
Lou, A., D. Inkpen, and C. Tanasescu. 2015, April. Multilabel subject-based classification of poetry. *In The Twenty-Eighth International Flairs Conference*: 187-192.
Marti, P., 2015. Poetry in design. *Design and semantics of form and movement*: 48-56.
O'Donoghue, B. 2019. *Poetry: A Very Short Introduction*. Oxford University Press.
Velasco, C. and M. Obrist. 2020. *Multisensory experiences: Where the senses meet technology*. Oxford University Press.
Yarshater, E., B.A.D. Khorramshahi, J.T.P. de Bruijn, D.M. Correale, J. S. Meisami, F. Lewis, and A. Lenepveu-Hotz. 2011. Hafez. *In Encyclopaedia Iranica Online*. Brill.
Zhu, S., and Z. Yu. 2015. Design of cultural products based on artistic conception of poetry. *In International conference on arts, design and contemporary education*: 347-351.

Colour Matching Experiments on LEDMax Technology: A Visual Colourimeter for Performing Colour Matching Experiment

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Abstract

A visual colorimeter based on two spectral tunable LED systems was constructed to perform a colour matching experiment between two side-by-side semi-circular stimuli. The visual colorimeter was based upon 18 LED channels whose center wavelengths ranged from 400 to 700 nm. A series of tests were conducted to evaluate the system performance on stability and consistency for both sides. Finally, colour matching experiments performed by normal vision observers were performed on this apparatus. Eleven different primary sets were selected as the primaries of the field of view to be matched, while the primaries of the reference field of view always remained the same. Five normal vision observers conducted a colour matching experiment. Each observer performed 11 colour matches for 5 times in the experiment. The results were used to reveal the inter- and intra-observer variations. In total, 55 colour matches were obtained. The collected data were analyzed from matching error, inter- and intra-observer variation.

Keywords: *Colour Matching Experiment, Visual Colourimeter, LEDMax*

Introduction

Human observers vary greatly between individuals. While everyone's color vision could be represented by color matching function (CMF). To obtain individual CMF, it is necessary to perform colour matching experiments. The typical example was that proposed by CIE, e.g. the CIE 1931 standard colorimetric observer [1] based upon the data accumulated by Guild (1931) [2] and Wright (1929) [3,4]. This paper describes a visual colorimeter to perform a colour matching experiment.

Figure 1 shows the system, consisting of control panels, identical left and right LED Cube units and a viewing compartment. Table 1 shows 18 LEDs of one cube with different centre wavelengths, ranging from 400 to 700 nm. The reference stimulus only emits white light at 4700K and its spectrum has multiple peaks, so it is not given in Table 1.

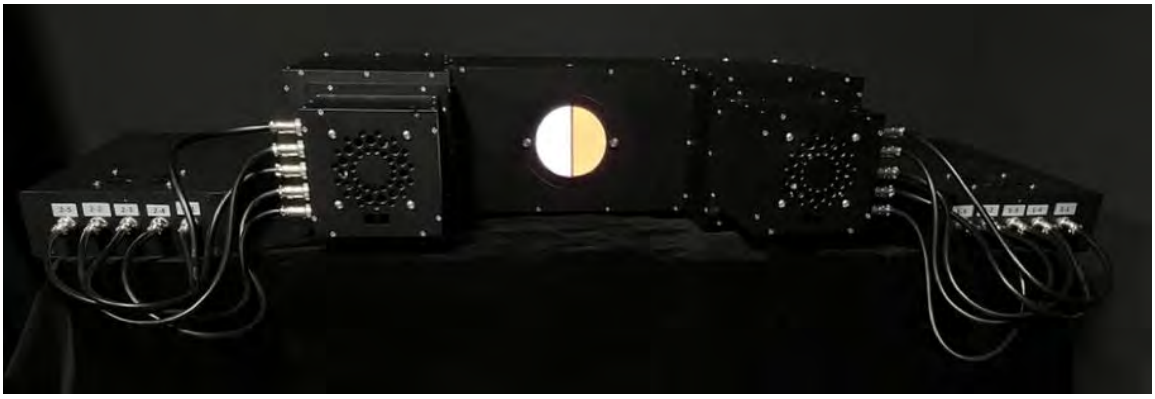

Figure 1. The internal structure and appearance of the visual colorimeter.

LED Channel ID	1	2	3	4	5	6	7	8	9
Centre wavelength (nm)	405	415	430	445	460	475	505	530	545
LED Channel ID	10	11	12	13	14	15	16	17	18
Centre wavelength (nm)	560	575	595	605	640	660	675	705	4700K

Table 1. Centre wavelength for 18 different LEDs in two LED cubes.

In Fig. 1, observers see the aperture including two uniform side-by-side semi-circulars. The field of view can be changed to 10° or 2° by exchanging the aperture of the aperture.

The two LED Cubes are wirelessly controlled by a colour control panel of the two illumination units. Observers can adjust the colour appearance of stimuli in the two semicircular fields of view. Two tests were conducted to show the performance of the visual colorimeter in terms of uncertainty. The first test examined luminance variation of the eighteen channels over a six-month period and the second test investigated the difference between the luminance of light emitted by the two LED Cubes. The spectral power distributions (SPDs) of the emitted light from two semi-circular apertures were measured by a Konica-Minolta CS2000 tele-spectroradiometer, which is named TSR in the following article. The results from the first test showed that the average error in luminance over six months was about 2%. Besides, the difference in luminance between left and right cubes was less than 5%. The test results showed that the stability of the device and the consistency of both sides were good.

Experiment

Subsequently, the visual colorimeter was used to perform a colour matching experiment using a 2° field of view. Maxwell's matching method [5] was chosen as the experimental method. Maxwell did the first careful, quantitative measurements of colour matching and developed the trichromacy colorimetry (1860). The method is illustrated in Figure 2.

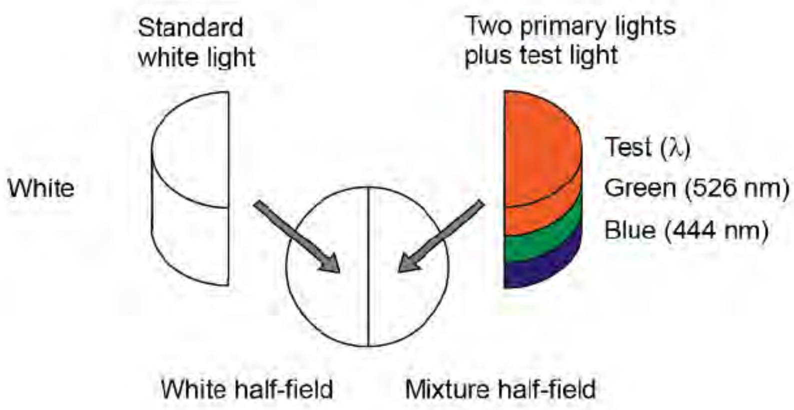

Figure 2. Maxwell's colour matching method.

As it is shown, the matched fields always appear white, so that at the match point the eye is always in the same state of adaptation whatever the combination of primary wavelengths.

Table 1 lists the wavelengths of 18 LEDs ranging from 400 to 700 nm. Table 2 shows different primary sets were used to match the reference stimulus, which was always in the White half-field with 3 fixed LEDs at 640 nm, 530nm and 445 nm, corresponding to CCT of 6500K at luminance of 100 cd/m^2.

Primary sets	1	**2**	3	4	5	6	7	8	9	10	11
R (nm)	640	**640**	640	640	640	640	640	595	605	660	675
G (nm)	530	**530**	530	530	505	545	560	530	530	530	530
B (nm)	430	**445**	460	475	445	445	445	445	445	445	445

Table 2. The 11 different primary sets for Mixture half-field. (Group 2 is also the primaries of White half-field).

For the test stimuli on the Mixture half-field, with different combinations from the 18 LEDs, the primaries on both sides always had a different one. Two boundary wavelengths were set – 485 nm (λ_{rc}: red primary complementary), and 555 nm (λ_{bc}: blue primary complementary). Rules for selecting primaries are: for $\lambda < \lambda_{rc}$, replace the blue primary with a test light of wavelength, λ; for λ ti λ rc and λ < λ bc, replace the green primary with a test light of wavelength, λ; for λ ti λ_{bc}, replace the red primary with a test light of wavelength, λ. In total, ten different primary sets were formed, plus a matching using the same primaries as the reference stimulus, to reveal the left/right observer variation.

Five male observers participated in this experiment. Their ages ranged from 21 to 25 years old with an average of 23. Before the experiment, observers passed the Ishihara Colour Vision Test to ensure they had normal vision.

At the start of the real experiment, the observers were first acclimated to the dark environment for two minutes. Then they started to perform colour matching until 11 sets were completed. The observers can adjust the channel intensity of the three primaries through the keyboard, that is, the R, G, B value, respectively, with two arrows for coarse and fine adjustments respectively. They can also adjust the brightness of the Mixture half-field overall luminance of the three primaries at the same time, to directly control the overall brightness. As mentioned earlier, to compare the inter- and intra-observer variation, observers repeated the experiment five times. Each observer attended two sessions, one hour each session. In total, each performed 55 matches.

Results

The SPDs of all the stimuli that were matched by the observers were measured after completion of the experiment using the TSR from the observer's eye position. Thus, inter-, and intra-observer variation, matching error could be represented by ΔE_{00} calculated from the CIEDE2000 colour difference formula, as well as by Δu'v' chromatic difference.

For the five observers, the matching error represented the mean colour difference between reference stimuli and the matched stimuli. When Δu'v' chromatic difference was used, the mean matching error was found to be 0.0116, with inter- and intra-observer variations of 0.0050 and 0.0035, respectively. These correspond to ΔE_{00} of 9.10, 4.09, and 2.64, respectively. Compared with those colour matching experiments performed on displays [6,7], the matching errors were larger than those on displays (typically 0.0050 Δu'v' units) [6]. This indicates that the different primary sets used here trigger a higher degree of observer metamerism than that of the unchanged primary sets on the two displays. Figure 3 shows the ellipses fitted to the 5 observer's matching data for each primary set. A shorter . u'v' distance between the centre of ellipse and target indicates a better match. A smaller ellipse size suggests a smaller observer variation.

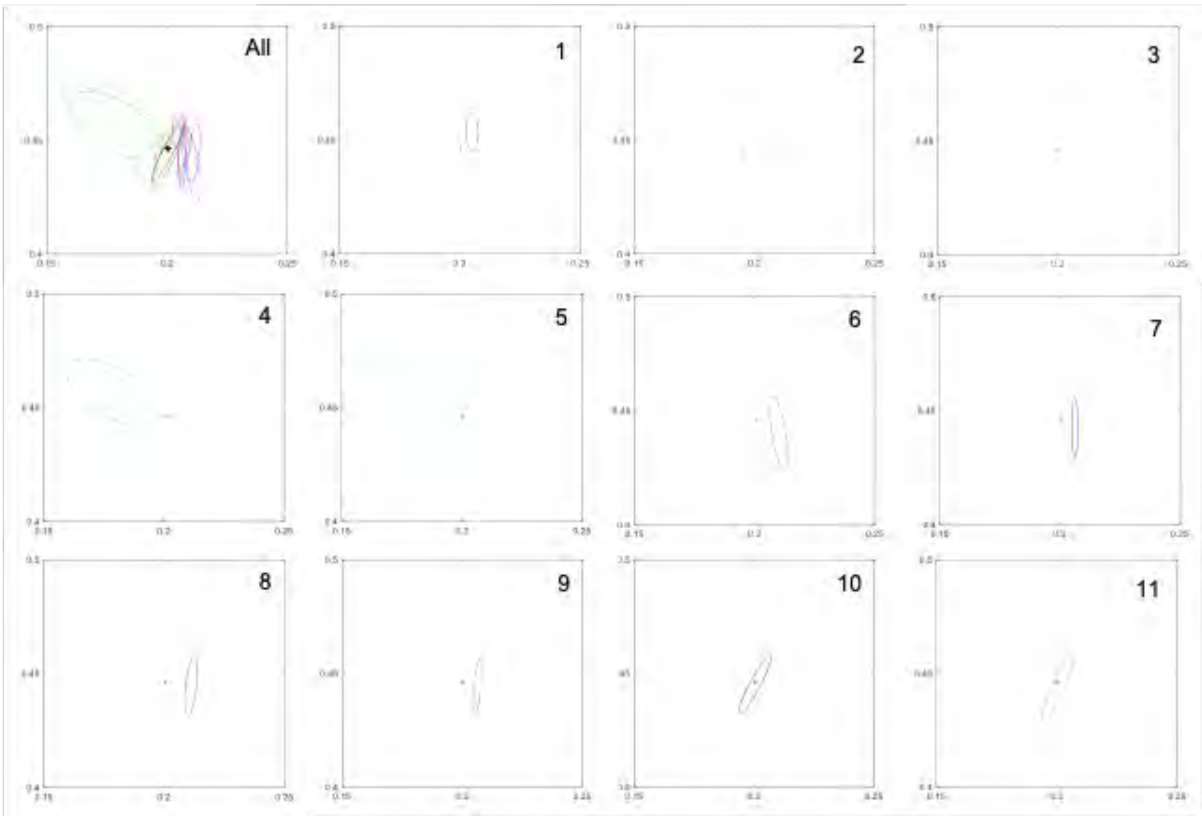

Figure 3. The 95% confidence tolerance ellipses on CIE 1976 u'v' chromaticity diagram, for 11 primary sets. (The colour centre of reference colour was drawn as the plus sign.)

The top left diagram of Figure 3 shows all ellipses agreed well with each other except that colour centres 4 and 5 were larger ellipse size than those of the others. This is due to the two primaries in a group being close to complementary wavelengths.

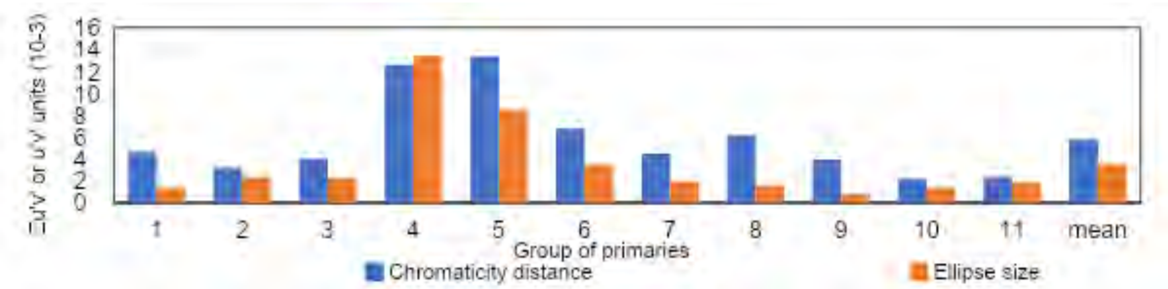

Figure 4. The average chromaticity distance between ellipse's centre and reference colour centre (Δu'v'), and ellipse size ($Size = \pi AB$) for each primary set (u'v' units).

Figure 4 presents the results in Figure 3 in a quantitative way, i.e. two parameters, the average Δu'v' distance and size of ellipses for each centre are given. The smaller the values, the better matching performance for that group. It is clearly shown that with the change of the primary sets, the state of the ellipse changes very obviously, including the size, and the distance from its centre to the reference colour centre.

Conclusion

Colour matching experiments were performed on a visual colorimeter based on a spectral tunable LED system. Two side-by-side semi-circular apertures were used to be the reference and test fields. The system performance in terms of instrumental uncertainty was first carried out. The test results showed that the temporal stability of the device and the agreement between both sides were good. At the same time, the results from the present experiment demonstrated LEDMax can perform well to collect colour matching data. The results were satisfactory to achieve the requirement for such a system. From the data available so far, it is entirely possible to use this device to conduct experiments and to derive everyone's colour matching function.

References

CIE 015:2018, Colourimetry, 4th Edition, Commission Internationale de l'Éclairage, Vienna, Austria.

Guild, J. The colorimetric properties of the spectrum. *Philosophical Transactions of the Royal Society of London. Series A,* 230: 149-187.

Wright W. D. 1929. A re-determination of the trichromatic coefficients of the spectral colours. *Trans. Opt. Soc.,* London 30(4): 141-164.

Wright W. D. 1930. A re-determination of the mixture curves of the spectrum. *Trans. Opt. Soc.,* London 31(4): 201-218.

Maxwell, J. C. On the theory of compound colours and the relations of the colours of the spectrum. *Philosophical Transactions of the Royal Society of London*, 150: 57-84.

Wu J., and M. Wei. 2021. Colour mismatch and observer metamerism between Conventional Liquid Crystal Displays and Organic Light Emitting Diode Displays. *Optics Express*, vol. 29, (8), pp. 12292-12306.

Huang, M., Y. Li, and Y. Wang. .2021. Effect of Primary Peak Wavelength on Color Matching and Color Matching Function Performance. *Optics Express*, vol. 29/no. 24, pp. 40447-40461.

CIECAM16 performance in high dynamic range based on a new corresponding color data set

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Abstract

The purpose of this study is to produce a visual dataset under a wide range of luminance conditions. The results can be used to verify color models such as CAM16-UCS, which is the latest color appearance model based uniform color space. It was developed using the color patch samples under standard dynamic range conditions. A color matching experiment under high dynamic range was conducted to obtain the corresponding colors between patches in an illumination box and a display. The results were used to verify the model. Six illuminance levels (15, 100, 1000, 3160, 10000,32000 lx) and 13 test color samples were used in the experiment. Ten observers were asked to adjust the color patches on the display to match the color patches in an illumination box. The results showed that the chroma and hue angle between the two fields are pretty similar in the CAM16-UCS a'b' plane. However, a clear trend was discerned in J'C' plane, for which the lightness (J') of real patches predicted by CAM16-UCS were invariant at different illuminance levels, while the J' values of visual results on display showed great difference between different illuminance levels.

Keywords: *Color appearance model, CAM16-UCS, HDR, SDR or LDR*

Introduction

CIECAM16 is a model of color vision capable of predicting color appearance under different viewing environments [Li et al, 2016; CIE, 2022]. A chromatic adaptation model, CAT16 [Li et al, 2016], is included in the CIECAM16. In our previous work [Shi, 2021], the background of the illumination boxes (IBs) was close to white, while the background of the display was a black. The difference between the two backgrounds was too obvious for observers. In the case of low illumination, the color samples were dark, and the display had a smaller gamut at low brightness. So, the observers could not achieve an equivalent color match. In the present experiment, we repeated the earlier experiment except to set the same neutral background for both IBs and display with a Y stimulus value of 35% and L* value of 35.

Experiment

Viewing devices

Three illumination boxes (IBs) were used to create a high dynamic range condition as shown in Figure 1. They were named IB1, IB2 and IB3. IB1 was located on the centre top position and its luminance can be adjusted within a range of 15 to 200000 lx. IB2 and IB3 were located in the bottom left and right respectively and their illuminances were set at 10 lx and 200000 lx, respectively. Figure 1 shows the experimental situation. In addition, the luminance of IB3 is too high for observers, so in the experiment, most of it was obscured, leaving the area where the color chart was located. In the experiment, the color samples to be matched were placed in IB1, and two X-Rite Macbeth ColorChecker Chart (MCCC) were placed in IB2 and IB3, respectively, so that observers did observe colors on the both charts, resulting a high-dynamic range environment. In the experiment, IB1 was set at 6 illuminance levels: 15, 100, 1000, 3150, 10000 and 32000 lx.

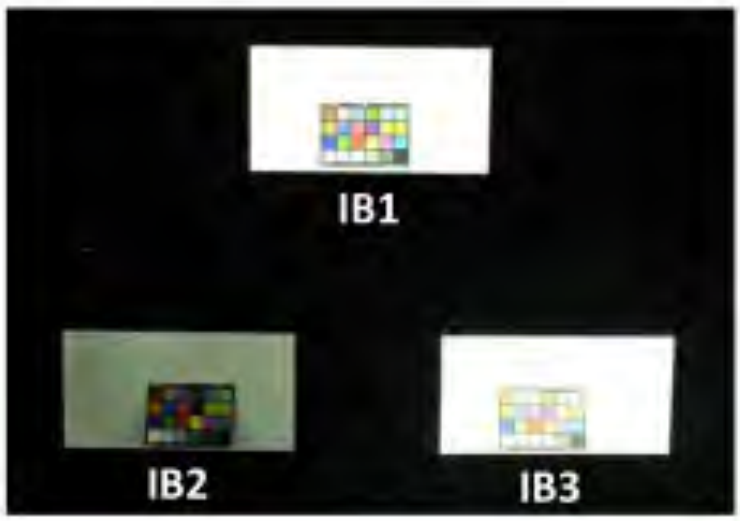


Figure 1. HDR Illumination Boxes.

The monitor used to match the colors was an Apple Pro Display XDR display with 2560 ×1440 pixels, which was set to a peak luminance of 550 cd/m2. The display was characterized using a Gain-Offset-Gamma (GOG) model [Berns, 1996]. By using 24 colors form X-Rite Macbeth ColorChecker Chart (MCCC) to test the GOG model, the mean accuracy was 0.63 ΔE^*_{ab}.

Stimulus

Thirteen color samples were used in the experiment, including 5 achromatic colors and 8 chromatic colors. They were selected from the NCS Album. Their NCS coordinates were 3040-R50B, 5020-R50B, 3020-B50G, 3040-B50G, 2020-G50Y, 3050-G50Y, 2040-Y50R and 6020-Y50R for 8 chromatic colors, and 2500-N, 5000-N, 6500-N, 7500-N, and 8500-N for 5 achromatic colors. These colors were selected to give a reasonable coverage of color gamut and hue angles as possible, which can be seen in Figure 2, each quadrant had a constant hue angle at different chroma in CIELAB a*b* plane.

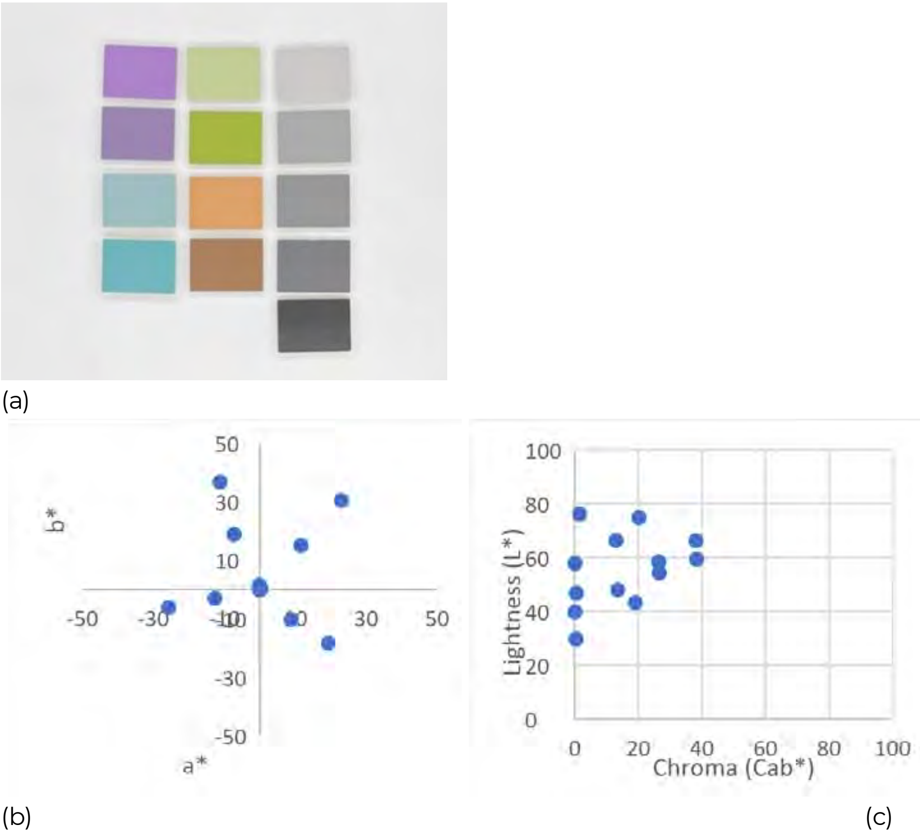


Figure 2. (a) 13 test samples from NCS Album, and 13 samples in(b) a*b* plane and (c) L*C* plane, respectively.

Observers

In total, 10 observers participated in the experiment, including 6 females and 4 males. Their ages ranged from 22 to 28 years old, with an average of 25 years old (standard deviation is 2.3). Each observer in the experiment passed the Ishihara color vision test. All the observers had received training before the experiment to ensure they could accurately and quickly match colors. The detailed introduction of the experiment will be given below.

Procedure

The experiment was conducted in a dark room. Before the experiment, each observer was given an instruction of the experiment. By looking at Figure 3, observers were asking to learn that different colors are roughly in which region of the CIELAB color space and to know how to adjust colors by using LCh controls in CIELAB space. Then, a short training was given to familiarize with the color control using the keyboard. For chromatic colors, observers were instructed to make adjustments using L*, C_{ab}*, h_{ab}. There were 12 keys, 6 for rough adjustment, 6 for fine adjustment. For achromatic colors, observers were instructed to only adjust L* scale. In particular, there were 4 other buttons (±a*, ±b*)for observers to fine tuning a* and b*, if they need to.

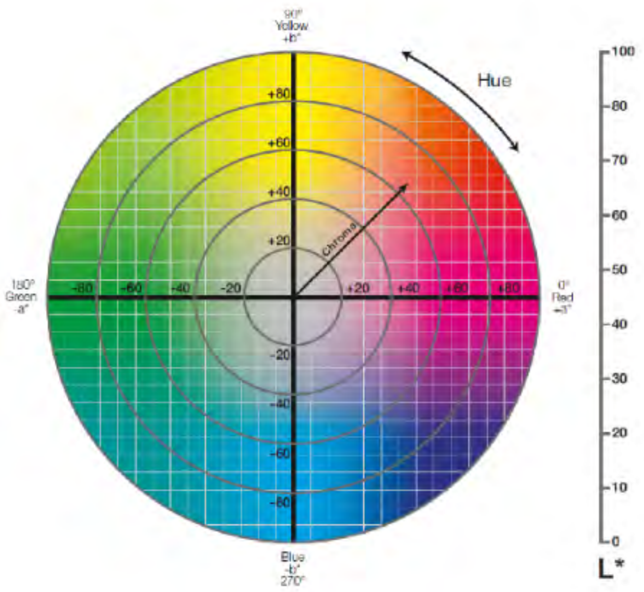


Figure 3. CIELAB Color Space.

The experiment was divided into 2 sessions. Each session included 3 illuminance levels, which were randomly arranged for each observer. For each level, observers took a 2-minute adaptation. Each illuminance level took about 25 minutes to complete the matching task. Thus, the whole experiment took about 25 hours (10 observers × 6 luminance levels × 25 minutes).

The initial color of the matching on the display was grey, which was set to L*=50, a*=0, and b*=0 in the experiment, meaning that it is half the maximum lightness of the display. In addition, the initial color was different from any of the 13 stimulus colors used in the experiment, ensuring that the observer was not affected by the initial color. And the initial hue angle was randomized.
After the experiment, the matching results were recorded in RGB values and these were measured using a Konica-Minolta CS2000 tele-spectroradiometer. The color samples in the IB1 were measured in the same way at the same position, recording their spectral data. All the results were reported as XYZ values for CIE 1964 standard colorimetric observer.

Results

Inter-observer variation

The inter-observer variation is used to judge whether the matching results of different observers tend to be consistent. In this case, the mean of color difference from the mean (MCDM) in CIELAB color space was used. Table 1 shows the MCDM for each observer. The mean variation was 6.17 ΔE^*_{ab}The 10 observers' data fluctuated between 4.62 and 9.25, with a standard deviation of 1.29, which indicated that the results were stable. Table 2 shows the MCDM under different luminance levels. When the luminance is increased, the difference does not change much. Only at 15lx level, when the color samples in IB1 look dark, it is difficult for observers to do the match compared to other illuminance, so the difference between observers is larger than other luminance levels. These data were similar to our previous experiment data which were based on black background of the display, except that the MCDM values for different luminance levels were more consistent in the present experiment. This seems to indicate that observers adapted better for the same background color between both fields.

Ob	1	2	3	4	5	6	7	8	9	10	Mean
MCDM	4.62	9.25	5.71	6.02	5.10	7.07	5.57	5.73	6.66	6.01	6.17

Table 1. MCDM for each observer

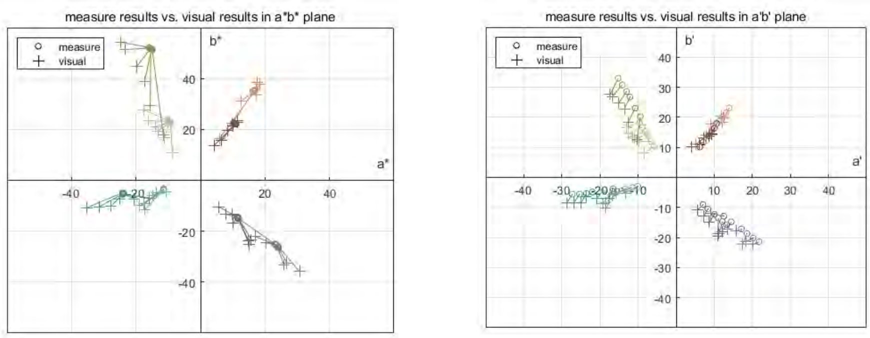
.

Illuminance level	15lx	100lx	1000lx	3160lx	10000lx	32000lx
MCDM	8.19	5.82	4.27	5.09	6.73	6.94

Table 2. MCDM for each illumination level.

CAM16-UCS model

Two groups of XYZ values for corresponding colors are obtained after data processing. One from the IB1 and another one from the XDR display. By using those conditions below, these data can be converted to the CAM16-UCS color space and compared. For the results in IB1 (represented the measured results below), Y_b=35, L_w=luminance of the reference white in each luminance levels, XYZ_w = adopted white in each luminance levels (for Yw=100), surround='dim'; For the results on XDR display (represented visual results below), Y_b=35, L_w=luminance of the peak white of the display (which was 550 cd/m^2), XYZ_w= adopted white (for Y_w=100), surround='dim'.



(a) (b)

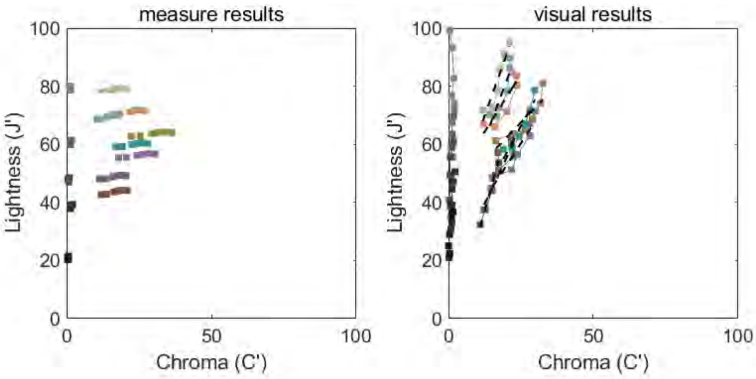
Figure 4. (a) CIELAB color space a*b* plane; (b) CIECAM 16 UCS color space a'b' plane.

It can be seen in Figure 4(a) that the difference between measure data and visual data in hue was quite small, the ΔH was only 0.04. However, results in CAM16UCS space were more reasonable, compared to the CIELAB space, as shown in Figure 4. In CIELAB space, the same color sample had a similar C* in different illuminations, but the visual data showed that when the same color block is in different illuminants, the C' of the color will increase with the increase of illuminance. At this point CAM16-UCS processes closer to visual results.

Illumination (lx)	▵E	▵J'	▵C'	▵H
15	4.39	4.47	0.54	4.01
100	3.49	2.95	-0.24	-7.74
1000	2.72	-1.67	-0.13	-2.46
3160	5.19	-7.32	-0.81	-1.37
10000	6.74	-11.74	-0.32	1.58
32000	7.83	-14.95	0.25	5.74
Avg	5.06	-4.71	-0.12	-0.04

Table 3. Average color difference between measure results and visual results of 13 color samples in CAM16-USC under different illuminance.

In the observer's vision, the color samples in the IB1 and the color displayed by the XDR had a relatively consistent color appearance. In that way, the measured results and the visual results should show a great similarity in color appearance model. Table 3 showed the average color difference of 13 samples in CAM16-UCS space. Most of the color discrepancies can be found in lightness (J'), also shown in Figure 5. It was more obvious that they had a big difference in J' scale. This was worse at higher illumination. Only when illumination was at 100 lx and 1000 lx, the J' of measured results and visual results were closer. This was related to the fact that most of the data used to establish CAM16-UCS space were viewed under typical interior illumination. Obviously, this could not apply to higher dynamic range environments.



(a   (b

Figure 5. (a) the measured and b) visual results plotted in J'C' plane.

Conclusion

A color matching experiment was conducted to match 13 color patches at 6 illuminance levels ranging from 15 to 32,000 lx on a display in HDR viewing condition. The results were shown on the CAM16-UCS color appearance model. By comparing the new corresponding color dataset, it proved that the model was more reasonable in predicting chroma (C' and hue (h for the corresponding colors. The average $\Delta C'$ was 0.12 and average ΔH was 0.04. However, for predicting lightness (J', the model is satisfactory under low illumination, but not satisfactory under high illumination. Further research will be carried out to fine tune CAM16-UCS model to give a better fit to the HDR visual results.

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References

Berns, R.S. 1996. 'Methods for characterizing CRT displays', *Displays*.

Luo, M. R., and R. W. G. Hunt. 1998. The structures of the CIE 1997 color appearance model (CIECAM 97s, *Color Research &. Application*, 23 138-146.

Moroney, N., M.D. Fairchild, R. Hunt, C. Li, M.R. Luo, and T. Newman. 2002. The CIECAM02 color appearance model. *Color & Imaging Conference*.

Li, C., Z. Li, Z. Wang, Y. Xu, M. R. Luo, G. Cui et al. 2017. Comprehensive color solutions: cam16, cat16, and cam16-ucs. *Color Research & Application*.

Xinye, S., Yuechen, Z., and Ronnier Luo, M, 2021. A new corresponding color dataset covering a wide luminance range under high dynamic range viewing conditions. In *Color and Imaging Conference* (Vol. 2021, No. 29, pp. 184-187). *Society for Imaging Science and Technology.*

Li, C.J., M. R. Luo, M. H. Brill, M. Melgosa, M. R. Pointer, C. Teunissen, M.T. Wei, et al. 2022. The CIE 2016 colour appearance model for colour management systems: CIECAM16. *CIE* 248:2022, Division 1Division 8.

Stories of Color Symbolism and its Significance in Indian Weddings

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Abstract

Traditional cultural practices in society have not faded away in the face of modernization; rather, they have been magnified, transitioned, and revived within the society's affluent strata. Weddings are one of the few rituals that people from all over the world share. A wedding is the most important event in a person's life in every society. Wedding ceremonies are events when two mostly unknown people come together (especially in India) to initiate a chapter in their lives.

Wedding traditions and customs differ greatly depending on culture, religion, and region. Even in a diverse country like India, where more than a billion people are united by around 1600 spoken languages and over 9 religions, spread across 28 culturally different states, there is this commonality, the unison of two souls known as marriage and the ceremony known as Wedding. The wedding ceremony is one of the most elaborate events in any Indian family, sometimes lasting several months or even days, making it the most memorable moment of one's life.

Religion is the most important tool for understanding a group's or society's way of life and cultural system, as well as an individual's global or universal perspective. Different cultures and religions assign different meanings to different colours. Certain colours that are significant in one religion may not have the same significance in another. Colour can be a powerful visual element that acts as a code, providing a deeper level of meaning to those who can decipher the signs.

This paper focuses on the significance of colours in Indian wedding ceremony rituals, depicting the variation of colour usage as we move across various regions of this vast country, and also provides insight into how the concept and significance of colours changes across religions and regions. Furthermore, the paper discusses how colours play an important role in various sub-ceremonies within a wedding ceremony.

Keywords: *Colour, Culture, Wedding, Fashion*

Introduction

India has long been known for its obsession with colours, which spans the country's culturally diverse demographics. Colors can be seen in a variety of tints, not only in important events, but also in the smallest details of life. Not only in festivities and cultural gatherings, but also in numerous religious and political facades, the gala link with colours may be noticed. Colors are chosen for special occasions based on the religion and faith of the people in that location, which adds to the variety of colours used in different parts of the world.

Weddings are one of the most essential aspects of a person's life all over the world, and weddings in India are a perfect example. The magnificence of Indian weddings necessitated the creation of a new term to describe them: "The-Big-Fat-Indian-Wedding." A wedding that lasts several days is usually made up of several rituals, some of which are simple and others which are highly lavish. Even the scale of grandeur of a marriage and its rites varies with the area and religion in India, as it does with everything else. The colour palette employed during diverse wedding ceremonies, on the other hand, does not vary considerably. Of course, given this enormous country's cultural and religious variety, Indian wedding styles and colours vary greatly.

The origins of colour selection for a ceremony can be traced back to nature, deity, and scientific belief. Turmeric, for example, is a natural shade of yellow and is a vital element of most weddings across India. It has been used for cooking in India for centuries and is a scientifically proven natural antibiotic. While a turmeric spa is renowned to 'purify' the bride and groom's bodies, it also imparts a natural shine to their skin, ensuring that they look excellent throughout the wedding procedures.

In the Indian subcontinent, colours have long acted as a symbol of identity. The colours of a clothing convey a wealth of social information, ranging from the wearer's age and marital status to his or her place of origin. Although colourful clothes may have had specified caste-based associations at some point in Indian history, such divisions are falling away in this new age of modernisation and globalisation.

Colours in Indian wedding ceremonies

Indian weddings are known for their lavish rituals and traditions. They are an important element of any wedding ceremony. Due to the vastness of this large nation, each religion, culture, and region has its own set of rituals and traditions. In one of the ***western states of India***, Gujarat, natives adorn themselves with colourful attires for wedding celebrations. The bride usually dresses up with the *Panetar*, a white sari with red *bandhani* border for one of the ceremonies and then the *Gharchola*, traditional red *bandhani* saree crisscrossed with woven gold squares, enclosing *bandhani* motifs for another ceremony. The red colour is considered to be the most auspicious colour for the bride. The Gujarati Groom traditionally wears *dhoti & kurta* of cream, fawn and lemon-yellow colour, along with red coloured *Bandhani dupatta* (ornamental piece of cloth, put across the shoulder). *Dhoti* is a large piece of cloth wrapped around the waist and is worn in place of trousers whereas *kurta* is a variation of shirt.

In the northern ***region of India***, yellow signifies prosperity because of the colour of the prime crop there, i.e. wheat and mustard. In that sense, yellow suggests that the harvest has been good which in-turn will bring prosperity to the local farming population and will positively impact the non-farming ones. Therefore, in the northern state of Bihar and Uttar Pradesh, the maternal grandmother showers gifts primarily comprising yellow colour saree and yellow metal(gold) to the bride. The bride usually wears the gifts for the *lagan* or wedding while the groom usually dons a golden yellow dhoti (worn in place of trousers). A piece of cloth used for covering the head of the bride, also known as *shawls or odhni*, is usually yellow in colour. In some of the communities, the same cloth is used for draping the bride or groom. A yellow *odhni* or shawl is placed on the groom's shoulders during the wedding ceremony in Uttar Pradesh while in another northern state, Punjab, *phulkari* shawls, cloth with elaborate embroidery, are given to the bride.

Moving on to the ***eastern part of India***, in the state of Assam, for marriage proceedings, the groom wears a traditional *Dhoti*, *Kurta* and *Cheleng* (an Assamese style shawl). The groom's attire is usually a gift by the bride's family and is traditionally accessorized by flowers and Indian Basil garland. Whereas, the bride wears *Mekhla, which is* created with *Muga* silk and bears heavy work with gold and silver threads and is an interesting ensemble of two pieces making it look like a saree. The first piece of the *Mekhla* is worn as a skirt and the other half like an *anchal* of the sari. The fabric of the skirt part is heavy in texture and is heavily embroidered with a broad border. In contrast, the fabric on the *anchal* part is lightweight and flowing. This custom is specific to the state of Assam and a vital part of the tradition and culture of the state.

Angami, one of the major tribes in another eastern state of Nagaland conduct very simple and elegant marriages. The ceremonial dress comprises a white blouse worn with a shawl, wrapped like a skirt on the lower part of the body. The shawl is red, white and black in color with predominant geometrical designs. There is special emphasis on hair make-up of the bride and involves beautiful water lilies in the hairs along with loads of red colored bangles on the wrists. Another big tribe of Nagaland, the Ao have bridal dresses similar to that of an Assamese bride. However, the fabric used for the mekhela is a long handmade shawl. The upper part of the body is covered with a piece of cloth wrapped around the chest with bare shoulders.

Going further down the ***southern landscape of the country***, the Maharashtrian bride wears a green *paithani* silk saree of nine yard long. Kanjivaram silk sarees are being worn by the brides in most parts of South India except Kerala where the bride wears *Kasavu* which is gold bordered off-white pattu saree. The choice of colour for various ceremonies in a region is also marked by the predominant climate of that region. One can realize that fact by looking at one of the southern states of India, Kerala. The landscape of Kerala is tropical lush green; thereby an austere white and gold *kasavu-saree* worn by the bride on the occasion of marriage provides a picturesque contrast to the lush green backdrop. Whereas in the desert land of Kutch, part of western India, the highly embroidered and brilliantly coloured wedding dress choice of the local nomadic tribe provides a seamless integration with the golden sand of the area.

Conclusion

Marriage is seen as sanctimonious in India, as it is in other areas of the world, because it is usually a once-in-a-lifetime event. The ceremony marks the start of a new era in the life of the couple who are entering into this wonderful relationship for the rest of their lives, therefore it's no surprise that it's related with a number of religious ceremonies and legendary traditions.

Based on the culture and religious beliefs of individuals, it is ascertained that this new phase of life is getting started on the best possible note. In most parts of the country, the color Red is associated with happiness, joy and celebration and is also considered to bring luck and long life, not just to the bride but to the groom as well. So, no surprise that the bride wears red color attire during the marriage ceremony along with accessories with shades of red, e.g. *bindi* (dot on forehead), *bangles* (worn on the wrists) and *kumkum* (put in the hair parting). In some cultures, white color is used by the bride during the wedding but it is always accentuated with a touch of red.

In the same line of thought, the "perceived" bad omens are kept away from weddings and since color black is always associated with not so good things in life as per Hindu culture, no wonder the color black has always been cast off from any marriage related proceedings.

Indian weddings are lavish celebrations that run anywhere from a few days to a week or more. Because of India's enormous cultural and religious variety, the forms and colours of Indian weddings vary greatly. The most popular colour for brides has always been red. In the face of development, however, a new generation with a diverse range of perspectives and lifestyles is developing their own colour language and questioning preconceptions in general, which is reflected in sartorial combinations and colour choices for modern weddings.

References

Burchett, K E. 2002. Color harmony. *Color Research & Application*, Volume 27, Issue 1, pages 28–31, February.

Elliot, A.J. and M.A. Maier. 2007. Color and Psychological Functioning. *Psychological Science* October, vol. 16 no. 5250-254.

Kim, Y. S. and J. Lee. 2014. Fashion Styles and Aesthetic Values represented in Bridesmaid dresses - Focused on Movie '27 Dresses', *Fashion & Text. Res. J.* Vol. 16, No. 6, pp.860-870.

Kumar, S. 2015. The Importance of Color in a Bridal Dress, Retrieved from http://www.bourncreative.com/meaning-of-the-color-black/http://marriage.sudesh-kumar.com/2010/07/importance-of-color-in-bridal-dress.html.

Smith, K. 2015. India A Country of Symbolic Colors, Retrieved from http://www.sensationalcolor.com/color-meaning/color-around-the-world/india-country-symbolic-colors-1935#.VPVTU_mUcu1.

My own color system

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Abstract

The creation of a personal and particular color system as a learning and self-knowledge tool is the main purpose of this text and the dissemination of this work of art in progress. Thinking of a color system that will meet all industrial needs, cultural demands, utilitarian, symbolic or any other issues that may exist is utopian. This is not to say that organizing and systematizing colors is not an interesting and challenging approach for anyone at any historical moment. By analyzing the emergence of different color systems throughout history, it was possible to perceive changes consistent with each moment and situation of the societies and individuals involved in the use of these systems. Today's society values buying and selling, a society that consumes color systems mainly for industrial and commercial purposes. Seeking a counterpoint to the teaching of color that tries to get rid of this premise, we propose a work of art that seeks to create its own system of color, personal and particular, in order to create a new educational approach to the theme.

Keywords: *Education, Colour System, Art Education, Colour Education, Colour in Art*

Introduction

Investigating the chromatic phenomenon has always been a great challenge throughout history. However, understanding the limits of creation and the delimitations of any systematization is a first step towards the elaboration of any system of color. There is, therefore, no theory or system of color to cling to without understanding that “the study of color cannot be separated, in general, from the general behavior of a society. (Francastel 1983: 206)”.

Color system, here, would be the possible ways of organization, the variables chosen to select each color, the way of organizing the colors, the amount of colors in the system, the mathematical formula used to reproduce or use those colors. Color theory, here, refers to how a given society deals with the color systems produced in a certain time, how it modifies and transforms culture, art, society.

Color can be organized from innumerable variables and it per se allows for different organizations. The most common ones use perceptible characteristics such as saturation, brightness or hue, but there are others. Rather, there is an intention of the system's creator. And perhaps this is the point that permeates the entire history of color systems and theories. There has always been an intention on the part of the creators of a system of color, there has always been a little investigated locality and identity in favor of the search for a general and universal system and theory of color.

“Today, when we look at the subject of art and at the production of art, on the one hand, and at the social, economic and political situation we need to confront, on the other, our investigation proves to be insignificant, if it brings with it no immediate practical use.” (Hui 2020: 137)

Quick background on color systems and societies

Many have tried to define what color is and how the perceptual process takes place. Aristotle was perhaps the first in the West to develop a structured logic about color. However, it should be noted that the philosopher drank from previous sources, such as Democritus, Leucippus and Epicurus. Thus, the atomists claimed that color was a form of light, a kind of effect caused by lightning striking body surfaces. Democritus suggested that images are formed in the eye, by contact, when the air enters the eyes loaded with effluvia coming from objects of different colors. For Leucippus, vision is a form of touch. Epicurus also thinks that particles or atoms that detach themselves from objects towards the eye transport colors (CAMPS and CARVALHO, 2016, p. 14).

Plato also investigated color, attributing its origin to the “fire” that bodies emanate in contact with the “fire” of the observer's sight. The philosopher's understanding is that we have an inner "energy" that goes out through the eyes and comes into contact with the "energy" of what is observed through the eyes. “Here's how we should name them: “white” is what dilates the visual ray and “black” is what does the opposite. When it is a question of a more poignant movement and of another kind of fire that collides with the ray of vision and dissociates it up to the eyes, bursting violently through the openings of the eyes, dissolving them, making that torrent of water and fire flow from them. what we call "tears".”(PLATÃO, 2011, p. 166, 167)

Plato uses the four elements to outline his brief theory of colors. Fire and water are the basis for visual perception, according to the philosopher. However, without a doubt, Aristotle is the one who made the greatest contribution to this investigation in antiquity. In *De Anima* (About the soul, in free translation) (2006), the philosopher investigates the phenomenon, not only chromatic, but perceptive, serving as one of the gateways to future perceptive and phenomenological studies on the subject. “418a26 [...] The visible is color, and this is what covers the visible by itself (not by itself in terms of definition, but because it has in itself the cause of being visible). Each and every color is what can move the transparent into actuality, and this is the nature of color. That is why there is no visible light, and every color of everything is seen in light. (ARISTÓTELES, 2006, p. 87).”

De Coloribus (1955), a text attributed to Aristotle , proposes a color theory in keeping with his reality and society. It is important to note that the proposed investigation is in line with what has been experienced, with the visa and with the scientific evidence known up to that moment. In this sense, some considerations may seem absurd today. The theory for color mixtures is formulated using plants and animals as its main theoretical foundation, as in Plato, the four elements. It is not up to us to make an anachronistic judgment of the correctness of these postulates.

"The primary colours of all plants are green; for shoots and leaves and fruit are all green to begin with. One can see exactly the same thing in rain water; when the water has stood for a long time, as it dries up again it becomes green in colours. This happens logically, and in all growing things this is the first colour that obtains. For all water that stands for a long time is green originally, being mixed with the rays of the sun, but gradually grows black, but becomes green again when mixed with fresh water." (ARISTÓTELES, 1955, p. 23)

The Middle Ages is marked by spiritual and religious conceptions of light, directly associated with God, saints and angels. Reflections from this historical period are strongly influenced by Plato and his conception of the "fire" that emanates from the soul within each individual. This duality runs through the whole story, sometimes bringing Platonic characters to light and color, associated with individual, personal, divine and emotional perception, sometimes bringing Aristotelian characters, associated with reality beyond the subject, the perceptive luminous ray and rational conception-scientific-empirical phenomenon.

Leonardo Da Vinci was one of the leading color investigators of his time. His *Treatise on Painting*, a compilation of texts by the author produced after his death, served for a period as the main manual for new artists. Da Vinci, when dealing with colors, recognized six main ones, based on the use of pigments available in his time, and ordering them by the opposition between white and black; green red; and yellow and blue. His work would influence countless artists from different periods. This conceptualization through the oppositions between colors would be used as a logical and theoretical basis for several other systems and theories throughout history.

Newton theorized for disciplinary separation, dealing especially with the physical aspects of color. The physicist achieves important advances and his work is fundamental for the development of the subject today. Newton does not seek to position the observer as an integral part of his investigation; his concern is almost strictly with the phenomenon and its unfolding beyond the subject. In this sense, it is strictly concerned with unraveling the phenomenon of the luminous ray. Goethe, on the other hand, places the observer as an integral part of the phenomenon, attributing to it, and especially to the eye, a good part of the perceptive process.

The Bauhaus would later be instrumental in the development of color teaching. The concepts of individual freedom and the growth of teaching practices and the idea of teaching for all are growing and provide that society with the need for an arts education that contemplates color and its possibilities. In this context, the works of Albers and Itten, for example, stand out. Kandinsky also has a strong influence and dialogues with the period bringing symbolic and psychological aspects about color, in line with the growing investigation of individual psychological aspects raised by Freud and Jung.

This first moment of this text aims to raise the inherent relationships of color practices, systems and theories with societies and their needs. We have antiquity and its philosophical concept of the four elements; we have the middle ages and relations between light and the divine; the clash between Newton and Goethe marks a central opposition between the use and perception of color in art and science; Bauhaus is fundamental for the development of color teaching, in a society that seems to be open to new artistic and teaching practices. All these theories and the systems proposed by these thinkers match the historical moment and needs of these societies. The aim now is to try to observe how the practices and theories of color (as we are postulating here) take place in today's society.

Observations on current society - consumable color systems

Contemporary society allows the purchase of different color systems that guarantee precision and easy communication between sectors of industry, design, etc., demonstrating that its interest is to systematize and optimize time to provide, thus, more consumer products. Current color systems meet this demand. They guarantee to “represent” and order all colors, facilitating the search for a specific one and, in this way, better coordinating communication between parties in the production chain. The organization of colors within the system follows different formulas, always seeking to facilitate production and the search for color. These organizations use catalogs and are composed of ready-made palettes that, instead of facilitating the understanding of the system, thus facilitating contact with colors, reduce observation, analysis and creativity in the processes.

It is possible to find on the websites of current systems such as Munsell, NCS, Pantone, among others, a strong appeal for sales and color management. The main contradiction always lies in the discourse of solving the individual problem with a generic system. Even a more individualized practice still involves the use of systems developed to be used across the globe, disregarding the individualities of the client, their experiences and their society. Obviously, the intention is not precisely to find the ideal color for the client, but the one that will expand and improve their production. In this sense, artistic aspects and more daring proposals are left aside in the name of productivity and profit. The reflections that remain in these cases are: the need to establish accurate colors for brands and products increases profitability and also the appeal and consumption of the products. Is chromatic precision really necessary or does it only contribute to the profit of the few and the establishment of an increasingly consumerist society? Is chromatic accuracy a determining factor in the complete apprehension of an object/brand/product? Is it not because of sociocultural conditioning based on this consumption that we seek products that are increasingly generic in their visual conceptions? We see no other way to dialogue and debate these issues than through the teaching of color: conceiving this teaching through the sensitive power of color in perception and in society, especially through art.

As postulated here, we believe it is possible to understand colors as cultural means that carry all the development and way of thinking of a society. Therefore, the difficulty in proposing a general theory resides, mainly, in the fact that our perception works in a strictly individual way, which is constantly changing. Each individual feels and perceives the world differently according to infinite possibilities. Applied to culture, this idea is amplified: each culture finds in color its way of organizing its standards, propagating its beliefs and giving meaning to its values. As much as we can list, even if not fully, standard functionings for certain physical, chemical and physiological behaviors of color. In this way, we will hardly be able to establish a general theory that does not change according to society and its cultural, social, psychological and artistic issues. Thus, it does not seem possible to separate and make this distinction fully. Physical aspects of color influence cultural issues, physiological aspects influence psychological issues, chemical aspects influence social issues. Therefore, the color is constantly changing.

My own color system as a teaching tool

The teaching of color that we seek, as said, is liberating. This is characterized as Freirean in the sense of enabling educational practices that enable self-knowledge and liberation from social standards imposed by the capitalization of people, things and science. Therefore, we believe in the importance of questioning profitable color systems and the color industry with no purpose other than to capitalize. For Freire (2000, p. 76), "the ability to learn, not only to adapt, but, above all, to transform reality, to intervene in it, recreating it". Among the possible practices to face the capitalization of color already discussed in this text, the teaching of individual practices and reflections on their own reality can instill in the student self-knowledge and perception of their reality.

We do not intend, in this work, to belittle the color systems that came before, nor even to propose a unique and particular way of creating and using color. On the contrary, the teaching for the creation of a color system must and is done as a fragment. Yuk Hui's sense of fragmentation (2020) interests us in this discussion. ""Fragmentation" means, above all, letting go of the convergence and synchronization imposed by modern technology, allowing thought to diverge and differentiate. When confronting the gigantic metaphysical force in technology, a possible initiative is the return to the question of locality." (HUI, 2020, p. 132).

Hui, when dealing with art and a locality focused on the question of “being”, arrives at a simple but fundamental question in the search for fragmenting knowledge: who did the artwork? That the author really arrives at the location he wants, the identity lost with the need of practical, global and universal uses of color. Hui is not only interested in the pure and selfish individuality of the artist, as a special being who creates works of art, as a gift, but rather in an individual loaded with all the cultural and social burden implicit in the work and its author. In this way, gender, class, ancestry, also compose this locality of the artist that the author deals with. To understand your own identity is different from turning it into individuality.

Here, as art professor and education researchers, we are interested in each student/person location, how each one deals with colors, how each one understands and builds symbolisms, patterns and logics, how ancestral references are present in this life’s, how the social class modifies its apprehension of the world, how your gender and your understanding of gender changes your perception. Regardless of whether or not to reproduce generic symbols and patterns or, of interest or not, of a color industry, the aim is simply to conduct educational practice through the person's location, history, ancestry, gender, class, etc. So we begin with “my own color system”.

A free systematization of colors seems to be a practice to face this capitalization of color. The proposal, here, to create a particular and personal system, seeks to individualize and thus question the subject, far from generalizations. Here, we are interested in thinking about a system that differs from the current ones, giving up universality and valuing individualities. A universal color system would hardly meet personal and particular demands. This hypothetical universal system is not a fragment and, therefore, does not respect localities.

In this work, the very memory of colors, revived through photos or videos, can produce a fascinating system. Memory can be as interesting a variable as saturation, perhaps not as measurable, but certainly much more sensitive. The visual memory of childhood, adolescence and, more recently, adulthood brings with it the experiences of these periods, with the peculiarities of each moment. Whether through clothing, locations, or purely the sensation experienced in remembering each situation, color is present and echoes in memory. To determine the color of a personal moment through memory is to give color another characteristic that need not be and that is not measurable. In this sense, unlike an organization of colors by saturation, hue and luminosity, for example, as most authors and systems propose, we will take another path.

I will, therefore, reflect on each color, each moment, and produce small texts of these reflections. Summarizing a moment to a color is also a process of self-analysis, self-knowledge. So maybe in the future this won't be my ideal color system, and these aren't the right colors to represent what I feel. The system itself, at the end of the process, will be memory and, therefore, can be summarized in a color. In this sense, the work becomes quite ephemeral. However, to some extent, which color system is not?

The system proposed here will be produced from digitized analog photographs and also undeveloped digital photographs. They served as a trigger for the memory of the situations experienced in a search for the sensation of the color of each moment. Each photograph will thus produce a color for the system and the organization will be guided by the desired, felt and lived intention during the process. The name of the color will also follow this pattern: it will be given by experience, location or intention. Each photograph will give me a look at my particular location as a white man born in January 1988 in the city of São Paulo, belonging to the lower middle class, single, with a daughter, a brother, student at the State University of Campinas, Capricorn, Umbanda believer , football Corinthians fan... So, I must report through the colors the particularities and experiences of being who I am. Each color will be accompanied by a brief account, a personal, private story. Colors will be posted on my personal Instagram profile @pedropinho88.

Figure 1. Branco de mãe (Mother's White) - One of my own color system colors.

The colors refer and recall lived moments and their memories. Whether they are memories of the photographs themselves (as in the case where I am a newborn or still a baby), of the moment itself, or of what I believe that a certain moment brought me when I came into contact with the image. The objective with this work of art is to practice in order to teach how to build a color system that concerns the individual rather than the so-called universal systems that meet all demands. This educational practice is still under development and future work will focus on developing systems together with students focused on their experiences, practices and individualities.

Conclusion

Starting from the premise that color theory is the cultural and social developments of certain analyses, systems and practices with color carried out in a historical period by a given society. We trace here possible analyses for today's society and consequently a proposal for teaching color, still in development, that serves as an example and path for a liberating teaching and self-knowledge, free from the ideas of profit and production present in today's society. This educational practice consists of creating your own color system, seeking to meet your particularities and individualities. The work is in progress and we wish to continue it with different students.

References

Aristóteles. 1955. I. Cambridge: Harvard University Press.

Aristóteles. 2006. *De anima / aristóteles*. São Oaulo: ed. 34.

Caivano, J. L. 1995. *Sistemas de orden del color*. Buenos aires: secretaría de investigaciones en ciencia y técnica. Facultad de Arquitectura, Diseño y Urbanismo - Universidad de Buenos Aires.

Freire, P. 2000. *Pedagogia da autonomia: saberes necessários à prática educativa*. São Paulo: Paz e Terra.

Francastel. *Imagem, visão e imaginação*. Lisboa, Portugal: Edições 70 ltda. (p. 1983).

Goethe, J. W. 2013. *Doutrina das cores*. São Paulo: Nova Alexandria.

Hui, Y. 2020. *Tecno diversidade*. São Paulo: Abu Editora.

Munsell. 2021. Official site of Munsell color © 2021, X-rite, Incorporated, 2021. Disponível em: <https://munsell.com/ti. Access: 10 may 2021.

Natural Colour System. 2020. Natural colour system website. Natural colour system website, 10 jul. 2020. Disponivel em: <https://ncscolour.com/ti.

Pantone. 2021. Pantone® referência mundial em controle e especificação de cores, 2021. Disponível em: <https://www.pantone.com.br/ti. Acesso em: 10 maio 2021.

Platão. 2011. *Timeu-crítias - tradução do grego, introdução, notas e índices: rodolfo lopes.* Coimbra: Centro de Estudos Clássicos e Humanísticos.

Not So Black & White: Colors in Early Cinema

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Abstract

Cinema from the first half of the twentieth century is often thought to be in monochrome; this is false. As previous and current scholarship in early cinema has shown, a significant proportion of films were colored in some way (Gunning, 1989; Cherchi-Usai, 1996; Yumibe, 2012). This scholarship has been concerned with tracing the production of, audience reception to, and cultural motivators for filmic colors. What has been less addressed are the ways in which color functions as a site of meaning in this early period of cinema. By analyzing the production context and visual content in Hell's Angels (1931) , this paper builds on past research to explore three functions of filmic color in early cinema: indexic, narrative, and affective. Colors in films today take on similar functions, prompting further questions of our relationship to colors and their meaning.

Keywords: *Film Colors, Semiotics, Mimetic Process, Applied Process*

Introduction

The average filmgoer's understanding of the history of film places color firmly after the advent of sound cinema. While film historians such as Gunning (1989), Cherchi-Usai (1996), and Yumibe (2012), have clearly demonstrated otherwise, the misconception that silent cinema was monochrome persists in popular imagination. Much of the current scholarship focuses on the technical and cultural history of color in cinema. This short case study extends that historical context by analyzing the functions of color in a single film that bordered the transition between silence and sound.

Case Study: Hell's Angels

Originally a silent film largely reshot to accommodate the advent of synchronized sound, *Hell's Angels* contains multiple color processes, including tinting, toning, and two-tone mimetic color. The film was a passion project for which director Howard Hughes created an entire film studio, the Caddo Company, to produce. As a film that sits on the cusp between sound and silent cinema, *Hell's Angels* provides a balanced look at the aesthetics of both. The two coloring types, autonomous and mimetic, are present in the film. Tinting and toning combinations, more common in the silent era, are used throughout while Technicolor, which gained traction with sound, is used sparingly.

In *Hell's Angels*, the only scene shot in two-tone Technicolor is a ball attended by the main characters, two brothers. Jean Harlow plays the seductress with whom both brothers are enamored. The two-tone process captures Harlow's brilliant hair, her cream-colored dress, and her warm peach skin. The ball scene was important enough to be shot in the expensive two-tone Technicolor process. The scene lasts a few minutes and in nearly every frame, Harlow with her platinum blonde hair is in the center frame. Her allure, accentuated by the color process, draws in both the brothers and the viewer.

Figure 1. Jean Harlow flirts at the dance. Howard Hughes, *Hell's Angels*, 1930.

What function does color play here? For starters, it functions indexically. The technology is inherently dependent on the natural colors of the profilmic world which the process captures. However, the selection and subject of this particular scene indicates there is more at play. At some point, there was a decision made to have one scene be filmed with mimetic color over another. Technicolor was an expensive process both in the filming and printing parts. Practically speaking, studios usually chose only one or two key scenes to shoot in Technicolor. Therefore, for each shot filmed in mimetic color, there is intent behind it. There is a reason for including color that goes beyond the desire to represent natural colors. In the case of Hell's Angels, we can observe two impulses: spectacle and narrative device.

First, there is a sensual pleasure in looking at Harlow. She is young, beautiful, and radiant. Her blonde hair is complemented by her reflective blush dress. The two-tone Technicolor brings out more of the warm tones in her skin, due to the absence of blue light. The layers of dye also produce an aesthetic effect, *faktura*, which, as Flueckinger (2020, 28) explains, refers to "interplay between various layers of film as a three-dimensional material aesthetic object" in color film. In the case of this scene in Hell's Angels, the layers of dye create a low-detail, low-contrast, hazy image. The result is a soft, dream-like scene that is as inviting as Harlow is. Behind the scenes, all films that utilized Technicolor were required to be supervised by the Color Advisory Service whose goal was to optimize the colors "to serve narrative functions" which included prioritizing colors that beautified the female lead, in this case, Harlow (Flueckinger, 2020, 26) . The hazy faktura is incidental but the combination of colors in the shot is not. The cream-colored dress accentuates her peach skin and blonde hair. The lush green vines in the background push Harlow even closer to the viewer.

The camera sits between her two suitors, mirroring Harlow, which serves as a visual metaphor to her affairs with both. As they watch and want her, the viewer takes the same position. The camera becomes another one of her admirers. Each of the men look at her, starstruck. Her warmth and elegance dominate the frame in a way that is only possible through color. If the scene were in black-and-white, the warm glow of her blonde hair would be absent, reduced to tonal values. Her blush dress would not compliment the rose tint of her skin. Every element of the shot, down to the very dyes themselves, is designed to make Harlow an appealing aesthetic object for the viewer to enjoy.

Figure 2. Harlow contemplating her next move. George Cukor, *Dinner at Eight*, 1933.

Many of Harlow's enticing visual characteristics would be rendered impotent if color was gone. Compare the image of Harlow from Hell's Angels to her appearance in *Dinner at Eight* released just a few years later in 1933. The starkness of the black-and-white removes the warm glow of her blonde hair in Hell's Angels and instead gives her a harsher, colder, impression. The dye transfer process for Technicolor III meant that "neither end of the luminosity spectrum can be properly recorded and thus both distort the images' color appearance" (Flueckinger, 2020, 26). In other words, high contrast images were better suited for black-and-white scenes and terrible for colored scenes. Although this shot from Dinner at Eight lacks deep blacks, the higher level of contrast sharpens all of Harlow's features. The unattainable dream-like quality of Harlow in Hell's Angels disappears with the colors.

Figure 3. The duel at dawn. Howard Hughes, *Hell's Angels*, 1930.

Figure 3 shows the duel between a nobleman and the older brother, Ray, who is taking the place of his younger brother who has had an affair with the nobleman's wife. The vibrant purple tint serves multiple functions. Indexically, the purple is intended to replicate the dawn. On another level, the purple represents Ray's emotional state, somber and reflective, affecting a similar emotional state in the viewer. The tenderness of purple softens the mood as it does the sky. Although this color gives the impression of dawn, the purple also provokes an emotional effect. The intense purple reflects the emotions of the older brother as he risks his life for his younger brother, who conducted an affair with the nobleman's wife. Even though the older brother is risking his life out of brotherly love, he does so only because of his brother's selfishness and immorality. While the older brother is contending with these conflicting emotions, the pinkish purple tint reinforces the somber tone created by the narrative.

Figure 4. The zeppelin explodes. Howard Hughes, *Hell's Angels*, 1930.

The destruction of the zeppelin is one of the most visually spectacular scenes in the film. The scene's shadows were toned a dark navy, following in the silent cinema tradition of blue night scenes.. The strip was then tinted an orangish pink. The function here is in part indexical. At night, the eye's ability to distinguish color is dramatically reduced. A fiery explosion at nighttime could register to the eye as contrasted and abstracted warm and cool colors. Even if the viewer has no real experience with a nighttime explosion, the colors in this scene trick the eye into believing it is seeing something true-to-life. Even if the viewer realizes the colors are unnatural, the colors double as spectacle. The contrast of orange-pink and blue creates a pleasurable sensation. The colors function as spectacle as well as indexical replication. These two colors are complementary and therefore strike a more spectacular contrast. The blue and orange-pink are also warm and cool colors which mirror the heat of the fire and the cold of the night.

Each of these shots demonstrate the potency of the functions of filmic color. The beauty and sensuality of Harlow, captured by an indexically-minded color process, as well as the combination of tint and tone in the zeppelin scene are spectacular. The power of each is communicated in part by the play of colors on the screen. If the dawn duel were to lose its dark lavender tint, the tender, somber atmosphere of the scene would disappear with it. No color in these scenes is without function and the complex interplay of representation, emotion, and narration would be weaker without said colors.

Conclusion

This short analysis demonstrates the continued semiotic value of color in early cinema. While Cherchi-Usai (1996, 27-30) estimates that 80% or more of silent films were colored in some way, color preservation was not a priority for early archivists. By highlighting the aesthetic beauty, narrative meaning, and affective power of color in one film, I hope to have shown the importance of finding, restoring, and preserving colors in all early films.

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References

Cherchi-Usai, P. 1996. "The Color of Nitrate. Some Factual Observations on Tinting and Toning Manuals for Silent Films." In: *Silent Film*, R. Abel, ed. New Brunswick: Rutgers University Press, 21-30.

Gunning, T. 2016 "An Aesthetic of Astonishment: Early Film and the (In)Credulous Spectator." In: *Film Theory & Criticism*, L. Braudy and M. Cohen eds. New York: Oxford University Press, 645-659.

Flueckinger, B. 2020. "Film Colors: Materiality, Technology, Aesthetics" In *Color Mania: The Material of Color in Photography and Film*. Edited by B. Flueckinger, E. Hielscher, N. Wietlisbach. Zurich: Lars Mueller Publishers, 17-49.

Flueckinger, B. "Timeline of Historical Film Colors." Accessed May 19, 2022. https://filmcolors.org/#/

Yumibe, J. 2012. Moving Color: Early Film, Mass Culture, Modernism. New Jersey: Rutgers University Press

The Effect of Bar Soap Color on Customer Perception Based On Expected Functionalities

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Abstract

Very few studies have been made regarding consumer perception towards actual product color. In this research, bar soap was selected as the object of interest since it is seen as the most common cleaning agent in human lives. The main objective was finding associations between different colors of soaps and the expected functionality in curing specific skin concerns. Measurement of CIELAB color parameters for twenty-one soaps was conducted inside a viewing cabinet before an online questionnaire was distributed. 121 observers participated and were asked their views about the expected benefits of those soaps only by their colors - moisturizing, anti-bacterial, nourishing, refreshing, or whitening. It was observed that specific hues, along with different levels of brightness and chroma gave different expectations regarding soap functionality, notably pale pastel colors for moisturizing and nourishing skin, relatively dark colors for anti-bacterial, vivid blues to refresh skin and white for whitening effect. Unfortunately, inconsistency in viewing experience among observers whilst filling the questionnaire largely contributed to experimental errors in our study. Nevertheless, it is hoped that these findings may provide useful guidelines for related design practices.

Keywords: *bar soap, functionality, skin concerns, color parameters, questionnaire*

Introduction

Consumer perception has always been a part while designing a product and customer feedback holds a crucial key to a brand's success. One important consideration is the design of both packaging and the content of the product itself, as people often make decisions on what to purchase by their eyes, and one of the ways is through color selection. Unfortunately, it was rare to find studies where correlation between the true color of actual products and how customers perceive them was actually observed.

Existing Studies

Westland and Shin (2015) conducted a survey in which 241 respondents from 17 countries were asked about how consumer color preference might impact their choice while purchasing a variety of toiletries (including body wash). The study showed that the color preference had a significant impact on the color choice of body wash – most people would choose the same color of body wash as their favorite color, and this was especially apparent on those who preferred green, orange and yellow.

The principle of the work conducted by Gatti (2013) involved consumer perception of liquid bath soaps based on actual color, weight and fragrance and not merely its container. It was observed that a soap's fragrance intensity was dependent on color and weight, while the expected efficacy (cleaning ability) was dependent on weight and fragrance intensity.

Soap as Object of Interest

Soap is considered as one of the most crucial daily necessities for human beings, mainly used for cleaning purposes. A variety of soaps are available in the market based on purpose, ingredient and manufacturing method. In this research, bar soap was selected due to its variety in appearance (size, shape and surface transparency). Based on customer demands, five common soap functionalities were eventually used as important keywords for this experiment, and paired them with the related skin concern, as described on Table 1.

Functionality (Keyword)	Description (from Mina (2020))	Related Skin Concern
Moisturizing	Maintains hydration all over skin	Dry skin
Nourishing	Gives skin a healthy complexion	Dull skin
Anti-bacterial	Protects skin from germs and viruses	Body acne
Refreshing	Has a fruity fragrance and its fresh scent that last most of the day	Sweaty skin
Whitening	Whitens skin	Want a whiter skin

Table 1. Definition of each soap functionality and the related skin concern.

Objectives

The aim of this study was to get an understanding of how different bar soap colors may influence consumers' expectations of their skin. In addition, the trend between soap colors and functionality was also examined, along with how specific color hues of bar soaps might be associated to overcome one or more skin concerns for users.

Methods

Soap Color Measurement

Management of soap samples

A total of 21 soaps with diverse color properties (hue, chroma, and lightness) were collected from online marketplaces. Next, all of the soaps were cut into a uniformly sized 4 cm x 4 cm shape in order to eliminate any bias from shape factor before they were labelled, as shown on Figure 1.

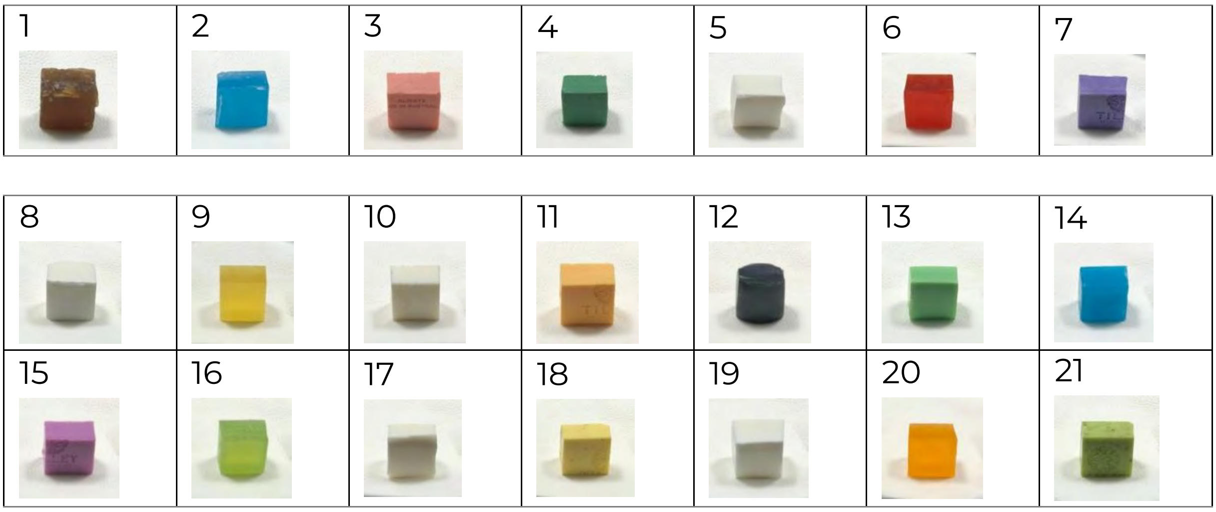

Figure 1. Complete list of soap photographs used in the experiment.

Measurement using CS-1000 Spectroradiometer

In this step, the soap samples were put one at a time inside a viewing cabinet, set into Daylight CIE Illuminant D65 with the illuminance level of 1581 lx and CCT value of 6167 K. Then, the corresponding colors were measured using a Konica Minolta CS-1000 spectroradiometer, tilted 30° so that it resembled observers' eyes as well as giving an accurate viewing like how observers would see the soaps while the viewing angle was set to 10°. Figure 2 below shows the experimental setup.

Figure 2. Experimental setup for color measurement process.

In this research, four CIELAB color properties were measured – lightness (L*), chroma (C_{ab}*), redness-greenness (a*) and yellowness-blueness (b*). The result can be seen on the two graphs below on Figures 3 and 4, in which they give information about color distribution of every soap.

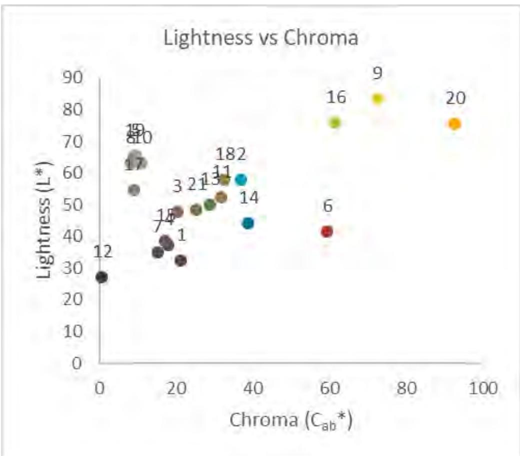

Figure 3. Distribution of soap colors based on lightness and chroma values.

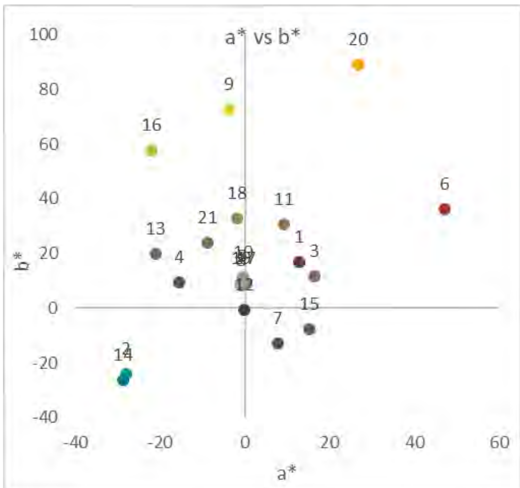

Figure 4. Distribution of soap colors based on hue.

Online Questionnaire

The data collection process took place on May 9-18, 2021. Initially, observers would have been requested to attend the experimental sessions in National Taiwan University of Science and Technology, Taipei, Taiwan. Due to the abrupt rise in local COVID cases across the country, this method was abandoned and distribution of online questionnaires was implemented instead.

Procedure

All participants were required to have a perfect color vision, i.e. no color deficiency disorders of any kind. First, they were required to describe skin concerns they frequently encountered. After that, the soaps were presented one at a time, and they were asked to choose their opinions about the possible functionalities of the soap from five possible answers only by judging from its color (multiple choices were possible). This step was then repeated for all remaining soaps.

Observers

A total of 121 participants (55 males, 66 females) showed their interest in taking part in this experiment. Unfortunately, 6 of those (4 males, 2 females) were not eligible to participate, leaving only 115 (53 males, 64 females). Regardless of gender, the most common skin concern among observers was sweaty skin (68 people), followed by dry skin and wanting a whiter skin (61 each), body acne (56) and finally, dull skin (22). Some observers might have a combination of two or more skin concerns, however in this experiment, all data from each skin concern were treated independently.

Results

From the questionnaire results, the top 5 and bottom 5 soaps based on observers' approval rate (in percentage) for each functionality can be seen on Table 2.

Functionality		Nourishing		Anti-bacterial		Whitening		Moisturizing		Refreshing	
	Rank	**Soap**	**Rate**	**Soap**	**Rate**	**Soap**	**Rate**	**Soap**	**Rate**	**Soap**	**Rate**
Top 5	**1**	18	66.94	4	65.29	5	72.73	3	57.85	2	66.94
	2	21	55.37	12	61.16	8	66.94	15	55.37	14	65.29
	3	11	53.72	13	57.85	10	66.12	10	52.89	16	61.98
	4	15	53.72	1	56.20	19	66.12	11	52.89	9	52.89
	5	7	49.59	21	48.76	17	65.29	17	52.07	20	48.76
Bottom 5	**5**	4	31.40	18	30.58	6	9.09	9	27.27	18	17.36
	4	16	30.58	5	27.27	13	6.61	13	26.45	10	15.70
	3	6	28.93	11	21.49	16	6.61	1	20.66	5	14.88
	2	14	17.36	15	20.66	4	5.79	4	14.88	1	11.57
	1	2	12.40	3	13.22	1	4.13	6	14.88	3	9.92

Table 2. Top 5 and bottom 5 soaps based on functionality.

From the responses shown in Table 2, the trend for each functionality may be summarized in Table 3 below.

Functionality	Top 5 Characteristics	Bottom 5 Characteristics
Nourishing	High lightness, low chroma; rather pale, pastel colors	Vivid colors with highly translucent surfaces especially blue
Anti-Bacterial	Low lightness and chroma; earth-tone color scheme (green, brown, black)	High lightness; reddish and yellowish hues
Whitening	Only white shades	Green and brown colors
Moisturizing	High lightness, low to medium chroma; mainly red hues (pink, purple, orange, yellow) and whites; opaque	More vivid or darker colors; highly translucent (exception: vivid red is the least moisturizing color)
Refreshing	High chroma, moderate lightness; translucent; vivid (especially blue)	White and pastel colors (also brown); opaque surface

Table 3. Characteristics of top 5 and bottom 5 soaps of each functionality.

After that, the data provided on Table 2 was used in order to gather information about the approval rate of top 5 soaps in providing the expected functionality between customers, analyzed separately for each functionality. For every participant, the average responses from five soaps was analyzed – if one perceived that soap as having such mentioned functionality, the response would be scored 1, otherwise the score would be zero. The results from all 121 observers were then averaged and the approval rate can be shown in Table 4 below. It was clear that people with a certain skin concern would be more likely to approve that the top 5 soaps would really help them than those who did not.

Skin Concern – Functionality	With concern	Without concern
Wanting a whiter skin – Whitening	74.10%	71.21%
Sweaty skin – Refreshing	62.24%	60.00%
Body acne – Anti-bacterial	61.79%	60.69%
Dry skin – Moisturizing	59.35%	57.07%
Dull skin – Nourishing	58.97%	55.46%

Table 4. Approval rate Top 5 and bottom 5 soaps based on functionality.

One obvious weakness of the results from this study was that there was no uniformity in viewing experience across all observers, i.e. highly dependent on the color gamut of gadget used while filling the questionnaire and therefore, there had been a certain degree of color difference across all observers, resulting in inevitable experimental errors.

Conclusion

Based on the study conducted, the recommended colors for each soap based on functionality are provided on Table 5 below.

Soap Functionality	Skin concern	Suitable Colors
Nourishing	Dull skin	Rather pale, pastel
Anti-Bacterial	Body acne	Earth-tone, green shades, dark color hues
Whitening	Wanting a whiter skin	Only white
Moisturizing	Dry skin	Bright, vivid, summer-tone
Refreshing	Sweaty skin	Highly chromatic, vivid (especially blue)

Table 5. Recommended colors for each pair of soap functionality and skin concern.

Recommendations

It is strongly advised for potential researchers to conduct on-site interviews in order to obtain a uniform viewing experience for all respondents, hence largely minimizing experimental errors. Regarding soap color selection, it would be excellent to include more soaps of blue and violet hues, as the representation of these colors were quite lacking. Finally, the analysis of translucency of bar soaps and its correlation to soap functionality may also be considered to be included in future studies.

Acknowledgements

This research was supported by the Ministry of Science and Technology, Taiwan (MOST 110-2410-H-011-029). The authors would like to express sincere gratitude to all observers who had allocated their time to fill in the online questionnaire.

References

Gatti, E., M. Bordegoni, and C. Spence. 2014. Investigating the influence of colour, weight, and fragrance intensity on the perception of liquid bath soap: An experimental study. *Food Quality and Preference* 31: 56-64.

Mina, J. C. 2020. Brand Positioning of Hygienic Products Using Conceptual Mapping Technique. *SSRG International Journal of Economics and Management Studies (SSRG-IJEMS)* 7(2): 150-158.

Westland, S. and M. J. Shin. 2015. The relationship between consumer colour preferences and product-colour choices. Journal of the International Colour Association 14: 47-56.

Color Theory and Creating Conversations About The Color of Us - A Makeup Artist's Discovery

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Abstract

There is a decisive lack of framework and commonality when talking about the color of skin. The reason for this is because we have for too long used racial identity as a way to describe the color of us. People are not described by the actual color of their skin, they are described with words like "black" and "white". Color Theory and the principles of color when expressed in neutral, give us an inclusive framework to discuss skin color without the bias of racial identity. When I created The Flesh Tone Color Wheel® I inadvertently made 2 powerful discoveries. The first was that all skin is neutralized color. We are simply brown. The second was that when teaching color theory in neutral, with The Flesh Tone Color Wheel®, I found a way to talk about the color of us without needing race identifying language.

Keywords: *color theory, skin tone, neutral, educa4on, racial bias*

Color Theory and Makeup Artistry

Color theory is an essential tool for any working makeup artist. Traditional color theory and the standard color wheel give an artist direction on covering areas that need to be hidden and enhancing areas that need to stand out. We can use the principles of color theory to create camera-ready natural makeup, to develop characters, prosthetics and help tell our stories. Color correction, in particular, is the most important color tool a makeup artist can understand. Based on the principle of complementary color, color correction makes it possible to cover blemishes, scars, tattoos, burns and discoloration in the skin.

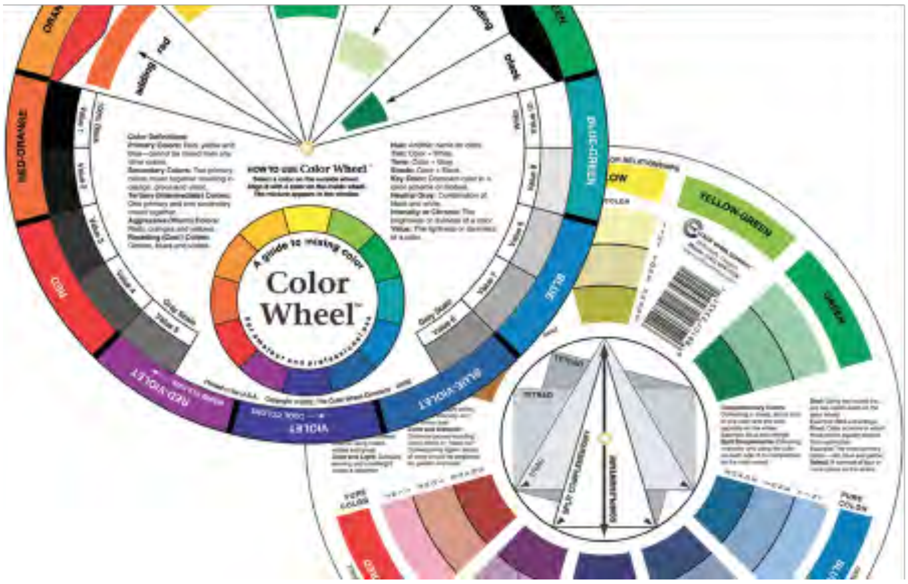

Figure 1. Traditional Color Wheel. Photo courtesy of The Color Wheel Company.

Color Theory and Makeup Education

As a makeup educator, I know that color theory needs to be a strong part of any curriculum. However, I was not taught color theory in makeup school. It was woven into the techniques and methods being taught but never broken down into a set of rules and guidelines. When I first opened Terri Tomlinson Makeup Training Academy, I created a module dedicated to color theory and teaching the principles of color. I used a traditional color wheel as a visual guide and makeup products that followed color theory. Students were given foundation and concealer/correction paleMes broken into “warms” and “cools”, laid out light-to-dark. Everything was in harmony.

Within a few years at my academy, I realized that my ability to visualize color was strengthened by my continued teaching and grew tired of the products my students used. They were too limited in range, would only get so deep or light and there was no way to adjust tone. I brought in a new line that had incredible versatility and color range, giving my students the ability to create any color they could visualize! However, without the labels and system to work in, my students struggled. They were not able to visualize skin tone or correction. I realized that my students had not been learning color theory with my program. They were working the system I was teaching and reading the names of products rather than learning to see color themselves. When I took away the system, when I gave them free rein, they could not grasp it.

The Birth of The Flesh Tone Color Wheel®

This was a lightbulb moment. I could visualize color theory in skin and makeup and needed to be able to convey that to my students. Out of frustration and a feeling of failure, I searched for some tool, some visual that would show my students what I could see. The idea came to me in a moment of brilliance: I would make my own color wheel, a special wheel for makeup artists that would show color theory in our "language", not pure hues but in skin tones.

I began the journey of creating a skin tone color wheel in 2016. During the year-long process, I made some profound discoveries. The first occurred in deciding how to lay out the wheel. Color wheels are very common and universally recognized, so I believed that this was the best format. Middleton. (2018: 5). Most color wheels start with a ring of pure hues and follow with rings of tints, tones and shades. I wanted to follow this, however I moved the pure hues to the center as they are less important in makeup work. I corresponded the ring of tints to light skins, the ring of tones to medium skins and the ring of shades to deep skins. This allowed me to think about the depth of skin as a scale from light-to- dark. Just as traditional color theory operates on a scale of gray from light-to-dark, my wheel operated on a scale of skin tones from light-to-dark. Suddenly, I saw that all skins could be visually mapped based on a scale of depth rather than seen in color families like "warm", "cool" and "neutral". Each of those scales could then be applied to any color hue represented on a wheel.

Figure 2. Brown Scale - photo courtesy of Terri Tomlinson.

Figure 3. Creating skin tones by neutralizing color. Photo courtesy of Terri Tomlinson.

The next profound discovery came when trying to create the colors of my wheel. I first tried to find colors that would fit into the sections. I tried skin colors that were “warm” and “cool” but it did not work. Many of these pre-mixed skin tones were not consistent in undertone, or the color within the color, and I could not find a proper range. In the world of makeup, we custom create skin tones by mixing uneven amounts of primaries together, essentially neutralizing them, and then saturating or desaturating them for depth. In another lightbulb moment, I decided that I had to custom create everything. Within this process of neutralizing color to create the skin tones for the wheel, I realized if skin tone is created by neutralizing color, then all skin should be considered “neutral”.

This was a powerful realization as the word “neutral” is often used in makeup and cosmetics to describe skin that has no distinctive undertone. However, all skin shows a prominent color within, which is its undertone. It was impactful to know I was creating more than a wheel of skin tones: I was creating a color wheel of neutrals, and all of those neutrals would be considered “brown". Just as I was able to see skin visualized as light-to-dark scales within the traditional hues of a color wheel. I now saw that each of those scales was a scale of browns. It made so much sense: skin is neutralized color, skin is brown.

Color Theory in Skin Tone

The Flesh Tone Color Wheel® launched in June 2017 and sold out within a week. An item that I had created for my students and classes was suddenly in demand from working makeup artists around the world. They saw the wheel as a visual guide for what they had been working out in their heads for decades.

The Flesh Tone Color Wheel® is a tool for working the principles of color theory in browns as well as a guide for seeing color and undertone. It shows us what skin looks like with the undertones of a traditional wheel; red-violet, yellow, yellow-green, green, etc. Because these skin tones are also neutrals, the wheel is a guide for seeing color in neutral and studying the variations. It also shows specific corrective colors based on complementary color theory. As I began using and teaching with the wheel, my makeup artistry began to change. I began creating all of my complexion colors in neutral and correcting in neutral. Suddenly, by having The Flesh Tone Color Wheel®, I was able to make subtle variations in skin tone by adjusting the color within the undertone. Foundations became more precise, correctors more specific.

Each time I worked with the wheel I found a new way to apply traditional color theory to it, even choosing the right brown eyeshadow based on eye color. I began teaching the same ideas in a class called, “Color Theory in Flesh Tone”. The more I presented the wheel and taught color theory with it, the more my ideas on the color of us expanded.

The Color of Us

As an educator I always ask my students “what color is skin?”. Many of my students have no answer to this question, others use terms that describe skin tone based on racial identity. But we know that there are no “black” people and there are no “white” people, those are terms used to describe old ideas of race. Many believe that dark skins and light skins are different kinds of people, however we now know that race is not based on biological differences. Fuentes et al. (2019) Humans are one species. Our skin and its color is created the same way for each of us. The color of us, our skin color, is created through a combination of pigment (melanin), UV light and our ancestor’s geographical history. Del Bino et al. (2018).

Figure 4. The Flesh Tone Color Wheel® image courtesy of Terri Tomlinson Makeup Training Academy. 2017.

If our skin color is created by the combination of geography, UV light and melanin, we all essentially have the same factors affecting the color of us. Jablonski et al. (2010) The Flesh Tone Color Wheel® shows us skin tones in a range of light-to-dark varied according to the 12 hues of traditional color theory. Each variation is a potential skin tone and all are neutral, all are brown. Isn't the only difference, between one skin and another, where it falls from light-to-dark combined with its undertone?

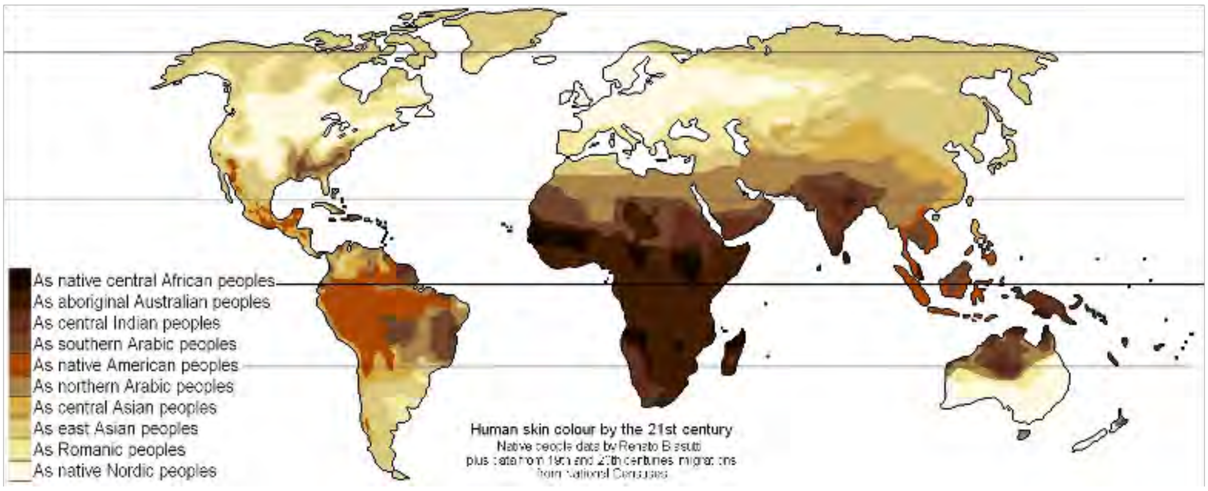

Figure 5. Skin color and UV distribution: World map of skin color. Collected by R. Biasun.

A Space to Talk

As I continue to speak about and teach "Color Theory in Flesh Tone" to artists, students, schools and organizations, I understand that we are talking about more than makeup. We are talking about what color we are, what actual color our skin is. Rather than a class of black, white and brown students, we see a room of browns with shades of Blue-Violet, tones of Olive, tints of Yellow-Orange, etc. No one is less-than in that space because we are all represented equally. Although unexpected, I have come to realize that The Flesh Tone Color Wheel® provides a kind of universal framework, to speak about the color of skin without racial bias. For many of my students this is a powerful and emotional moment.

Once we can see color in skin and work the principles of color in skin, neutral and brown, it opens up a dialog about the color of us that isn't based on racial bias or racial identity. We are all the same color and that color expresses itself in an infinite number of variations because of the affect of melanin, UV light and our ancestry. What a beautiful way to see the color of us. We can all be found on The Flesh Tone Color Wheel®, we all are represented equally in that space.

A Hope for More Conversations on Inclusion and Connection

Color Theory had always felt separate from makeup because it was not translated into the "language" of skin. There are no skin tones on a traditional wheel or in traditional color education. By creating The Flesh Tone Color Wheel® and education supporting it, I had to explain why skin was not shown on a traditional wheel, and more importantly, what color skin was. I had to show how I was able to move from traditional color theory to color theory in neutral. I inadvertently started a dialog on the color of us that was inclusive and free of racial identity. In the realm of The Flesh Tone Color Wheel® and color theory in flesh tone, we are all the same color with infinite variations.

The color of our skin affects our experience in the world. How we talk about and share that experience can create new connections that go far beyond old ideas of race. Racism is a complex social, historical and biological issue. It will not be solved easily or with one idea. Edgar et al. (2009).

However, I have seen the effect color theory in flesh tone can have on a group, especially those that have felt marginalized. The use of color and the languagewe use with it can have a powerful effect on us, as individuals and within communities, leading us all to a place of beMer understanding.

References

Del Bino, S., C. Duval, and F. Bernerd. 2018. Clinical and Biological Characterization of Skin Pigmentation Diversity and Its Consequences on UV Impact . *The International Journal on Molecular Sciences.*

Edgar, H. J., & K.L. Hunley. 2009. Race reconciled?: How biological anthropologists view human variation. *American Journal of Physical Anthropology*, 139(1), 1-4.

Fuentes, A., R. R. Ackermann, S. Athreya, D. Bolnick, T. Lasisi, S. Lee, S. McLean, and R. Nelson. 2019. American Association of Physical Anthropology (AAPA) Statement on Race and Racism.

Jablonski, N.G., and G. Chaplin. 2010. Human skin pigmentation as an adaptation to UV radiation. *Proc. Natl. Acad. Sci. USA*, 107 (Suppl. 2), 8962–8968.

Middleton, K. 2018. *Color Theory for The Make-up Artist.*

Colour-naming: Intercultural connotations and multisensory colour contexts based on the names of wall paints

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Abstract

This paper attempts to present cultural similarities and differences in the metatextual elements – Dulux "let's colour" and Dulux "VALENTINE" names of wall paints in three different languages The main research questions concern the inter-cultural and intra-cultural associations in naming paint colours in different European cultures: Polish, English, and French. The paper examines qualitative analysis with a method of the linguistic image of the world in contrastive studies. The discussion is based on the names of hues appearing in basic colour categories: red, blue, green, and yellow. The research explored the colour naming systems and categorized them in eight subsystems. The subject of colour naming reveals cultural and sense associations. The research proves some universal strategies in colour naming and highlights unique cultural aspects of creating terms.

Keywords: *colour naming, Dulux, wall paints, linguistic image of the world, connotation*

Introduction

Colour is used for social and communication purposes in specific contexts. "It is the society that 'makes' the colour, that gives it its definitions and meanings, that constructs its codes and values, that organizes its customs and determines its stakes" (Pastoureau, 2008: 16). However, research has consistently shown that there is no universal human concept of colour (Wierzbicka, 2006). This aspect still rages on, and more recently, there has been raised research in various contexts represented by e.g. Ou Li-Chen et al. (2018) and Chen Y. et al. (2020). Nevertheless, the colour gives sensations and impressions, which affect the human mind by evoking emotions and triggering memory – as Goethe conveyed, colour is primarily effective (Goethe, 2017[1810]: 167). Colour is also an influential visual identifier used to express personality and to identify brands. Therefore, we can observe cultural similarities and differences in how we talk and think about colours. The nature of these associations brings interesting results in the connection of visuality and language. This paper attempts to present these factors on the metatextual elements – Dulux "let's colour" and Dulux "VALENTINE '' names of wall paints in three different languages: French (FR), Polish (PL) and English (UK). The selected wall paint brands (Figure 1) belong to the international company AkzoNobel, which specialises in producing paints and coatings. The concern operates in over 150 countries, striving to become an industry leader.

Figure 1. Unified brand logo and digital interface for French, Polish and English websites.[1]

Methods

The presented analysis focuses on local products offered by the global concern, wherein colour plays a predominant role, to determine whether material utility products with a global scope globalise contexts and colour references in names. The main research questions concern the similarities (repeatability) and differences in naming paint colours in different European cultures: Polish, English, and French. The following criteria were considered during the selection of the material:

- the category of diversity – the material comprises different languages;
- the category of territorial and cultural constraints – the languages represent European countries;
- the category of objective research material – the wall paint names appear in the native languages in selected local markets.

The paper examines the qualitative analysis in the category of the linguistic image of the world in contrastive studies. The linguistic image of the world is a summary of everyday experiences and norms, values, ideas, and attitudes towards reality adopted by a given communicative community. One of the essential categories in studying the cultural character of language is semantic content (Anusiewicz, 1994). The linguistic image of the world method contains profiling, landmarks and trajectories, stereotyping, and valuation through anthropocentric approach. The paper focuses on profiling and valuation through colour names presented by the brand at the local scale.

The discussion is based on the names of hues appearing in basic colour categories: red, blue, green, and yellow (Figure 2). These colours are connected with the term

[1] French: https://www.duluxvalentine.com/ [dates on: 17.05.2022]; Polish: https://www.dulux.pl/ [dates on: 17.05.2022]; English: https://www.dulux.co.uk/en [dates on: 17.05.2022].

"basic" based on a long tradition in art/painting, and elementary design factors (Rzepińska, 1973:15; van Leeuwen, 2021: 85).

Figure 2. The selected colours in Dulux paint palettes.

In a detailed study of multimodality, van Leeuwen concluded that "colour now plays a key role in communicating the lifestyle identities of individuals and communities and the branding of corporations and other organizations. In the process, identity design began to shift from a psychological to a semiotic approach, an approach based on cultural provenances and the creative use of the experiential meaning potential of colour" (2021: 82). This paper seeks to address the following questions: Can we find the intercultural contexts and references in the paint's colour names in different European cultures? The second one concerns some universals of colour associations and specific intercultural contexts. The last question is consistent with the central hypothesis that colour evokes multisensory impressions in paint naming. Does the research conclude what 'qualia' it refers to? Whereas the second hypothesis conveys the opinion that the names of the paint colours indicate the carrier of intercultural colour meanings.

Result and Discussion

Creating names for paint hues is defined as a deliberate and purposeful process of strategic importance, e.g., creating consumers' needs and purchasing decisions. "Naming strategies have an impact on consumer behaviour. [..] The results of each experiment revealed that names significantly influence how colors are perceived, and that fancy names result in significantly more favourable ratings than do generic names" (Skorinko, Kemmer, Hebl, and Lane, 2006: 975). Diana Olvera, Behr's[2] colour marketing manager, says that paint names can typically be divided into the following descriptive categories: visual, geographic, emotional, and empirical. Inspiration may come from nature, fashion, or pop culture (Janeway,

[2] A popular brand of paints and coatings in the USA and Canada.

2017). The research explored the colour naming systems and categorized them in eight subsystems (Table 1).

Implicit colour names			**FR**	**PL**	**UK**
1.	Nature	• Flora	11	5	13
		• Fruits/Vegetables	7	-	4
		• Ground	5	1	2
		• Landform	2	4	10
		• Atmospheric/Astronomical Phenomena	5	2	5
		• Sky and Celestial Objects	3	2	8
		• Animals	1	-	-
2.	Food	• To Eat	5	2	9
		• To Drink	4	1	5
3.	Places	• Geographic Places	10	4	2
		• Common Places	2	1	2
4.	Cultural References	• Material Culture	2	1	1
		• Non-Material Culture	1	4	2
		• Word Formation	1	6	3
5.	Substantial Values	• Material	10	2	1
		• Common Items	1	-	4
6.	Descriptive Colour Names	• Collocations (with adjective)	15	26	17
		• Collocations (with adverb)	2	4	1
		• Collocations (with noun)	12	-	-
7.	Other	• Other	4	2	4
Explicit colour names					
8.	Common Colour Names	• Generic Colour Terms	11	1	1

Table 1. The categories of implicit and explicit Dulux colour names.

Table 1 shows the total number of all four colours (not repeated) included in given categories. The data set the collection of an intercultural nature of colour name associations. The analysis shows that in the French, the intercultural phenomenon is observed in material culture, e.g. *Rouge Boléro* (*Red Bolero*) as a reference to traditional Spanish clothing; in the non-material culture, relating to traditional Irish holidays: *Vert Patrick 2017* (*Green Patrick 2017*). It was also observed in the category of geographic places, e.g., *Dunes de Sahara Moyen* (*Middle Sahara Dunes*), or food: *Chamallow* (*Marshmallow*) relating to a popular American snack. According to the Polish colour names, intercultural contexts consist of the category of geographic places: *Malinowa Granada* (*Raspberry Granada*); *Wino z Cordoby* (*Wine from Cordoba*); *Złoto Cejlonu* (*The Gold of Ceylon*), *Las Równikowy* (*The RainForest*).

Furthermore, it is also presented in the names of material and non-material cultures like a monumental sacred building: *Złota Świątynia* (*Golden Temple*) or cultural phenomenon, e.g., *Gorączka Złota* (*The Gold Rush*), lifestyle: *Ogród Zen* (*Zen Garden*), and food like traditional Spanish appetizer: *Apetyczne Tapas* (*Tasty Tapas*). In the English language only one example has been noticed – in the category of food: *Salsa Red* interpreted as traditional Mexican food. Furthermore, specific intercultural context arises from examples of loanwords from the English language, in Polish: *Baby Blue*, *Urban Jungle*, or in French: *Blue Note*; *Baby Doll*, *Girly*.

Even more interesting is the result of the local context observation. Intra-culturalism observed in paint names arises from differences and variety. In this connection, English presents the most extensive group. First of all, it refers to their political system: *Monarch* (for red), and by the symbol: *Buckingham* (for green). In comparison to other languages,as Table 1 shows, English has the most greens and other colour names in the category of nature. Analysis culturally connotes those aspects with symbolic green island. There is also a food subgroup providing symbolic products: e.g., *Butter Biscuit*, *Lemon Pie*, *Golden Cookie* – all for yellow hues. There is a difference in Polish colour names. Cultural associations are revealed in the metalinguistic perspective, e.g., idiomatic phrase: *Czuję Miętę* ('to have a crush on someone') for green or *Cud Miód* ('extraordinary') for yellow; homophonic phrase: *Może Nad Morze* ('maybe at the seaside') for blue. These collocation-tricks combine metaphorical aspects and rhyming specific to Polish construction and cognition. According to French, there are again some intercultural symbols implying, e.g., *Crème de Cassis* ('Black currant liqueur from Burgundy') or places: *Vert Provence* (*Green Provence*), *Vert Pays Basque* (*Green Basque Country*).

This study also presents the impact of the senses on creating colour names. A small number of those were found in the category of smell and sound. The observation provides only two examples. For smell, it is a Polish *Różane Perfumy* (*Rose Perfume*), and for sound (or maybe even for sight), it is also Polish name: *Ogniste Flamenco* (*Fiery Flamenco*). It is interesting to find that there is a rich subgroup of food both to drink and to eat in a taste context. The material shows the names refer to summer fruit drinks: in Polish *Malinowe Smoothie* (*Raspberry Smoothie*); in English *Berry Smoothie*, and French: *Lait Fraise* (*Strawberry Milk*), *Citronnade* (*Lemonade*), *Citron Frappé* (*Lemon Frappe*). Moreover, the analysis shows a group of names that refer to alcohol drinks and liqueurs, especially in English: *Raspberry Bellini*, *Banana Split*, *Lemon Punch*, *Lemon Spirit*, and in French: *Crème de Cassis*. Sweets and desserts are another extensive group which refer to taste in naming. The observed names include Polish name: *Lody Malaga* (*Malaga Ice Cream*); English *Sorbet*, *Golden Cookie*, *Lemon Pie*, *Vanilla Sundae*, *Butter Biscuit*, and French *Rose Dragee* (*Pink Dragees*), *Chamallow* (*Marshmallow*), *Coulis de Framboise* (*Raspberry Sauce*), *Coeur d'Amande* ('dessert called almond heart'). The resulting observation of touch sense shows oppositions: warm and cold, e.g., *Lodowy Brzask* (*Ice Dawn*), *Frosted Lake*, *Volcanic Red*, *Rouge Feu* (*Red Fire*). Furthermore, touch sense associations create a groups of material, especially in French, e.g., *Gres Rose* (*Pink Gres*), *Rose Organza* (*Pink Organza*), *Cuir Bordeaux* (*Burgundy Leather*), *Bleu Jean* (*Blue Jeans*). The last sense is associated with oppositions of bright/dark, clean/dirty, pale/intense. The sight connotations create naming like: *Le Bleu Clair* (*Light Blue*), *Bleu Stone* (*Blue Stone*), *Przybrudzony Róż* (*Dirty Pink*), *Krystaliczny Błękit* (*Cristal Blue*), *Pale Citrus*, *Le Rose Intense* (*The Intense Pink*).

Conclusions

The subject of colour naming reveals specific and ambiguous designations arising for cultural and sense associations. Nature is the most often used category of the colour naming process for English and French. In English, this subgroup contains sixty percent of all green names (most in the flora) and fifty percent of all blue names related to landform and sky/celestial objects. Flora is also the most popular group for red hues. In French, the nature subgroup contains forty-four percent of all reds, while most of them belong to flora and fruits/vegetables categories. Thirty-three percent of French greens and thirty-nine percent of blues refer to the ground, atmospheric/astronomical phenomena, and sky/celestial objects.

The difference arises in Polish material, with the extensive 'descriptive colour names' group providing 56% of all greens, 48% of reds, and 44% of blues. Yellows reveal clear differentiation. As the smallest group, it consists of fifteen hues in French, nine hues in Polish, and eighteen hues in English. Yellow has the biggest representation in the following subgroups: descriptive colour names, cultural names, nature, and food.

The analysis presented in this study shows the impact of intra- and intercultural associations on colour naming in Dulux products. The results show that both local and global features connote some universal naming strategies. Intercultural factors were included in the category of food, geographic places, material and non-material culture, and also loanwords in the case of French and Polish names. In the case of food, there were common associations, e.g., lemon drinks and mustard for yellow (FR, UK); smoothies for red (PL, UK). The material proves common psychological aspects connoting in all languages Besides *Coeur d'Amande* (green hue), there are only red and yellow hues in the category of food[3]. In contrast, blues and greens are used to describe and name nature's horizontal and vertical perspectives. Associations for blue are also culturally convergent with sky and its attributes. The material brings much more observations in the case of similar connotation, e.g., for green including space: *Vert Véranda* (*Green Veranda*) – *Zielone Tarasy* (*Green Terraces*) or implying sport: *Vert Golf* is connected with *Putting Green*. In some cases, the name couples can be distinguished, e.g., *Jawnie Oliwkowy* (PL) – *Overtly Olive* (UK), which share the exact meaning. The name couples can also share the description, e.g., industrial, intense, or tropical.

However, the material also provides individual perspectives of culture and language. In Polish names, an intercultural perspective is provided in the metalinguistic reflection. There are no examples which connote local places, e.g., *Provence*, *Buckingham* or food, e.g., local liqueur or butter cookies, like in other languages The analysis shows that English and French hues refer to national goods and material values. In this case, the linguistic image of the world provides the connection between colour names and economic status of the country[4].

In some cases, the analysed data revealed universal strategies of colour naming through the opposition and connotation (especially for the food subsystem). Results are consistent with the opinion of other researchers that "it seems clear that colour emotion responses, in terms of warm/cool, heavy/light and active/passive, are somewhat culture-independent, showing consistent patterns across the regions" (Ou Li-Chen et al., 2018:746).

To sum up, the colour meaning is enriched by unique cultural factors, but at the same time the material provides argumentation for integration and globalisation in using and thinking about colour. The analysis broadens the knowledge about communication strategies in colour naming and the cultural diversity of three European countries. The analysis showed more contexts which are worth further exploring, e.g., cultural stereotypes in colour naming or investigation of other languages.

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[3] Warm colours influence appetite.

[4] The United Kingdom and France belong to The Group of Seven (G7) – the wealthiest countries group with the largest world economy.

References

Anusiewicz, J. 1994. *Lingwistyka kulturowa: zarys problematyki*. Wrocław: Wydawnictwo Uniwersytetu Wrocławskiego.

Chen, Y., B. Guo, D. Li, S. Westland, and M. Vazirian. 2020. Crowdsourcing word-colour association. *Journal of the International Colour Association* 25: 55-64.

Goethe, J.W. 2017 [1810]. *Theory of Colour.* Mineola, Nowy Jork: Dover Publications, INC.

Janeway, K. 2017. *How Paint Colors Get Their Names.* [online: https://www.consumerreports.org/paints/how-paint-colors-get-their-names/ dates on: 09.12.2021].

Ou, L.-Ch., Y. Yuan, T. Sato, W.-Y. Lee, F. Szabó, S. Superman, and R. Huertas. 2018. Universal models of colour emotion and colour harmony. *Colour. Research and Applications* 43 (5): 736-748.

Pastoureau, M. 2008. *Black – the history of colour*. Princeton NJ: Princeton University Press.

Rzepińska, M. 1973. *Historia koloru w dziejach malarstwa europejskiego*. Kraków: Wydawnictwo Literackie.

Skorinko, J.L., S. Kemmer, M.R. Hebl and D. M. Lane. 2006. A Rose by any other name...: Color-Naming Influences on Decision Making. *Psychology & Marketing* 23(12): 975–993.

van Leeuwen, T. 2021. *Multimodality and Identity*. London/New York: Routledge.

Wierzbicka, A. 2006. The semantics of colour: A new paradigm. In: *Progress in Colour Studies: Volume I. Language and Culture*, NJ Pitchford and CP Biggam, ed. Philadelphia: John Benjamins Publishing Company, 1-24.

Towards the number of discernible skin colours

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Abstract

A set of 1500 measurements of skin colour were obtained and used to estimate the gamut volume of skin colour. Three methods were used to estimate the number of discernible colours that were defined within the colour gamut. The grid method, sphere method and dodecahedra methods revealed estimates of 6547, 9258 and 9084-18748 colours respectively. The study concludes that there are approximately 10000 discernible skin colours. However, the work is very dependent upon whether the original data used were themselves representative of human skin colour. In addition, the work was carried out in CIELAB colour space which is not perceptually uniform.

Keywords: *skin colour, colour measurement*

Introduction

Variation in the colour of human skin is understood to be caused by variation in the presence of biological pigments (especially, but not exclusively, the pigment melanin). For example, the distribution pattern of melanosomes within keratinocytes has been identified as a major factor in determining skin colour (Thong *et al.*, 2003). Variation in levels of melanin can in turn be affected by genetics and by exposure to sunlight (Yuen and Jablonski, 2010). Temporary variations in an individual's skin colour can also result from physical exercise or from changes in emotional state (such as anger, embarrassment or sexual arousal). Unusual and temporary changes in skin colour can also result from various health conditions (e.g. hepatitis and liver disease) and from diet (e.g. eating too much of foods rich in carotene). Skin colour can also change with age. For example, production of melanin does not reach a peak in young humans until after puberty. Over the age of 30 skin can lighten and fade as melanin-producing cells gradually die. Interest in the variation and colour gamut of human skin colours stems from several areas including colour correction of images taken under different illuminants (Crichton *et al.*, 2012). In one study that explored the accuracy of colour measurement of skin it was concluded that the variability in measurements from different locations on the body was in fact greater than the variability between instruments (Wang *et al.*, 2018).

There are many applications (including medical applications, developments in cosmetics, and prosthetics) where colour assessment of skin is valuable. Although colour measurement is used (Wang *et al.*, 2018) the use of skin charts as an aid for visual assessment is also very common. The Fitzpatrick skin chart has achieved widespread popularity. The Fitzpatrick chart was developed in 1975 and consists of just six colour categories (Fitzpatrick, 1988). It was originally developed as a way to assess the response of different skin to UV light (for example, for determining the appropriate dose of UV light in treatment of skin disorders such as eczema and psoriasis). Although the chart has found use in other applications since, the small number of skin colour categories is limiting in terms of its usefulness. The Pantone Plus Skintone Guide includes 110 colours and is more suitable for many applications but other skin charts also exist. The existence of various colour guides with varying numbers of colours represented raises the question of how many samples a skin chart should have. How many discernible skin colours are there?

Methods

This work uses a skin-colour database [Wang, 2018] of 1500 measurements to determine the number of discernible skin colours. As the first step in this aim, the colour gamut of skin (based on the 1500 measurements) is determined by calculating the convex hull of the 1500 points in CIELAB colour space. The MATLAB command *convhulln* is used which implements the Qhull algorithm (Barber *et al.*, 1996). The problem of how to determine the number of discernible colours within the gamut volume is then addressed. A previous study explored methods to determine the number of discernible colours that can be produced by an emissive display [Li *et al.*, 2014] and these are used here to estimate the number of discernible skin colours. The first method – the *grid method* - uses a grid of points that are equally spaced (so as to be just discernible) in CIELAB space and calculates the number of these points that are contained by the gamut of skin colour (defined by the convex hull of the colour data). The second method – the sphere method - calculates the number of spheres (with diameter 1 ΔE unit) that can be contained within the convex hull of the human skin colour gamut. However, since spheres have a sub-optimal packing density, the sphere method may underestimate the number of discernible colours. The third method – *the dodecahedra method* - calculates the number of regular dodecahedra that can be contained within the convex hull. Dodecahedra have the interesting property that they pack in a 3-D space with a density of 1. Figure 1 shows a visual representation of the sphere method and the 3-D dodecahedron shape.

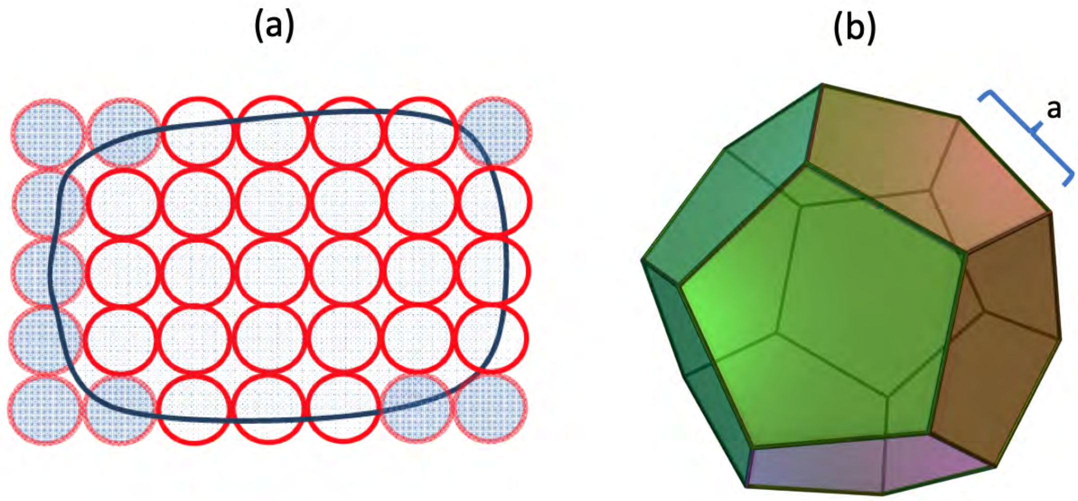

Figure 1. Visual representation of (a) the sphere method shown in 2-D and (b) a dodecahedron showing the side length *a*.

Results

Figure 2 shows a visual representation of the 1500 data points in CIELAB colour space. The *convhulln* MATLAB script calculates a 3-D convex hull that is a boundary that includes all of these points within it. The grid method is easily implemented and using this method arrives at a total of 6547 discernible skin colours. For the other two methods we need to explicitly calculate the gamut volume; this is calculated using the *convhulln* script and is 6545 units^3. For the sphere method we calculate the gamut volume and multiply this by the packing density ($\pi/(18^{0.5})$ = 0.7405) to arrive at the volume of space occupied by the spheres. This is then divided by the volume of a sphere to arrive at the number N of spheres. Thus N = 0.7405 V/v where V is the gamut volume and v is the volume of a sphere. This method estimates the number of discernible colours as being 9256. For the dodecahedra method we make sure of the fact that there is a relationship between the edge length a (see Figure 1b) and the radius r which is either a = r/1.1 or a = r/1.4 depending whether we are referring to the radius of an inscribed sphere or the radius of a sphere that touches the middle of each edge. These two methods yield estimates of 9094 and 18748 respectively. These estimates are summarised in Table 1.

Method	**Number of Discernible Colours**
Grid Method	6547
Sphere Method	9256
Dodecahedra Method	9084 (18748)

Table 1. Summary of the number of discernible skin colours according to the three methods. Note that the Dodecahedra method yields two estimates depending upon the assumptions that are made.

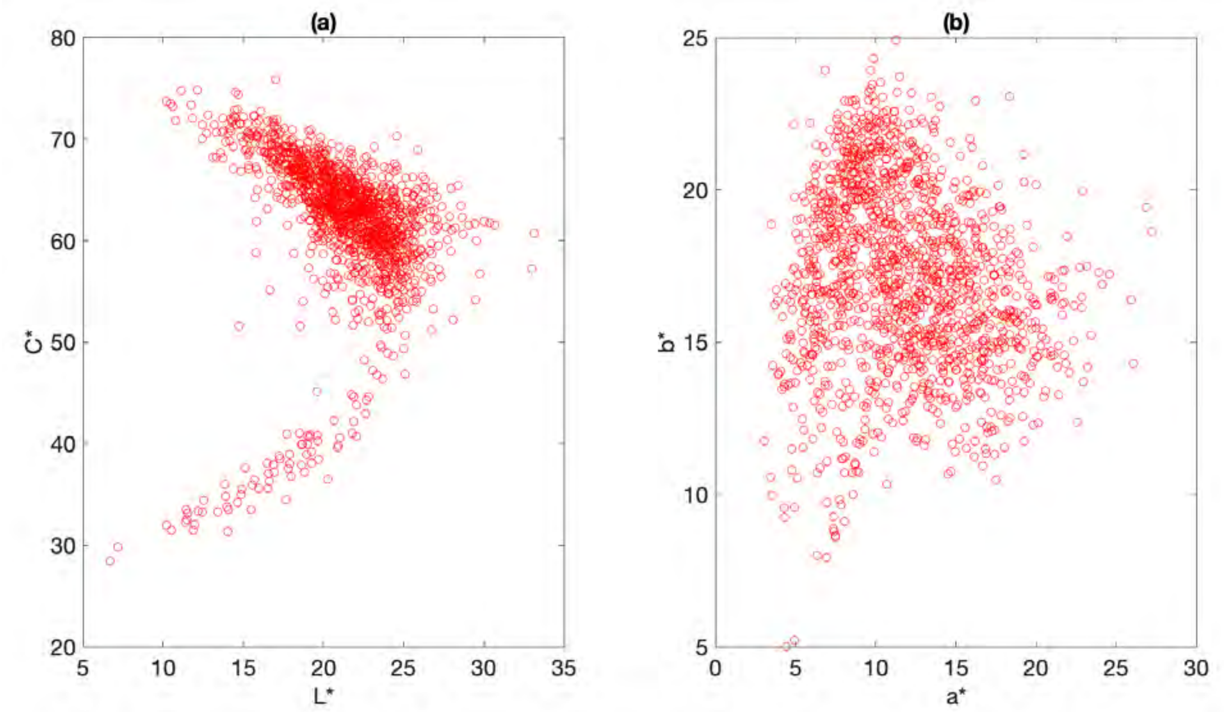

Figure 2. Visual representation of the 1500 samples in CIELAB space showing **(a)** L* v. C* & **(b)** b* v. a*.

Discussion

Three methods were used to estimate the number of discernible colours that were defined within the colour gamut. The grid method, sphere method and dodecahedra methods revealed estimates of 6547, 9258 and 9084-18748 colours respectively. The study concludes that there are approximately 10000 discernible skin colours. The data set of 1500 samples is, however, not huge and may not be fully representative of the full range of human skin colour. In addition, the work was carried out in CIELAB colour space which is not perceptually uniform. It would be interesting to repeat the analysis using a more uniform colour space. This work does provide methods that could be used to determine the number of skin colours or other estimates of particular interest (such as the number of different human tooth colours) if a suitably representative set of colour measurements could be obtained. This study does suggest that the number of discernible skin colours is in the thousands however; and this could have implications for the design and constitution of skin colour charts for various applications.

References

Barber, C.B., D. P. Dobkin, and H. T. Huhdanpaa. 1996. The Quickhull Algorithm for Convex Hulls. *ACM Transactions on Mathematical Software*: 22 (4) 469–483.

Crichton, S., J. Pichat, M. Mackiewicz, G. Y. Tian, and A. Hurlbert. 2012. Skin chromaticity gamuts for illumination recovery, Conference on Colour in Graphics, Imaging, and Vision: 266-271.

Fitzpatrick, T.B. 1988. The validity and practicality of sun-reactive skin types I through VI. Archives of Dermatology: 124 (6), 869-871.

Li, Y., S. Westland, Q.Q. Pan, and V. Cheung. 2014. Methods to assess the relative number of discernible colors for displays, IS&T/SID's 22nd Color and Imaging Conference: 151-154.

Thong, H.Y., S.H. Jee, C.C. Sun, and R.E Boissy. 2003. The patterns of melanosome distribution in keratinocytes of human skin as one determining factor of skin colour. British Journal of Dermatology: 149 (3), 498-505.

Wang, M. (2018), PhD Thesis, University of Leeds.

Wang, M., L. Xiao, M. R. Luo, M. Pointer, V. Cheung, and S. Wuerger. 2018. An investigation into the variability of skin colour measurements. Color Research & Application: 43 (4), 458-470.

Yuen, A.W., N. G. and N. G. Jablonski. 2010. Vitamin D: in the evolution of human skin colour. Medical hypotheses: 74 (1), 39-44.

Color for all Organisms: Landscapes Outside the Human Visible Spectrum

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Abstract

A more nuanced and empathetic understanding of the lives and intrinsic values of nonhuman species may be achieved by learning how to see the world through their eyes. Humans already use technology to sense “colours” outside those we can perceive and use them in scientific and commercial applications. We propose to use images created with these technologies to “see” and understand the world from the standpoint of nonhuman organisms. By transforming spectral wavelengths perceived by nonhuman visual systems into coordinate systems that we can see, we can create images that help us enter into the nonhuman world and develop empathy and compassion for its myriad inhabitants. The differing tonal values, contrast ranges, and objects revealed in our images support more complex narratives about nonhuman organisms and their interactions with one another and their environments. Seeing the world through their eyes also opens a window for us to use to see them for themselves, not just as resources for us to exploit. Finally, we expect that a detailed analysis of the aesthetic properties of images representing wavelengths and colours outside of the human visible spectrum will lead us to an expanded color theory and new directions in art and ecology.

Keywords: *Colour in Nature, Ecology, Perception*

Introduction

As humanity grapples with the Earth’s ongoing sixth “mass-extinction,” scientists, policymakers, and humanists alike continue to debate its proximate causes and consequences (e.g., Pievani 2013, Dirzo et al. 2014, Brondizio et al. 2019). Ecologists and environmental scientists have asserted that the sixth mass extinction is a result of complex interactions between anthropogenically-driven climatic change and Wilson’s (2002: 50) HIPPO: habitat fragmentation, invasive species, population growth and urbanization, pollution, and overexploitation of biological resources (Peviani 2013, but see Chew 2015 for an opposing point of view). In our view, an underlying cause of at least some of these drivers can be attributed to humans’ inability to see the world through the eyes of the other organisms who share the Earth with us but whom we treat only as “natural resources' ' to be commodified and exploited.

Wilson (2016; see also Dinerstein et al. 2020: 1) called for setting aside half of the Earth as a "global safety net" for the protection of biodiversity. Although setting aside 50% of the Earth's surface in large conservation zones is technically feasible (Dinerstein et al. 2017, 2020), gaining broader support for conserving and protecting biodiversity requires that people see its value (Norton 1988). We already use utilitarian and aesthetic criteria in deciding, either consciously or subconsciously, which species to protect (e.g., Justus et al. 2008, Gunnthorsdottir 2015, Kress and Krupnick in press). But if we are serious about preserving a large amount of Earth's biodiversity, we also need to recognize its intrinsic value and protect those species that we perceive as ugly, unattractive, or useless (Norton 1988). Finally, we need to do more than value diversity. We need to empathize with other species, too.

We suggest that a more nuanced and empathetic understanding of the lives of all nonhuman species would be achieved by learning how to see the world through their eyes (Zeigler and Ellison 2022). Even though it is conceptually and philosophically daunting to truly know what it is like to "be" another species (e.g., Nagel 1974, Haraway 2008), there are technical approximations. Using examples from our own work, we illustrate how photographing natural environments in spectra outside of the range of normal human colour vision and transforming these images into our colour spectrum allow us to envision how other species may perceive their world.

Methods for visualizing other spectra

We are interested in the spectrum ranging from ≈290 to 1100 nm. This spectrum extends beyond the range of human colour vision (≈380–750 nm) and includes spectra perceived by many other species. We first modified existing cameras so that they could record ultraviolet (< 380 nm) and infrared (750–1100 nm) spectra in addition to wavelengths in the spectrum visible to humans. We then photographed scenes from identical vantage points but in different wavelengths. Finally, we created comparison sets of images to reveal similarities and differences in perceptible details.

Specifically, we produced four images from each vantage point. Visible light images (both colour and a monochrome version of it that was subsequently "desaturated" in Photoshop) were made using a Nikon D800e camera with no modifications. Digital infrared and ultraviolet images were made using a self-modified Nikon D3000 camera that captures wavelengths from ≈325–1100 nm; ultraviolet images (340–380 nm) were made using this camera outfitted with a Kolari Vision ultraviolet bandpass transmission lens filter. Infrared images (850–1100 nm) were made using this same camera outfitted with an 850-nm infrared lens filter. We also made some ultraviolet images on Ilford HP5+ sheet film using a

Linhof 4 × 5 camera outfitted with a Kodak 18A Wratten ultraviolet-pass filter (allows wavelengths 290–400 nm).

Each set of four images taken from a single vantage point is displayed below in a four-panel "multi-spectral grid," with the images consistently positioned. Starting in the upper left of each four-panel set and moving clockwise, the first image shows the scene in the familiar colours of the human visible spectrum. The second image (upper right) has had the visible wavelengths desaturated in Photoshop; the third (lower right) shows only the infrared wavelengths; and the fourth (lower left) shows only the ultraviolet wavelengths. By focusing on particular spectra, we see changes in the images, such as white skies in ultraviolet images and bright foliage contrasting with dark skies in infrared images.

We note that we cannot actually see reflected light in the ultraviolet (wavelengths below 380 nm) or the infrared (wavelengths beyond 780 nm). However, we can mathematically transform ultraviolet and infrared images into ones that reflect light into our own visual spectrum. Such transformed (or "mapped") images can be gray-scaled or artificially colored. We have chosen to work with the gray-scale images, which are superficially similar in appearance to the desaturated, monochrome versions of the colour visible-light photographs. We also note that the lack of colour in these images is a way to avoid the complexities of choosing how to map tones from different spectra into those that make sense to humans; how to make these choices will be a focus of our future work.

Examples

The images we have made so far are of forests, living and ancient, fire-scarred and heavily managed. These subjects also draw attention to plants, which many people ignore entirely (i.e., "plant blindness" sensu Allen 2003; more appropriately called "plant awareness disparity" by Parsley 2020) or think of only when they are edible, medicinal, or otherwise useful (e.g., Kress and Krupnick in press). In addition, the images challenge our sense of time. For example, the Great Basin Bristlecone Pine (*Pinus longaeva*) forests of Nevada and California in the United States also reveal ecological interactions on a time scale humans rarely consider, as the trees can live to 5,000 years of age. The images of fire-scarred and managed forests reveal the speed of transformation to human and non-human effects.

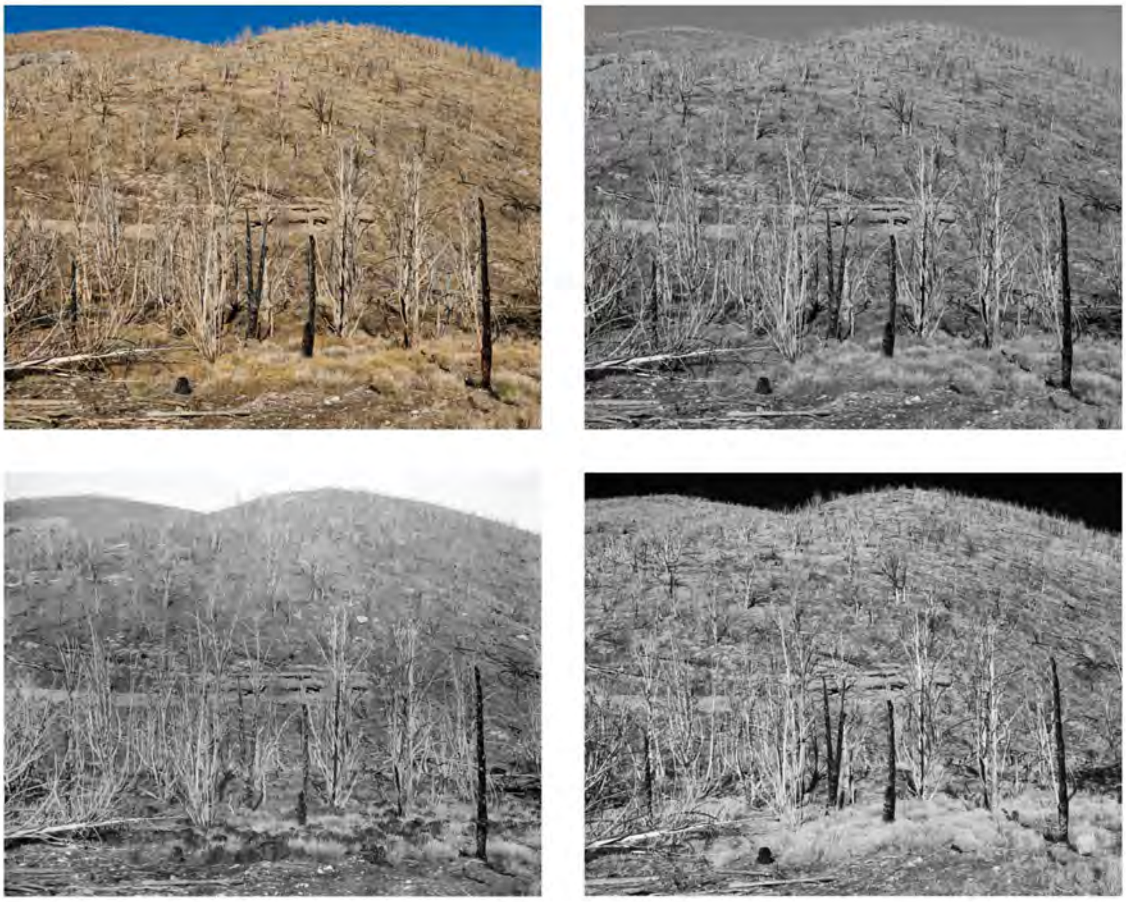

Figure 1. *Lexington Arch, Charcoal Snags on Hillside in Multiple Spectra* (2021), Original digital and film images © Eric Zeigler and Aaron M. Ellison.

Figure 1 shows a Nevada hillside scarred by fire. The area photographed is within the section of the Great Basin National Park that was burned by the Black Fire in July 2013, a fire that was started by a lightning strike (Roberts 2013/2014). This comparison of the scene in different spectra reveals many of the differences commonly seen in ultraviolet, visible light, and infrared images. For example, the infrared image displays a dark sky, while the ultraviolet is rendered in near white, and living vegetation glows in the infrared, just like snow does in the visible spectrum. This same living vegetation is not reflective in the ultraviolet, so it shows up as dark tones in the image. These tonal differences can be useful to art photographers who may differentiate areas of an image with heightened or lowered contrast, but for nonhuman species, these different tones or reflected wavelengths may identify food, shelter, or predators (Zeigler and Ellison 2022).

Another difference among these images is the relative clarity of "information from a distance" or how we see through the atmosphere. In the ultraviolet, there is less contrast and differentiation between the foreground and the distant landscape. In contrast, tonal distinctions in the infrared image are clear at all distances. Because most other animals perceive ultraviolet wavelengths, their "vision" may be limited by an apparently "thick" atmosphere (e.g., Marshall 2010).

A more extreme vision of this phenomenon is illustrated with images of fire taken in different spectra (Figure 2). In the infrared spectrum, the flames are spectacular and far more dramatic than in the visible spectrum. However, the flame licks are not visible at all in the ultraviolet, whereas the smoke, not nearly as opaque to our eyes in the visible spectrum, clouds out any view of the distance. Consider an ultraviolet-seeing bird flying through a visually thick atmosphere. In the apparently dense smoke of even a small fire, the bird may be unable to orient and fly into another area as the fire danger increases. Such scenes are likely to be much more common as we move from the Anthropocene epoch into the so-called Pyrocene (Pyne 2022).

Figure 2. *Burning Orchard Prunings in Multiple Spectra* (2022), Original digital images © Eric Zeigler and Aaron M. Ellison.

Even in the Pyroxene, fire can have positive value; small, controlled fires can reduce the likelihood of large ones, and many species and even entire ecosystems are adapted to and thrive as a result of frequent, small fires (e.g., Bond and Midgley 1995, Odion et al. 2010, Scott et al. 2014). In our images of a forest stand managed with fire (Figure 3), different densities of plants in the regenerating forest understory are visible in different spectra; some species are clearly visible only in some spectra (e.g., bramble vine [*Rubus*] in the infrared).

Our sense of management, species diversity, and ecosystem structure in Figures 1–3 is conditioned by our relatively short lifespan. What would it mean to "see" the dynamics and changes of nonhuman species in natural systems through their lifespans (e.g., Bestelmeyer et al. 2011)? As an extreme example, Great Basin Bristlecone Pine trees can live for at least 5000 years on windy and cold mountains above 2900 m (9500 ft) above sea level (Figure 4; Schulman 1958, Ross 2020). The glistening foliage in the infrared, along with the dark, nonreflective foliage in the ultraviolet, shows us what light spectra are important for these plants. The ultraviolet is absorbed, and the infrared is scattered about in every direction; the plants make use of specific, narrow wavelengths across the entire spectrum from the ultraviolet through the near-infrared (Jones 2014). How might anthropogenic changes to the atmosphere affect what plants "see" and how they can use the light to eat?

Figure 3 (left) *Maumee State Forest Thinning and Prescribed Burn Test Plot* (2022), Original digital images © Eric Zeigler and Aaron M. Ellison. **Figure 4 (right)** *Great Basin Bristlecones #5* (2021), Original digital and film images © Eric Zeigler and Aaron M. Ellison.

Conclusion

The visions of the world in our photographs are helping us understand and tell the complex stories of how humans and nonhumans share and interact with one another and the environment. The "hidden stories" (sensu Chua et al. (2017) our images reveal by putting our colour vision into broader contexts may lead us toward a much richer discussion and understanding of our place on Earth.

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References

Allen, W. 2003. Plant blindness. *BioScience* 53: 926.

Bestelmeyer, B. T., A. M. Ellison, W. R. Fraser, K. B. Gorman, S. J. Holbrook, C. M. Laney, M. D. Ohman, Peters, F. C. Pillsbury, A. Rassweiler, R. J. Schmitt, and S. Sharma. 2011. Detecting and managing abrupt transitions in ecological systems. *Ecosphere* 2: art129.

Bond, W. J., and J. J. Midgley. 1995. Kill thy neighbour: an individualistic argument for the evolution of flammability. *Oikos* 73: 79-85.

Brondizio, E. S., J. Settele, S. Díaz, and H. T. Ngo. 2019. Global assessment report on biodiversity and

ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Bonn: IPBES Secretariat.
Chew, M. K. 2015. Ecologists, environmentalists, experts, and the invasion of the `second greatest threat.' *International Review of Environmental History* 1: 7-40.
Chua, F., K. Morrison, D. Perkins, and S. Tishman. 2017. *Exploring complexity*. Project Zero, Harvard Graduate School of Education. Available online: http://www.pz.harvard.edu/resources/exploring-complexity, accessed 11 May 2022.
Dinerstein, E., D. Olson, A. Joshi, C. Vynne, N. D. Burgess, E. Wikramanayake, N. Hahn, S. Palminteri, P. Hedao, R. Noss, M. Hansen, H. Locke, E. C. Ellis, B. Jones, C. V. Barber, R. Hayes, C. Kormos, V. Martin, E. Crist, W. Sechrest, L. Price, J. E. M. Baillie, D. Weeden, K. Suckling, C. Davis, N. Sizer, R. Moore, D. Thau, T. Birch, P. Potapov, S. Turubanova, A. Tyukavina, N. de Souza, L. Pintea, J. C. Brito, O. A. Llewellyn, A. G. Miller, A. Patzelt, S. A. Ghazanfar, J. Timberlake, H. Klöser, Y. Shennan-Farpon, R. Kindt, J.-P. B. Lillesø, P. van Breugel, L. Graudal, M. Voge, K. F. Al-Shammari, and M. Saleem. 2017. An ecoregion-based approach to protecting half the terrestrial realm. *BioScience* 67: 534-545.
——,Joshi, A. R., C. Vynne, A. T. L. Lee, F. Pharand-Deschênes, M. França, S. Fernando, T. Birch, K. Burkart, G. P. Asner, and D. Olson. 2020. A "Global Safety Net" to reverse biodiversity loss and stabilize Earth's climate. *Science Advances* 6: eabb2824.
Dirzo, R., H. S. Young, M. Galetti, G. Ceballos, N. J. B. Isaac, and B. Collen. 2014. Defaunation in the Anthropocene. *Science* 345: 401-406.
Gunnthorsdottir, A. (2015). Physical attractiveness of an animal species as a decision factor for its preservation. *Anthrozoös* 14: 204-214.
Haraway, D. J. 2008. *When species meet*. Minneapolis: University of Minnesota Press.
Jones, H. G. 2014. Plants and microclimate: a quantitative approach to environmental plant physiology, third edition. Cambridge: Cambridge University Press.
Justus, J., M. Colyvan, H. Regan, and L. Maguire. 2008. Buying into conservation: intrinsic versus instrumental value. *Trends in Ecology & Evolution* 24: 187-191.
Kress, W. J., and G. A. Krupnick. in press. Lords of the biosphere: Plant winners and losers in the Anthropocene. *Plants, People, Planet*. https://doi.org/10.1002/ppp3.10252, accessed 11 May 2022.
Marshall, J. 2010. Why are animals colorful? Sex and violence, seeing and signals. *Journal of the International Colour Association* 5: 8, 1-8.
Nagel, T. 1974. What is it like to be a bat? *The Philosophical Review* 83: 435-450.
Norton, B. G. 1988. *Why Preserve Natural Variety*? Princeton: Princeton University Press.
Odion, D. C., M. A. Moritz, and D. A. DellaSala. 2010. Alternative community states maintained by fire in the Klamath Mountains, USA. *Journal of Ecology* 98: 96-105.
Parsley, K. M. 2020. Plant awareness disparity: a case for renaming plant blindness. *Plants, People, Planet* 2: 598-601.
Pievani, T. 2014. The sixth mass extinction: Anthropocene and the human impact on biodiversity. *Rendiconti Lincei* 25: 85-93.
Pyne, S. 2021. The Pyroxene: how we created an age of fire, and what happens next. Oakland: University of California Press.
Roberts, B. 2013/2014. Black Fire account. The Midden: The Resource Management Newsletter of Great Basin National Park 13: 7-8.
Ross, A. 2020. The bristlecones speak. *The New Yorker* 95(45): 44-53.
Schulman, E. P. 1958. Bristlecone pines, world's oldest living things. *National Geographic* 63: 355-372.
Scott, A. C., D. M. J. S. Bowman, W. J. Bond, S. J. Pyne, and M. E. Alexander. 2014. *Fire on Earth: an introduction*. Chichester: Wiley-Blackwell.
Wandersee, J. H., and E. E. Schussler. 1999. Preventing plant blindness. *The American Biology Teacher* 61: 82-86.
Wilson, E. O. 2002. *The future of life*. New York: Alfred A. Knopf.
——. 2016. *Half-Earth: our planet's fight for life*. London: W. W. Norton & Company, Ltd.
Zeigler, E., and A. M. Ellison. 2022. Learning to see differently. In: *Seeing across disciplines: The book of selected readings 2022,* J. Lee, S. Beene, X. Chen, W. Huang, L. Okan, and F. Rodrigues, eds. Stockton: International Visual Literacy Association, 68-81.

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