AIC2013
Bringing Colour to Life

AIC Colour 2013

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

Proceedings
Volume 2

Editors:
Lindsay MacDonald,
Stephen Westland,
Sophie Wuerger

The Colour Group (Great Britain)

AIC

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

programme overview

Times (07:00–22:30, in half-hour steps): 07:00, 07:30, 08:00, 08:30, 09:00, 09:30, 10:00, 10:30, 11:00, 11:30, 12:00, 12:30, 13:00, 13:30, 14:00, 14:30, 15:00, 15:30, 16:00, 16:30, 17:00, 17:30, 18:00, 18:30, 19:00, 19:30, 20:00, 20:30, 21:00, 21:30, 22:00, 22:30

Sunday 7th July

- ***Lit & Phil*** – AIC Executive Committee Meeting
- ***BALTIC Terrace*** – Welcome Drinks + Registration Open

Monday 8th July

Registration and Exhibition Open

- Registration and Exhibition Open
- ***Hall One*** – Opening Ceremony
- ***Hall One*** – Keynote - Andrew Parker
- COFFEE
- ***Hall One*** – Special Symposium: LED Lighting
- ***Hall Two*** – Colour and Food
- ***Hall Two*** – Colour and Wellbeing
- ***Northern Rock Room*** – Colour in Art
- LUNCH
- ***Foyer*** – Posters and Exhibition
- ***Hall One*** Special Symposium: Museum Lighting
- ***Hall Two*** – Colour Ergonomics
- ***Northern Rock Room*** – Colour Aesthetics
- ***The Hatton Gallery*** – Official Congress Opening

Tuesday 9th July

Registration and Exhibition Open

- Registration and Exhibition Open
- ***Hall One*** – Keynote - Fiona Jenvey
- COFFEE
- ***Hall One*** – Special Symposium: Fashion
- ***Hall Two*** – Architectural Colour
- ***Northern Rock Room*** – Colour Technology
- LUNCH*
- ***Foyer*** – Posters and Exhibition
- ***Barbour Room*** – Special Symposium: Sustainable Coloration
- ***AIC Study Groups***
- ***Northern Rock Room*** – Colour Imaging
- ***The Sage Gateshead*** – Concert

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

Wednesday 10th July

Registration and Exhibition Open

- Registration and Exhibition Open
- ***Hall One*** – JUDD Award
- COFFEE
- ***Hall One*** – Special Symposium: MCS2013
- ***Hall Two*** – Fashion
- ***Hall Two*** – Product Design and Branding
- ***Northern Rock Room*** – The Colour of Culture
- ***Hall One*** – AIC General Assembly
- Coaches depart for city excursion
- ***Durham City*** – City Excursion

Thursday 11th July

Registration and Exhibition Open

- Registration and Exhibition Open
- ***Hall One*** – Keynote - Hilary Dalke
- COFFEE
- ***Hall One*** – Special Symposium: Aesthetics
- ***Hall Two*** – Colorimetry
- ***Hall Two*** – Colour Difference
- ***Northern Rock Room*** – Interdisciplinary Colour
- LUNCH
- ***Foyer*** – Posters and Exhibition
- ***Hall One*** – Special Symposium: Environmental Colour
- ***Hall Two*** – Colour Printing
- ***Northern Rock Room*** – Colour Vision
- Coaches depart for Alnwick
- ***The Alnwick Gardens*** – Official Congress Banquet

Friday 12th July

Registration and Exhibition Open

- Registration and Exhibition Open
- ***Hall One*** – Keynote - Stephen Palmer
- COFFEE
- ***Hall One*** – Special Symposium: Human Colour Vision: From the Retina to the Cortex
- ***Hall Two*** – Colour Education
- ***Northern Rock Room*** – Interior Design and Lighting
- ***Foyer*** – LUNCH, Posters and Exhibition
- ***Hall One*** – Special Symposium: Colour Harmony
- ***Hall Two*** – Colour and Music
- ***Hall Two*** – Colour Naming
- ***Hall One:*** Capstone Presentation
- ***Hall One*** – Closing Ceremony

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Contents

judd award lecture

Conversations with an Artist

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ABSTRACT

Color science requires knowledge of chemistry, physics, psychology, physiology, mathematics, statistics, engineering, and computer science: a true interdisciplinary experience. Many fellow color scientists are applied scientists, using their knowledge to advance color technology. My passion is to use color science to enhance how artwork is created, conserved, displayed, reproduced, and documented. I imagine a conversation with an artist where I posit the usefulness of color science. Color-order systems have long been a popular communication tool. They can also be used to help teach how to achieve visual effects such as shading, shadows, and atmospheric effects. Understanding whether blue and yellow mix to form a gorgeous green or offal olive can help a painter select a more efficient palette. Many artists produce editions using inkjet printing where the goal is to match an original work. Understanding color management basics may save much grief (and consumables). The display of artwork is a balance between maintaining the artist's intent, the viewing experience, and damage from light exposure. Computer graphics can provide new tools to understand the tradeoffs. The sobering effects of how some colors can change over time cannot be overstated. How will the conversation end?

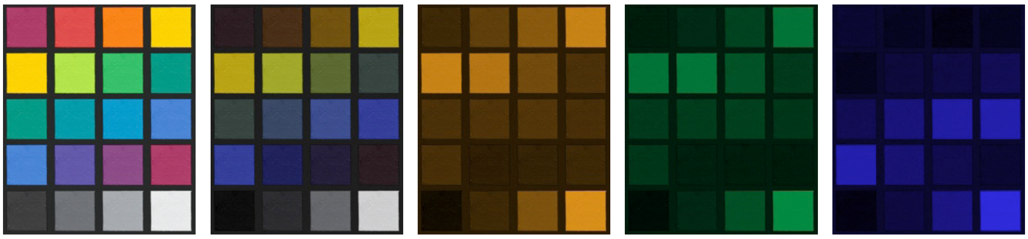
1. INTRODUCTION

Applying colorants to surfaces including cave walls, our bodies, architecture, manufactured products, and visual art predates color science by millennia. Color technologists know how to achieve a specific color without knowing why the colorants produce the specific color. A painter purchases tube paints, brushes, solvents, and canvas and can take the step from materials to masterpiece seemingly without a hitch or stumble. Can a color scientist offer anything of value to the painter? Several examples are presented in this paper using the common color technology tools of CIE colorimetry and Kubelka-Munk (K-M) turbid-media theory along with the Saunderson equations.

2. DEFINING COLOR USING CIELAB

Let's face it, CIELAB is not going away. It is used for specification, setting tolerances, color encoding, and color management. Can it be taught in a way that is more palatable to an artist? To me this means avoiding XYZ and using visual aids.

A target was produced using artist acrylic dispersion paints (see Figure 1). Observers with normal color vision have three cone receptors, LMS, and images can be produced representing each cone type. These images are false color where LMS maps to RGB or where the individual cones map to orange, green, and blue. Similar images can be produced to explain adaptation and compression. Finally, CIELAB can be explained using LMS cones as input (Figure 2). There are three important observations. The first is that only the L and M signals contribute to lightness. The second is that all three cone signals contribute to a^*. The third is that the scaling is unequal when signals are combined (e.g., L^* and the positive component of b^*). As such, CIELAB is not a strict representation of opponent two-stage theory, in which case, L* would include all three cone signals equally, a* would only include L and M signals, and b* would have equal signals for L and M and their sum would equal the S scaling. Although the architects of CIELAB used two-stage opponent theory as a point of departure, the space was designed to achieve approximate uniform spacing resulting in formulas that depart from theory. This is further justification that CIELAB's axes should not be referred to using the color names of red, yellow, green, blue, black, and white. Plotting the target's color in an a*b* projection and some further explanation results in the polar coordinates of hue and chroma. Thus, there are both words and numbers for color communication.



(true color) (LMS) (L) (M) (S)

Figure 1: Color target rendered for daylight (true color) and false-color where L = Red, M = Green, and S = Blue channel.

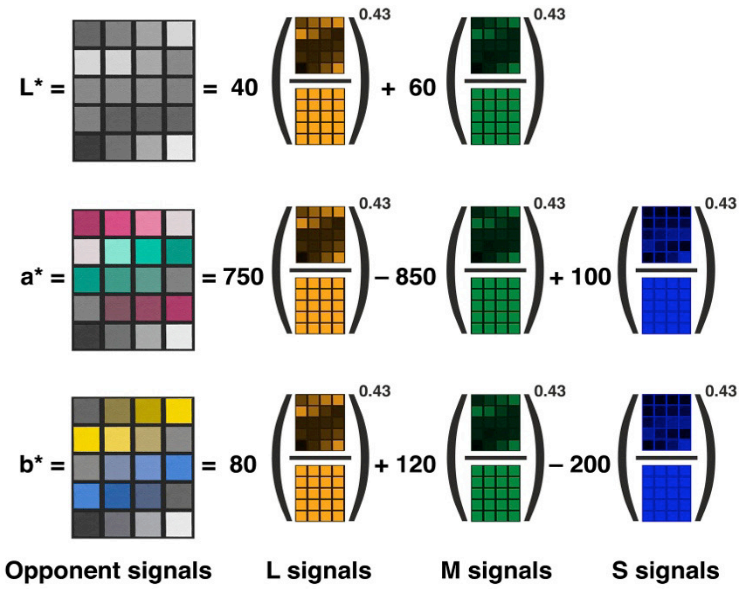


Figure 2: The mathematics of CIELAB from cone signals. (Note this is an approximation of the CIE mathematics.)

3. EXTENDING CIELAB TO IMPROVE TEACHING PAINTING

CIELAB's fundamental rectangular coordinates are often transformed to cylindrical polar coordinates of lightness (L^*), hue (h_{ab}), and chroma (C^*_{ab}) to improve visualizing differences in color. Albert H. Munsell, an easel painter and teacher, developed a color order system using these dimensions with the goal of improving communication with his students. Ironically, mixing oil paints rarely correspond to changes in only chroma or lightness and

I believe a system similar to the NCS would have better served Munsell as an teacher. This is seen in Figure 3 where colors of increasing chroma are plotted for nine hues at three lightness levels. It is quite challenging to produce colors that vary in chroma while maintaining constant lightness. Recently, I derived three new CIELAB coordinates: vividness, depth, and clarity, defined in Table 1 (Berns 2013). Examples of each coordinate are shown in Figures 4-6. Depth is correlated with concentration when a single colorant is mixed with white. The change in color from a specular highlight to "body" color is an increase in depth. As an object becomes shadowed, it is decreasing in vividness. As objects recede towards a distant point, their clarity decreases. These dimensions are far more useful to a painting teacher than chroma and lightness because such dimensions are more correlated to color mixing.

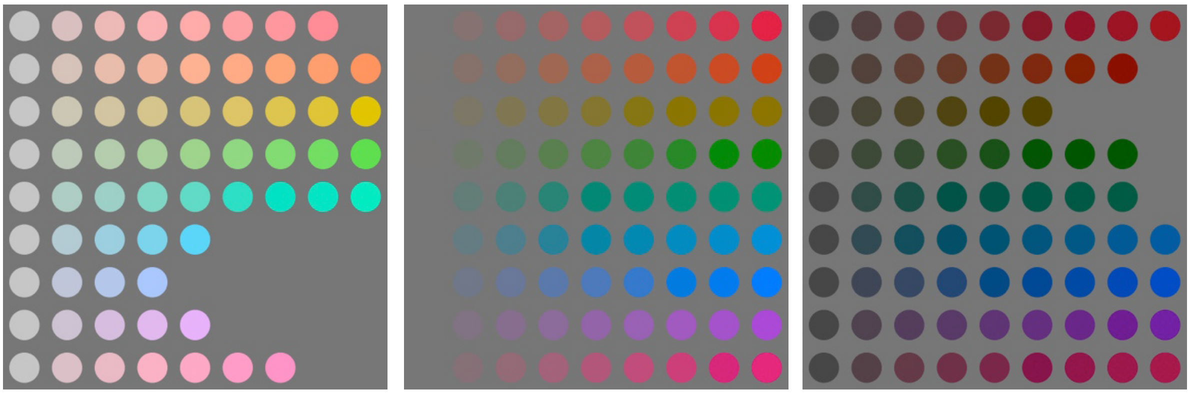


Figure 3: Changes in chroma for different hues having h_{ab} of 22.5°, 45°, 90°,..., 360°. The maximum chroma (rightmost color) was 80. Colors for each image have constant lightness of 80 (left), 50 (center), and 30 (right).

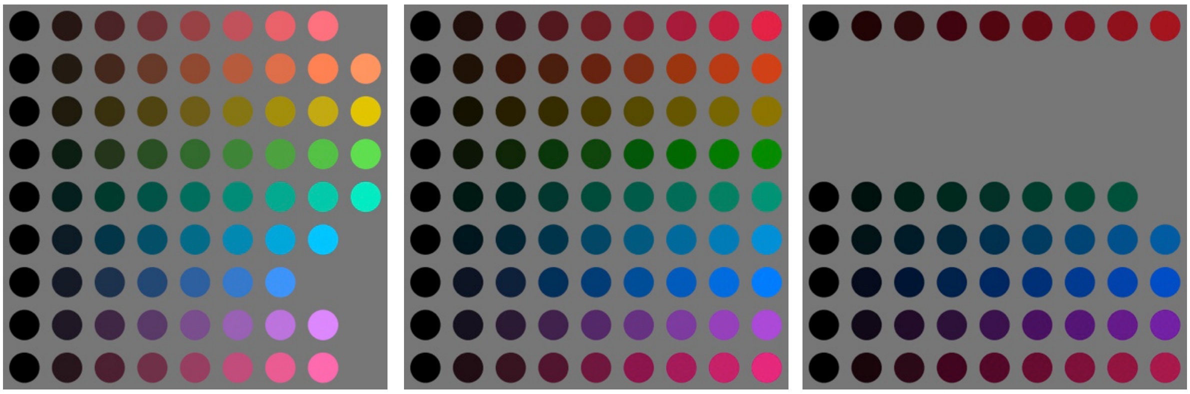


Figure 4: Changes in vividness for different hues.

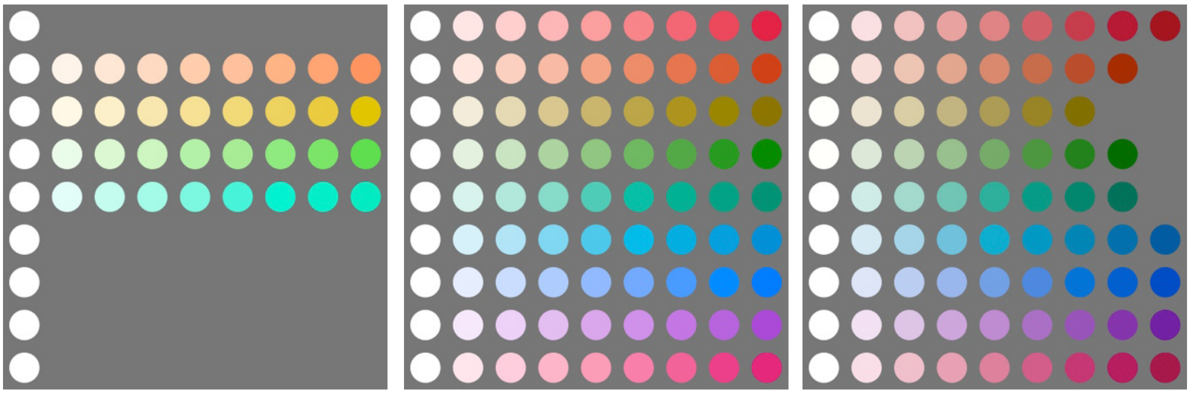


Figure 5: Changes in depth for different hues.

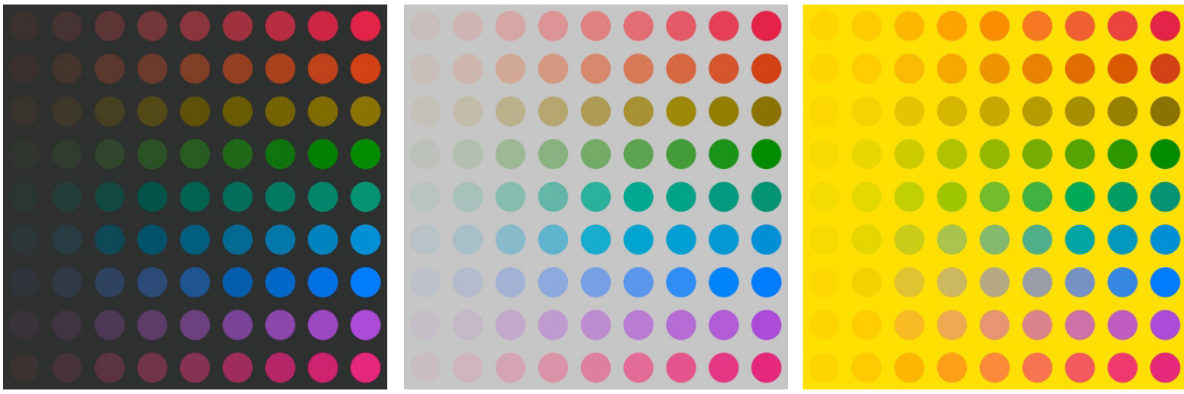


Figure 6: Changes in clarity for different hues and different backgrounds.

Table 1. Terminology for chroma, vividness, depth, and clarity.

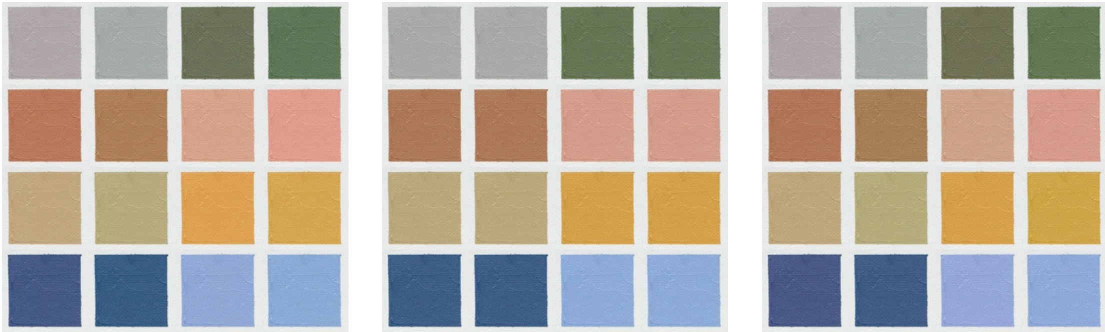
Term	Variable	Definition
Chroma	C^*_{ab}	Chroma is an attribute of color used to indicate the degree of departure of the color from a neutral color of the same lightness
Vividness	V^*_{ab}	Vividness is an attribute of color used to indicate the degree of departure of the color from a neutral black color
Depth	D^*_{ab}	Depth is an attribute of color used to indicate the degree of departure of the color from a neutral white color
Clarity	T^*_{ab}	Clarity is an attribute of color used to indicate the degree of departure of the color from its background color

4. METAMERISM

Because our visual system has three color-channels, LMS, that integrate incident light, there can be many ways to produce a color sensation. Colors that match and are produced using different colorants are metameric. Metamerism is both a boon and bane. It is a boon because we can produce the same color sensation without producing the same physical properties. Imaging systems such as television and photography rely on this property. It is a bane because the color match does not persist when lighting and observers change.

A target was produced using artist acrylic dispersion paints where the samples comprising each metameric pair were made using different pigments (see Figure 7). The paints were mixed to produce matches when viewed by an average observer under 6500K daylight. The lighting was changed to 3000K incandescent and the quality of the matches reduces substantially. Recently, it has become possible to calculate observer response data for observers considered “color-normal” (Heckaman 2013). The observer most dissimilar to the average observer was used to evaluate whether the match quality reduced in similar magnitude to changes in lighting. As seen in Figure 7, changes in observer are just as detrimental as changes in illumination.

Do artists encounter metamerism? When their palette has more than three chromatic colorants plus white, absolutely. Suppose one wants to rework a passage (*pentimento* in Italian) and different colorants are used. A metameric match will result. Using a fixed palette does not mean that metamerism will not occur. Suppose a portrait is made where the subject wants the color of their garment to be matched perfectly. Because the fabric and paint color produces a metameric match, it's possible that the subject will see a mismatch.

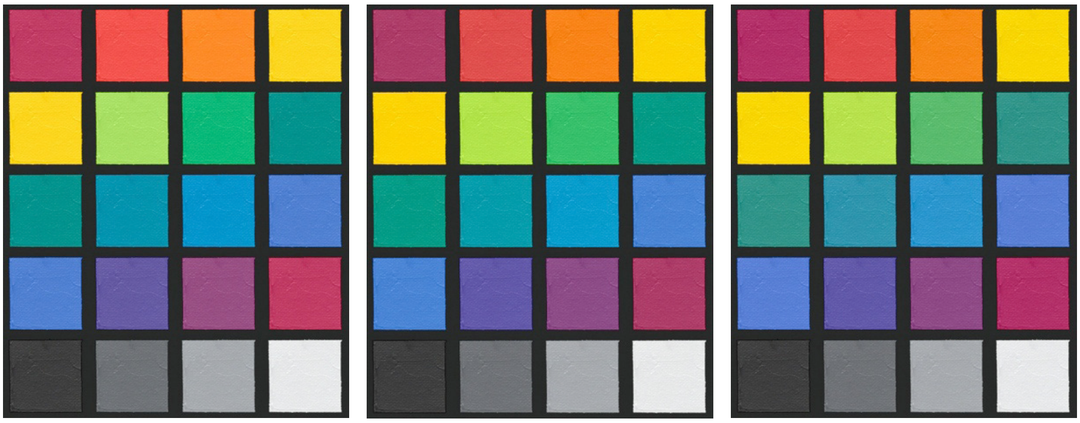


Avg. obs. 3000K *Avg. obs. 6500K* *Dissimilar obs. 6500K*

Figure 7: Metamerism target rendered for an average observer under 6500K daylight, an average observer under 3000K incandescent light, and a dissimilar color-normal observer under 6500K daylight.

5. COLOR INCONSTANCY

Very few colors retain their appearance with changes in lighting or observer, especially when evaluated critically. These colors are color inconstant. The CIELAB target shown in Figure 1 was rendered for the same observers and lighting as used in Figure 7. As shown in Figure 8, these effects are very large. A *plein air* (outdoor) painter may be quite shocked when the painting is displayed in a gallery with tungsten halogen spot lights (or any light with a low correlated color temperture).



Avg. obs. 3000K *Avg. obs. 6500K* *Dissimilar obs. 6500K*

Figure 8: CIELAB target rendered for an average observer under 6500K daylight, an average observer under 3000K incandescent light, and a dissimilar color-normal observer under 6500K daylight.

6. VARNISH EFFECTS

Picture varnishes are often characterized by their ability to “saturate” a painting. A conversation reveals that they are referring to color saturation. As a color scientist, I want to relate this to physical aspects of the painting. In this case, it is a change in surface roughness and the light propagation of the first-surface reflection caused by the refractive index discontinuity between air the the varnished painting. This effect is shown in Figure 9 where three different glosses were simulated by changing the amount of first-surface reflection that reaches the viewer for a tint ladder of dioxizine purple and titanium white acrylic dispersion paints. As gloss increases, the maximum chroma increases and minimum lightness decreases. Using the terminology defined above, depth increases with glossier varnishes.

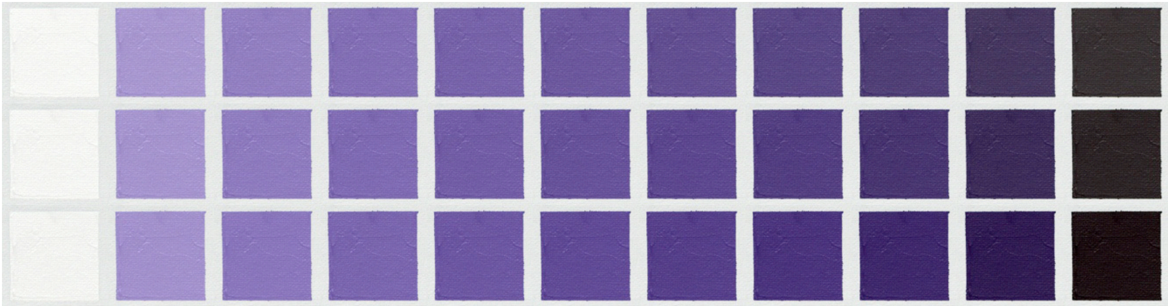


Figure 9: The effect of varnishing tint ladders of dioxizine purple and titanium white using a matte (top), semi-gloss (middle), and gloss (bottom) varnish.

6. CONCLUSIONS

These are just a few examples where color science can help explain why color-related visual effects occur. I have used K-M theory to “produce” these targets and the Saunderson correction to simulate varnishing. Colorimetry was used to color manage these images. CIECAT02 was used to calculate corresponding colors to simulate the effects of lighting on metamerism and color inconstancy. Only through continued conversations with artists will I know if this type of information is useful for artists.

ACKNOWLEDGEMENTS

This paper accompanies the AIC Judd Lecture. I am grateful to the Natural Color System for sponsoring the 2013 Judd Award. The irony is appreciated since my laboratory was established by the Munsell Foundation.

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symposium:
MCS2013

Estimation of Surface Properties for Art Paintings Using a Six-band Scanner

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ABSTRACT

The imaging sytems using cameras to archive art paintings have essential problems like image resolution and lens distortion. A scanner is considered as a precise imaging device, which can acquire images with high resolution and without camera lens distortion. The present paper proposes a method to estimate the surface properties of art paintings for digital archiving using the six-band scanner. The surface properties include surface-spectral reflectance, surface height, and reflection model parameters. The performance of the proposed method is compared with the previous studies that used the multiband camera system. The current method has not only found to be as precise as the multiband imaging method in estimation accuracy, but also accompanied with several additional advantages.

1. INTRODUCTION

The traditional techniques of image capture to archive art paintings used camera systems for acquiring surface properties of the paintings (Shumitt et al. 2005, Tominaga et al. 2008). However, camera systems have the following essential problems: (1) resolution is not enough, (2) there is a lens distortion, (3) imaging system is complicated, and (4) the cost is expensive. A scanner is considered as a precise imaging device for document and objects with flat surface. The device can acquire images with high resolution and without camera lens distortion. However, traditional three color scanners could suffer from color reproduction errors due to the significant mismatch between their spectral sensitivities and those of the human visual systems. Recently, a scanner was developed for capturing additional color channels to reduce the color reproduction errors (Hunter et al. 2008). The novel scanner captures six color channels in total from two separate scans using two different fluorescent lamps. In a previous work, fundamental properties of the six-band scanner were verified, and the effectiveness for estimating the spectral reflectance function of an object surface was shown (Tominaga et al. 2009). This paper proposed a method to estimate the surface properties of art paintings for digital archiving using the six-band scanner as a multiband spectral imaging system. In our study, the surface properties include surface-spectral reflectance, surface height, and reflection model parameters.

2. IMAGING SYSTEM

Figure 1 draws a schematic diagram of the six-color scanner. An object on the scanning plane is illuminated by light bulbs L1 and L2 with two different spectral properties from two directions. The scanner system uses a single three color CCD and two different cold cathode fluorescent lamps for two scans. The scanner outputs are quantized in 16 bits and normalized with a white reference at every scan. We investigated the linearity of the responses for reflecting objects. The Munsell Neutral Value Scale was used as a set of gray scale samples. We confirmed that a good linear relationship is obtained in both scans. We investigated the resolution of the present scanner system by using an ISO12233 resolution chart. The scanner had a high resolution of 4905 LW/PH (Line Width per Picture Height), while the camera system in our lab had a lower resolution of 2721 LW/PH. We also considered the lens distortion. Although there is no distortion in the scanner, the camera system had a distortion of 19.85 pixels as a mean value.

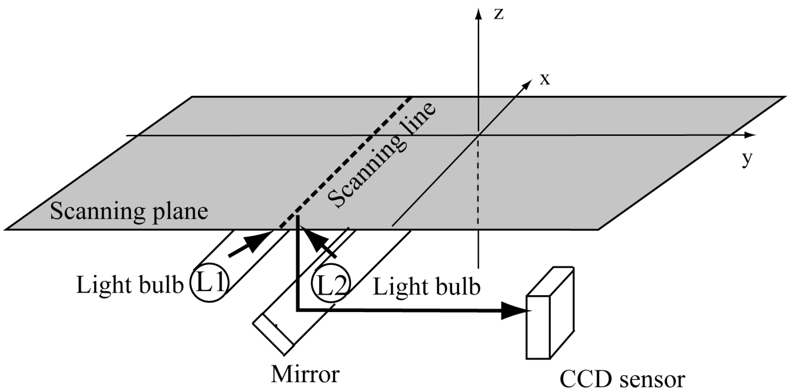


Figure 1: Schematic diagram of the scanner used in this study.

3. ESTIMATION ALGORITHMS OF SURFACE PROPERTIES

3.1 Spectral Reflectance Estimation

The surface spectral reflectance is estimated from 6-band image data captured by using our imaging system. Let $S(\lambda)$, $E(\lambda)$, $R_i(\lambda)$ and be the surface spectral reflectance, the illuminant, and the spectral sensitivity of the i-th sensor. Assume that each spectral function is sampled at 61 points with an equal interval $\Delta\lambda$ (5 nm) in the region [400nm, 700nm]. Let **S** be a 61-dimensional column vector representing $S(\lambda)$, **H** be a 6 × 61 matrix with the element $h_i = E(\lambda_i)R_i(\lambda_i)\Delta\lambda$, ρ be a 6D column vector representing the sensor outputs, and **n** be a 6D noise column vector. Then we have a matrix equation.

$$\rho = \mathbf{Hs} + \mathbf{n} \tag{1}$$

When the signal component **S** and the noise component **n** are uncorrelated, an optimal solution is given by using the Wiener estimator:

$$\mathbf{S} = \mathbf{C}_{SS}[\mathbf{HC}_{SS}\mathbf{H}^T + \sigma^2\mathbf{I}]^{-1}\rho, \tag{2}$$

where σ^2 is the noise variance, **I** is a 61×61 unit matrix, and C_{SS} is an 61×61 covariance matrix. To determine C_{SS}, we used a spectral reflectance database for different paints.

3.2 Estimation of Surface Normal

To reconstruct surface shape, the surface normal vector is estimated using a photometric stereo method. The painting surface is observed at the eight illumination directions by rotating the paintings on the scanning plane. Let $I = [I_1, I_2, \ldots, I_8]$ be a 1×8 matrix of the observed radiance values at pixel point. We have the observation relationship $\mathbf{I} = \alpha\mathbf{N}^T\mathbf{L}$, where **N** is a normal vector and **L** is a 3 × 9 matrix of illumination directional vectors. An estimate $\hat{\mathbf{N}}$ of the surface normal is obtained as a LS solution $\hat{\mathbf{N}} = \mathbf{L}^{+T}\mathbf{I}^T/\alpha$.

3.3 Rendering Model

Many models have been developed for light reflection, and the validity and application of these models to real objects have been discussed in the computer graphics and computer vision communities. In this study, we use the Torrance-Sparrow model (Torrance et al. 1967) as a basis for describing light reflection of oil paintings and extracting reflection parameters from the measured spectral reflection data.

4. EXPERIMENTS

Figure 2 shows an oil painting called "River" in our painting collection. First, we estimated the surface spectral reflectances and calculated the root mean square errors between estimation results and measurements by spectrometer among 20 areas indicated in Fig. 2. The averaged errors for the scanner and the camera were 0.0275 and 0.0284, respectively. Figure 3(a) shows the estimation results of surface spectral reflectances for area 2 as an example. The estimated spectrum is depicted in red curves, which contrast with the black curve of the spectroradiometer measurements. We also estimated the surface normals in Fig. 2. Figure 3(b) shows the surface reconstruction results. The estimated surface-shape is depicted in red mesh, which contrasts with black mesh of the laser-scanning measurements. The averaged errors of estimated surface normal for the scanner and the camera were 9.77° and 9.25°, respectively. The averaged 3D shape difference for the scanner and the camera were 164.6 µm and 175.9 µm, respectively.

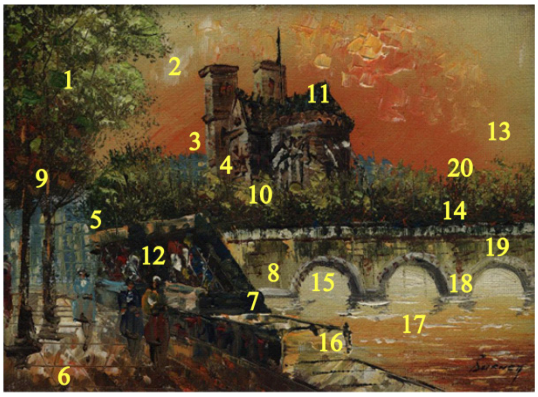
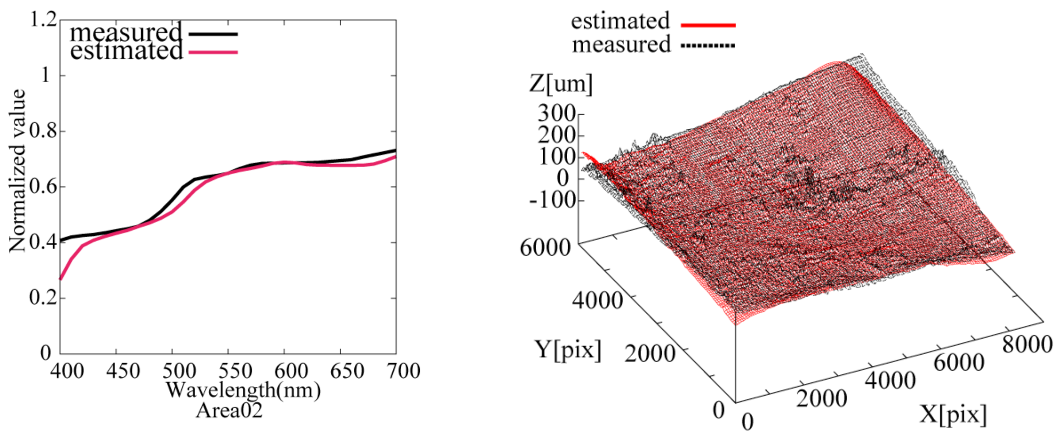


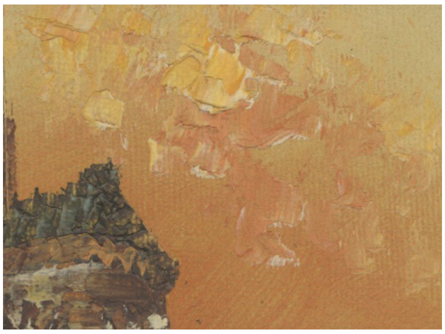
Figure 2: Test sample "River" of oil painting.



(a) Spectral reflectances *(b) Surface reconstruction*

Figure 3: Test sample "River" of oil painting.

Realistic color images of "River" were rendered based on the estimated surface properties by the present scanner sytstem. Figure 4 shows close-up images of rendered images by the six-band scanner and high-resolution camera. Note that the resolution is significantly improved by using the scanner.



(a) Six-band scanner system

(b) Camera system

Figure 4: Close-up of rendered images for the oil painting "River".

5. CONCLUSIONS

This paper has estimated the physical properties of the surface of the oil painting by using a six-band scanner. The performance of the proposed method was compared with the previous studies that used the multiband imaging method by digital cameras. The current proposed method had not only found to be as precise as the multiband imaging method in estimation accuracy, but also accompanied with four additional advantages: (1) high resolution is obtained, (2) no worries of lens distortion, (3) imaging system is compact, and (4) the cost is lower compared to the multiband imaging method.

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Behind the Surface – Hyperspectral Image Spectroscopy for Artist Authentication

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ABSTRACT

The identification of authorship of an important Portuguese artist, Amadeo de Souza-Cardoso (1887-1918), by image processing techniques based both on spectral UV-VIS data and elemental analysis will be presented. Despite his youth, Amadeo was internationally acclaimed, and very successful at the most important International exhibitions, side by side with Brancusi, Cézanne, Delaunay, Gauguin, Matisse, Picasso, van Gogh, and others. Since he was rediscovered, at the end of the fifties, the value of his works increased and forgeries appeared in the art market. Here we develop hyperspectral image processing algorithms for pigment characterization and mapping, which combines molecular information (reflectance UV-VIS spectral data) with the identification of the chemical elements present. The data was obtained by hyperspectral imaging and X-ray Fluorescence spectrometry (EDXRF). Finally, we combine molecular information with computer based image processing to explore its potentiality as a routine tool in authentication studies of Amadeo's work.

1. INTRODUCTION

This research is carried out in the framewrok of ‹*Crossing Borders*. History, materials and techniques of Portuguese painters from 1850-1918›, an ongoing project that focus on the artistic practices of Portuguese masters. It aims to promote collaboration between science and art; specifically, conservation, computer science and art history.

In 2008, the edition of the Catalogue Raisonné of Amadeo de Souza-Cardoso, coordinated by Helena de Freitas (de Freitas, 2008), besides contributing to the recognition of the importance of Amadeo in the European history of art, created the opportunity to study the authorship of a nucleus of ambiguous paintings. Surprisingly, the art historians' "eye" and what discovered at the molecular level were usually in agreement. This motivated us to start the work discussed here.

In the first part of this work, an algorithm to detect the brushstroke patterns was developed. This algorithm, based on digital image processing, provided positive results to solve attribuition problem (Montagner, 2012). To be able to offer a more robust method for paintings authentification, we considered that in a second part, molecular data should be processed and integrated. Here we will be presenting our strategy to select and procees it. The molecular information was acquired using hyperspectral imaging combined with elemental information obtained by μ-Energy Dispersive X-ray Fluorescence.

Fiber Optic Reflectance Spectroscopy (FORS) in the ultraviolet, visible and infrared range is primarily used to identify pigments and dyes, evaluate colour and colour changes, and to detect alteration in products (Bacci, 2003). The development of hyperspectral cameras allowed extending this analysis to the overall painting surface, i.e., the mapping of the surface. To obtain reliable results with these techniques, comprehensive reference databases are required. It is also important to take into account that there are numerous historical colorants that are no longer available (Oltrogge, 2008). More recently, the use of chemometrics methods and remote sensing software for analysing hyperspectral image has proven efficient to decompose the spectra into mutually independent end members. A weakness of these strategies is that such end members do not necessarily have any physical meaning (Liang, 2012).

2. METHOD

The system here proposed identifies single pigments or mixtures present in the paintings, by comparing them with a database of paint tube samples used by Amadeo. The data for the paintings and the paint samples was acquired with a hyperspectral system, using a fast-tunable liquid-crystal and a low-noise Peltier-cooled digital camera (Hamamatsu, model C4742-95-12ER). The data was acquired in range of 400 nm to 720 nm, with a spectral resolution of 10 nm. This spectroscopic information was complemented with elemental analysis performed by μ-Energy Dispersive X-ray Fluorescence, an in-situ technique used for the identification of elements with atomic number higher than sodium.

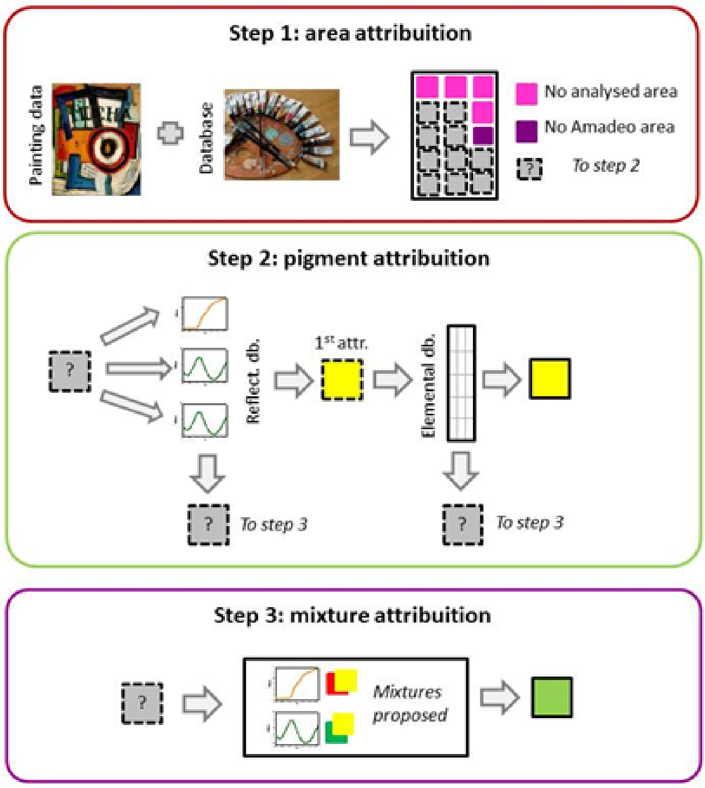

Figure 1: Scheme of the classification system.

The attribution of the colourants present is performed comparing each reflectance spectra of the painting hyperspectral image with the spectra of the paint tube database. The comparison is performed using Spectral Angle Mapper (SAM) and Euclidian Minimum Distance (EMD). Further information on the algorithm will be presented in a forthcoming paper (Almeida, 2013). The characterization of the pigments present in the paintings is made in three consecutive steps (Figure 1). In the first one, are detected the areas of the painting created with materials that are not present in Amadeo's molecular palette (labeled as No Amadeo area) and the areas where elemental analysis was not performed (labeled No Analysed area). This selection avoids performing the classification with incomplete analytical data. The second and the third step identify, respectively, the pigments or mixture of pigments present in the painting.

3. RESULTS AND DISCUSSION

UV-Vis spectral data was selected as the spectroscopic technique able to provide us information at the molecular level because it enable us to select features that can be straightforwardly related to the painting surface and, at the same time, it enables a fast and reliable data acquisition. The colour information, extracted by the hyperspectral camera, offered both good quality spectral data and spatial distribution. The elemental analysis was used as complementary information and it turned out to be valuable in overcoming some of the limitations of reflectance spectroscopy.

Here we discuss the results obtained by the analysis of two paintings: an original, *Mucha* (1915) (Figure 2a) and a "fake" prepared by the students of the Department of Conservation and Restoration (Figure 2c). The system produces two outputs: numerical and visual. The numerical output reports the percentage of the different areas identified on the painting. As already described, the areas considered are: *No Amadeo* (depicted with pink), *No analysed* (depicted with grey), and finally the areas with pigment or mixture belonging to Amadeo's palette (depicted with the reconstructed colours).

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

Figure 2: Mucha painting (a) original image; (b) visual output; DCR painting (c) original image (d) visual output. No Amadeo (pink), No analysed (grey), Amadeo (all other colours).

The visual output is a simple and efficient way to evaluate the results obtained by the system and it is accessible for people with different background. The *No Amadeo* and *No analysed* areas are depicted always with a pre-defined colour, pink and grey, respectively. The others areas are represented with RGB values computed from the reflectance spectrum proposed by the system as possible material (see Figure 2 b and d). The user can choose to visualise all the areas together or analyse the distribution of a specific pigment or mixture.

4. CONCLUSIONS

The proposed system performs the characterization of the pigments present in the painting and identifies the area painted with colour ants that belong to Amadeo's molecular palette. Accessing this information is crucial in the detection of forgeries; the work is in progress to combine it with the brushstroke analysis, and also with computer-based techniques, to build a robust system to solve problems of attribution and authenticity.

The use of hyperspectral camera allowed extracting colour information from the painting surface and at the same time to characterize the pigments present. The colorimetric values were used to extend the elemental information over the whole surface of the painting. The elemental information complements the spectroscopic analysis and was successful used to confirm the attribution performed.

ACKNOWLEDGEMENTS

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Development of a Low-resolution Spectral Imager and Its Application to Hybrid-resolution Spectral Imaging

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ABSTRACT

We developed a low-spatial-resolution spectral sensor (LRSS) which realized real-time capture of 68-pixel spectral images. In addition, as an application of the LRSS, a prototype of hybrid-resolution spectral imaging system was developed by combining with a high-resolution RGB camera. In this prototype, high-resolution RGB images are combined with the data acquired by the LRSS to generate high-resolution spectral image data. Through the experiment to capture spectral images of a color chart and flowers, it was confirmed that spectral images can be accurately acquired by the developed prototype system.

1. INTRODUCTION

Spectral image acquisition requires specialized hardware, and usually includes spectral or spatial data scanning. In order to simplify hardwares and to realize one-shot spectral data acquisition, we have been proposed a hybrid-resolution spectral imaging method (Murakami et al. 2009). In this method, a high-spatial-resolution RGB image and a low-spatial-resolution spectral image are captured, and they are combined to generate a high-spatial-resolution spectral image. Similar approaches have been proposed by another research groups (Imai 1998 and Kawakami 2011). However, there is no commercialized low-spatial-resolution spectral imager. In this paper, we report a newly developed low-spatial-resolution spectral imager called LRSS, and a prototype of hybrid-resolution spectral imaging system using the LRSS.

2. SYSTEMS

2.1 Low-resolution spectral sensor (LRSS)

LRSS was built up by connecting the following components straightly in light-travelling direction: camera lens, two-dimensional to one-dimensional optical fiber array, ImSpector (a direct sight imaging spectrograph; Specim), and monochrome CCD camera (Figure 1). The configruation of the LRSS was basically same as a previously reported device for microscopes (Matsuoka 2002). The optical fiber array consists of 68 fibers; hence single-frame image of CCD output includes the spectral data of 68 positions of a scene.

In order to obtain spectral data from the CCD output of the LRSS, we have to know (i) the relationship between the vertical pixel position and the wavelength of spectra and (ii) the spectral sensitivity function of each fiber. The relationship of (i) was represented by a quadratic function considering the barrel distortion of the ImSpector; the parameters were determined for each fiber using tweleve emition lines of a fluorescent lamp. The spectral sensitivity of (ii) was determined by comparing the measurement data of a tangsten lamp with a commercailized spectrophotometer (Topcon SR-3), where the relative spectral functions of the all fibers were supposed to be identical. The sensitivity ratio among the 68 fibers were measured by using a spatially uniform illumination.

The measurement accuracy of the LRSS after calibration was examined. The three kinds of lamps, fluorescent, LED, and SOLAX (artificial sun light), were measured and compared with the spectra measured by SR-3 (Fig. 2). The normalized root mean squared error (NRMSE) is 16.1%, 1.4%, and 2.8% for fluorescent, LED, and SOLAX lamps respectively. The NRMSE of the fluorescent lamp is relatively large because of the difference in the bandwidth of the two systems. From these results, we confirmed that the LRSS was able to measure spectra with a small percentage of NRMSE.

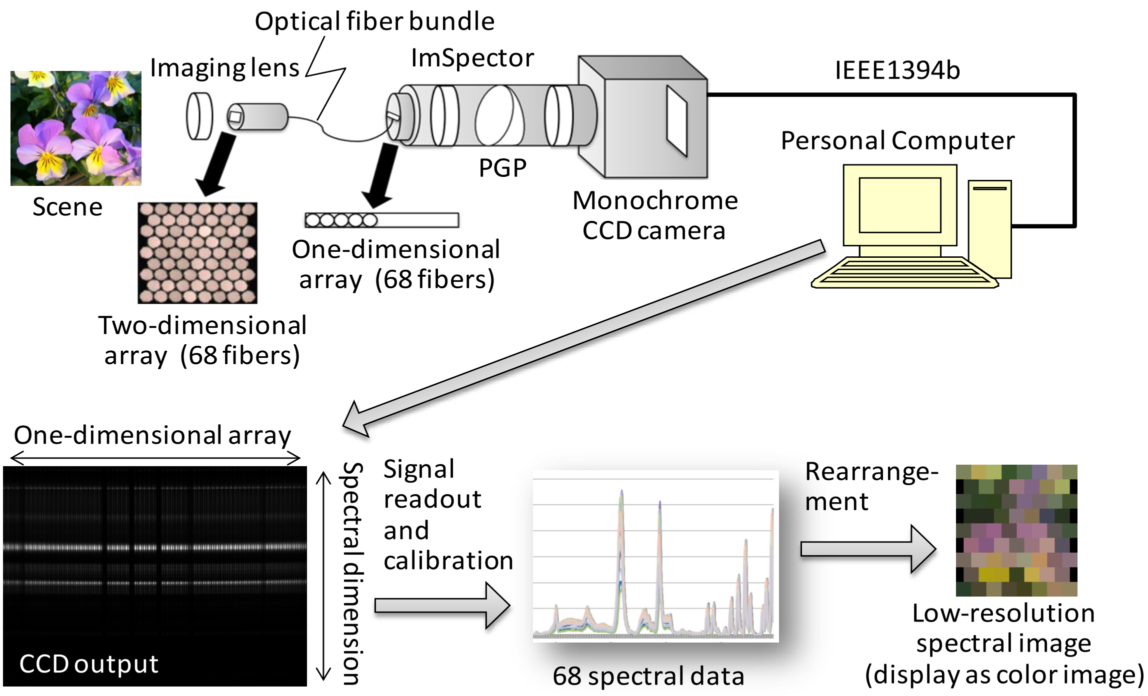

Figure 1: Schematic diagram of low-resolution spectral sensor.

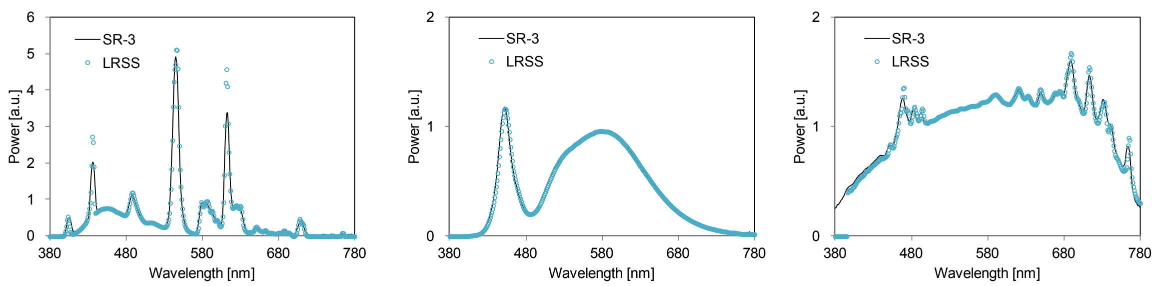

Figure 2: Comparison of spectra of fluorescent (left), LED (middle), and SOLAX (right) lamps measured by LRSS after calibration process and by commercialized spectrophotometer SR-3.

2.2 Hybrid-resolution spectral imaging system using LRSS

Hybrid-resolution spectral imaging was proposed as a method to obtain high-spatial-resoluation spectral image data by combining the two measurement data with different spatial and spectral resolutions. Several algorithms have been proposed for combining two measurements.

A hybrid resolution spectral imaging system was constructed using a color CCD camera and the LRSS. The color camera and the LRSS are arranged side-by-side to able to shoot the same scene. They are connected to a PC through IEEE 1394b, which enables to transfer data to the PC in scynchronization. Spectral images are reconstructed per frame, and the results are stored/displayed as a movie of selected-wavelength image, spectrum-based-reproduced color image, etc. The spectral image reconstruction can be performed by Wiener or piecewise Wiener estimation methods (Murakami 2008 and Murakami 2009), both of them requires no serious registration between two measurements and only small amount of computation.

3. EXPERIMENTS AND RESULTS

A color chart and flowers were captured by the developed hybrid resolution spectral imaging system, and the color images were reproduced from the acquired spectral image data. In the experiment, two color patches of the color chart were captured in a frame, and the images for two different color combinations (green & yellow, blue & red) were obtained. The flowers consitsted of a red rose and yellow carnations. The subjects were illuminated by SOLAX lamp. The measurement data by the color camera and the LRSS are shown in Figure 3. The spectral reconstruction was performed by Wiener estimation method for color chart, and by piecewise Wiener estimation method for flowers.

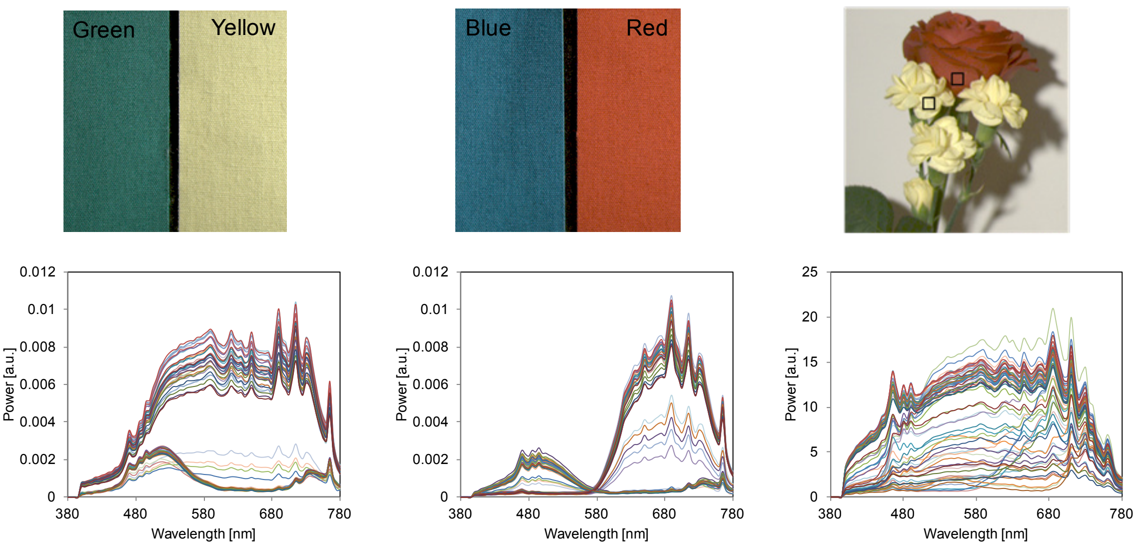

Figure 3: Measurement data by RGB camera (top) and by LRSS (bottom) for green & yellow (left), blue & red (right) color patches of color chart and flowers (right). The two rectangles in flower image indicate the areas for accuracy evaluation.

The accuracy was examined for four color patches of the color chart and the two areas of flowers, by compared with the measurements by SR-3. NRMSE of the spectra and the difference in CIELAB space were calculated, where the power of the estimated spectra were adjusted to coincide with the power of the SR-3 measurements to remove the error caused by the arrangement error of the instruments. For comparison, accuracy of the reconstruction only from the RGB image was calculated. In this case, the spectra were estimated by Wiener estimation method, where the spectral correlation matrix was generated based on a Markov model. The results are shown in Table 1. It was confirmed that the proposed hybrid-resolution spectral imaging system ('RGB camera + LRSS') realized less than 10% NRMSE, except for dark blue color, and around or less than 10 CIELAB error.

Table 1: Experimental results.

		NRMSE of spectra [%]		CIELAB error	
		RGB camera only	RGB camera + LRSS	RGB camera only	RGB camera + LRSS
Color chart	Green	61.4	9.8	18.16	6.63
	Yellow	9.8	3.8	2.49	0.67
	Blue	42.8	13.6	17.69	10.38
	Red	15.1	4.1		
Flowers	Rose	33.7	7.9	21.96	1.62
	Carnations	10.2	7.5	7.31	10.11

4. CONCLUSIONS

Measurements of the three kinds of illumination spectra showed that the accuracy of the developed LRSS was a small percentage of NRMSE by means of the calibration process. In addition, the hybrid-resolution spectral imaging system using the LRSS realized real-time spectral image acquisition with high accuracy.

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Material Sensing based on Spectral Decomposition

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ABSTRACT

This paper shows a method for material sensing based on spectral signatures calculated using components related to sensor channels and the residual components not contributing to the sensor channels. The method was tested on a set of representative spectral reflectances, and it was shown that the proposed method has a better performance in material discrimination compared to a spectral signature dervied from the measured spectral information without decomposition, especially for man-made objects, since it removes the color component.

1. INTRODUCTION

Human beings, as well as digital imaging systems mimicking human vision, capture trichromatic signals that can be represented by device-dependent encoding. Trichromatic representation has been used to successfully reproduce the appearance of objects, but in order to accurately discriminate and classify materials regardless of the sensing and illumination nature, we need to consider physical parameters, such as spectral properties of the material.

The advent of imaging devices with spectral discrimination capabilities has enabled spatial non-contact, non-destructive spectral-image analysis. However, spectral imaging generates large amounts of data, and it might not be effective for man-made material discrimination. Especially in this case there is a need to decouple the material component responsible for color from its residual achromatic component. The use of both trichromatic and some form of spectral component has been used in the past to optimize spectral encoding to minimize visual color difference, as shown by Keusen and Praefcke. One way to implement this decomposition is by using ***[R]*** matrix decomposition of the spectra, proposed by J. Cohen based on a hypothesis by G. Wyszecki, separating the fundamental visual component and the metameric black. The ***[R]*** matrix decomposition has been used as a method to capture high-spatial resolution multi-spectral images for archiving purposes, and it is suitable for material classification applications as well. Moreover, considering that surface reflectances fall within a linear model composed of band-limited functions with a small number of parameters, as elaborated by Maloney, it is possible to decompose the spectral component(s) into a small number of components without losing the capability to reconstruct the original spectra.

This work proposes a generalization of the concept of fundamental and metameric black proposed by Wyszecki and formulated by Cohen to a general sensing device not restricted to human vision. This work also presents a proposal of using residual components as spectral signatures. The next section shows the method, followed by results and discussion, before closing with a conclusion.

2. METHOD

The process of sensing can be mathematically described as a projection of reflectances in the sensing representation space. The sensing is a projection $[\boldsymbol{T}]$ that is calculated as $\boldsymbol{W}*(\boldsymbol{W}'*\boldsymbol{W})^{-1}*\boldsymbol{W}'$, where $\boldsymbol{W}$ is an m by c matrix of weights calculated as a term-by-term product between the normalized spectral power distribution of a selected illuminant and the spectral sensitivities, where ***W'*** denotes the transpose matrix of ***W***, and where the superscript $^{-1}$ denotes an inverse matrix. The detection component of captured channels is given by ***D*** = [***T***]****Ref***. The result ***D*** carries all information captured by an image acquisition system under a specific illumination. The residual ***Res*** carries no information for sensing. The residual ***Res*** can be correlated to the spectral curve shape of different materials not captured by the sensor and can be calculated as ***Res*** = (***Id***-[***T***])****Ref***, where ***Id*** is an *m* by *m* identify matrix. The Wyszecki fundamental component is a special case of detection component for human vision, and the metameric black is a special case of the residual component when the fundamental component is employed. The residual component could be further decomposed in basis functions: ***Res*** = ***Ar*******Er***, where ***Ar*** is the coefficients of basis functions ***Er*** for the residual component. The coefficients ***Ar*** give the material signature. An a priori table of material signatures could be created based on representative materials, and the correlation between the individual or joint signatures of a testing material could be used to estimate a probability value for each material. A schematic diagram of material identification from spectral images is shown in Figure 1.

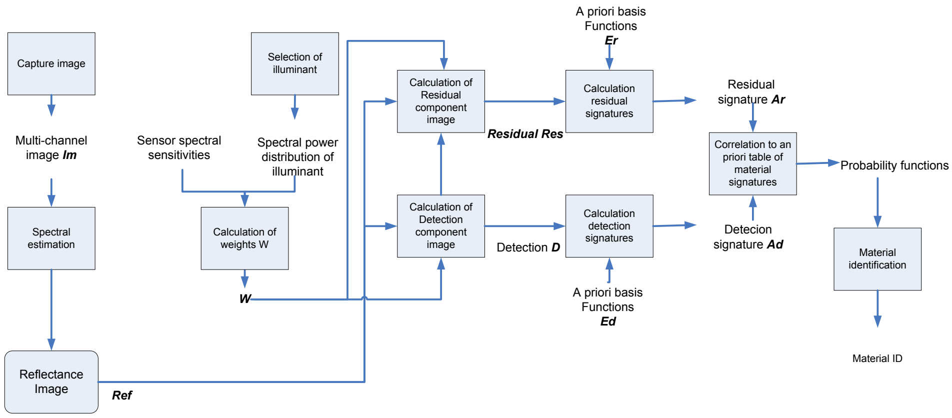

Figure 1: Flowchart illustrating the material sensing method.

In the experiments described in this paper, we compare the performance of using measured spectra (spectral correlation) and the newly proposed method (metameric black correlation).

2.1 Spectral reflectance samples

A database of 192 spectral reflectance samples comprising natural and artificial objects was used in the experiments. All samples had measurements in visible and near-infra-red spectrum, from 400 to 1000 nm in intervals of 10 nm, as shown in Figure 2.

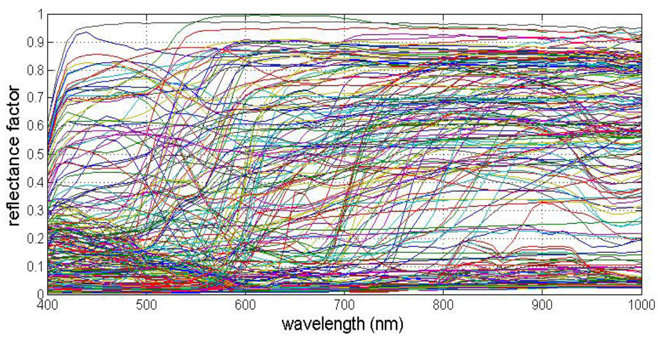

Figure 2: Spectral reflectances of 192 measured objects.

2.2 Influence of number of basis functions on material discrimination performance

It is possible to analyze the overall performance of the methods for a certain dataset by calculating the averaged correlation. In order to improve material discrimination it is desirable to decrease cross-correlation between samples. Figure 3 shows the influence of the number of channels (or basis functions, since same number of channels and basis functions were used) on average correlation. It is possible to notice that no significant improvement occurs using more than 6 basis functions, and the proposed method improves performance compared to the traditional method of comparing spectral curves.

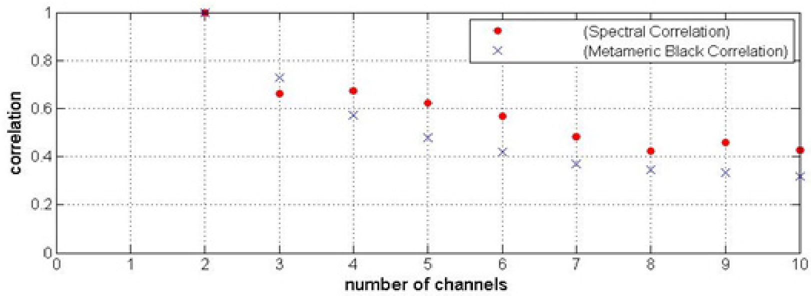

Figure 3: Average correlations of spectral correlation and metameric black spectral component correlation as a function of the number of channels for all 192 samples.

2.3 Material discrimination performance metric

A probability function is calculated using a very simple equation for correlation: $P = (C+1)/2$, where C is the Pearson correlation (covariance of the samples divided by the product of the standard deviations for each sample). The rationale for the decision to use correlation is based on the fact that for material property discrimination it is important to compare the overall similarity in shapes between two spectral reflectances, and that can be accomplished better by using correlation rather than a spectral curve similarity metric, such as spectral root-mean-square error. A threshold of correlation of 0.6 was used as a minimum acceptable to discriminate materials.

3. RESULTS

Table 1 shows the comparison between proposed and traditional approaches, and the success rates were improved with the new method, especially for man-made materials.

Table 1. Material discrimination success rate (with correlation parameter 0.6) for both overall spectral correlation and residual component correlation using 6 channels.

Material	Success rate for overall spectral correlation (%)	Succes rate for residual correlation (%)		Material	Success rate for overall spectral correlation (%)	Succes rate for residual correlation (%)
Banana	63	67		Leather	47	65
Carrot	51	64		Green cotton shirt	55	63
Pink Rose	46	63		White paper	58	65
Human Skin	63	63		Asphalt	53	68
Ivy Leaf	53	68		White marble	62	67
Pine Wood	62	63		Pink plastic	47	65
Ham	46	47		Wild violet paint	44	67

4. CONCLUSIONS

The current work shows that decomposing spectra into detection and residual components and using coefficient of eigenvectors of the residuals as spectral signatures have potential to improve material discrimination. However, more experiments have to be performed, and other material properties beyond spectra also must be considered, for a more global solution.

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Design of a Multispectral System based on Transverse Field Detectors

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ABSTRACT

Transverse Field Detector (TFD) sensors are tunable, full spatial resolution, color sensors, currently still under development (Langfelder 2009). One of their main advantages over common imaging systems is that their spectral sensitivities can be modulated by applied voltage and also that they can achieve full spatial resolution by exploiting the wavelength-dependency of the penetration depth of photons in silicon (Langfelder 2012). Some previous works have studied their properties, functionality, and some limitations arising when they are used as part of a multispectral imaging system (Langfelder 2011). This work aims to improve TFD performance beyond its initial 'raw' capabilities by narrowing down their spectral sensitivities with additional color filters added to the sensor matrix, and so achieving better quality of estimated spectra trading off full spatial resolution to some extent. Results show that decreasing spatial resolution by 1/6 using a Color Filter Array (Murakami 2012) (CFA) with 6 different transmittances and tuning alternate pixels to two different biasing conditions, we can get 18 channels in one shot, significantly outperforming existing traditional imaging capture devices both spectrally and colorimetrically.

1. INTRODUCTION

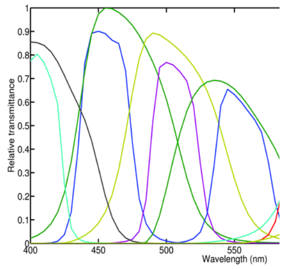
In previous work (Martínez 2012), TFD sensors were already proposed as part of multi-shot multispectral imaging systems. Additional channels were obtained via a tuning procedure. Previous results have shown that their spectrally broad sensitivities have a negative influence in the quality of the estimated spectral reflectances from TFD sensor responses. In this work we have studied whether including some band-pass color filters as part of a CFA-TFD system could increase the device performance, making the loss of spatial resolution be worthy. We have demonstrated that, unlike in the previous works, now including the CFA in the TFD-based system, it can outperform a scientific RGB camera with a double shot configuration using a cut-off filter. Since TFDs are still only a prototype, simulations were done to get the noisy sensor responses of all compared systems. With these sensor responses, a kernel-based regression method was applied to recover the spectral reflectances of 1700 color samples belonging to the NCS color atlas. The assessment of the performance of each system was done by calculating ΔE00 color difference, RMSE and GFC metrics. In Section 2 we explain the methods used in the simulations and calculus of results. In Section 3 we show the results and discuss about them, and finally in section 4 we deduce some conclusions.

2. METHOD

This section is divided in three subsections. First we explain how we selected the filters and the biasing conditions of the TFD out of all the available ones to do the simulations. Secondly we describe the simulation of the noisy sensor's responses, and finally we explain the spectral estimation procedure.

2.1 Channel selection

In this work we define channel as the combination of one sensor sensitivity and a filter transmittance. We selected a set of 13 band-pass color filters covering the visible spectrum and with some overlapping between them, out of a database of real existing filters that belongs to Andover Corp. USA. (Andover). We can see in figure 1(a) the 13 normalized transmittances of these filters, and in figure 1(b) the relative responsivities of 8 different biasing voltage conditions provided by TFD developers (Langfelder 2012).



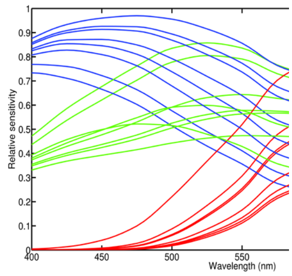


Figure 1: a (left) 13 candidate filter transmittances. b (right) 24 TFD sensitivities.

Combining the 13 transmittances and the 24 sensitivities we get a total of 312 channels. Our aim is to find the optimal combination of them using only a maximum of 2 different biasing conditions, since TFD does not allow for more than 2 different biasing voltages applied in single shot configurations. Increasing the number of shots on the other hand would increase the capturing time, complicating the real time capture applications. Then we apply the voting PFA method explained in (Lu 2007) and (Chatzis 2007) and chose the 6 channels corresponding to the two most voted biasing conditions. Therefore tuning half of the total pixels with each biasing condition, and taking into account that we have selected 6 filters to be placed in front of 3 sensitivities each, we get up to 18 channels in just one shot. The other compared systems were: 2-shots and 8-shots TFD configurations without any color filter (6 and 24 channels respectively with full resolution), a 2-shots system composed by scientific RGB camera (model Retiga 1300) using an IR-UV-cut-off filter (one shot with the filter in front and one without it, yielding 6 channels and 1/3 resolution), and a common monochrome silicon sensor with the CFA placed in front of it (one shot, 6 channels and 1/6 resolution).

2.2 Sensor's responses simulation

Since there is still no imaging system that includes the prototype TFD sensor in it, we have computed the sensor responses including additive noise. We assumed standard D65 illumination, then we calculated the photocurrent and checked for saturation in order to set an optimal integration time for the 1700 NCS samples. Finally we add the thermal noise, dark current noise and quantization noise. This approach was used in the simulation of all systems examined in this study.

2.3 Spectral reflectance recovery

As shown in (Martínez 2012), a suitable candidate algorithm for spectral estimation from TFD sensor responses is kernel-based regularized regression. In this work we used an inhomogeneous polynomial kernel (Heikkinen 2007). We assessed the performance of the different systems by a 10-fold cross validation method. We divided the data set of samples in ten parts of equal size. Then in each iteration we separated one of these parts for evaluation and optimized the kernel parameters with the remaining 9 parts. The optimization was also done using 10-fold cross validation. For each optimization iteration we calculated the ΔE00 error surface for the parameter grid range (for imaging systems colorimetric accuracy is very important), and found its minimum to get the kernel parameters (polynomial degree σ and regularization term λ). See Figure 2.

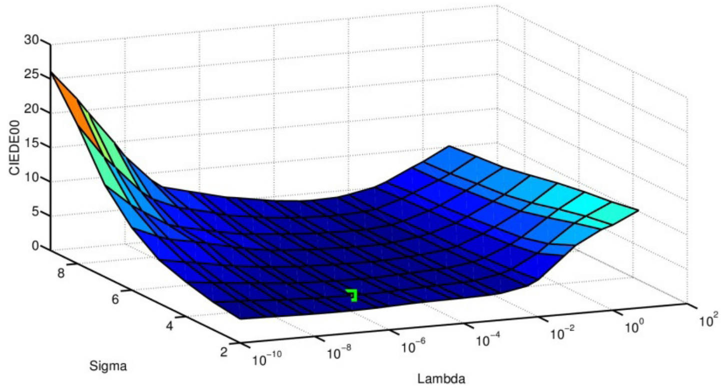


Figure 2: Error surface for an optimization iteration and its minimum found (green dot).

3. RESULTS AND DISCUSSION

In Table 1 we can see the summary of the results for the experiment. Configuration 1 combines half sensor polarized in one way and other half differently with the CFA. Takes one shot and uses all 3 channels under each filter of the CFA. Configurations 2 and 3 use 2 and 8 shots respectively, with the whole sensor polarized differently for each shot. Configuration 4 uses two shots of an RGB camera, one of them placing a IR-UV-cut-off filter in front of it (proposed in (Martínez 2012)). Configuration 5 uses a normal monochrome silicon sensor together with the same CFA used in configuration 1.

Table 1. Summary of the results from the experiment.

Config #	System	# shots	# channels	Resolution	ΔE00	RMSE	GFC
1	*TFD + CFA*	1	18	1/6	0.336	0.009	0.999
2	*TFD double shot*	2	6	1	3.149	0.017	0.998
3	*TFD multi shot*	8	24	1	1.892	0.014	0.998
4	*RGB + Cut-off*	2	6	1/3	0.662	0.010	0.999
5	*Monochrome + CFA*	1	6	1/6	2.870	0.032	0.993

As we can see, the best colorimetric and spectral results are found for the first configuration. Adding the CFA we are reducing the spatial resolution in 1/6, but the 18 narrow channels we get improved color metric results in 89.3% compared with a full resolution system that takes 2 shots (conf. 2) and 82.2% from a system that takes 8 shots (conf. 3), increasing significantly the exposure time required for a capture. We also see how configuration 1 outperforms the effect of the CFA itself together with a silicon monochrome sensor in a 88.3% (conf. 5). The closest result we could achieve was using the RGB camera with the cut-off filter (conf. 4). We would need to take 2 shots and the spatial resolution would still be 1/3, and also the TFD+CFA would be better by a factor of almost 2 in colorimetric quality. Regarding spectral metrics, the GFC is also best for first configuration (together with the fourth one), and the RMSE improves a minimum of 10% respect to the fourth configuration and a maximum of 72.9% respect to the fifth one.

4. CONCLUSIONS

We have proposed a new CFA-based configuration which improves the colorimetric and spectral performance of TFD multispectral imaging systems, outperforming previous full spatial resolution TFD-based approaches and also other common systems like RGB cameras or monochrome sensors with CFAs. The improvement was achieved by trading off spatial resolution down to 1/6 compared to full spatial resolution systems (1/2 compared with common RGB systems). The new approach will provide an elegant single-sensor, one-shot, 18-channels, portable size multispectral imaging system.

ACKNOWLEDGEMENTS

This work has been done under the framework of Erasmus Mundus master CIMET. It has been possible thanks to University of Granada, Polytechnic University of Milan and University of Eastern Finland. This work was supported by the Ministry of Economy and Competitiveness, Spain, under research grant DPI2011-23202.

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Chromatic Maps of Portuguese Roman Mosaics Obtained by Hyperspectral Imaging

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ABSTRACT

Chromatic characterization of Roman mosaics is typically done by observation and comparison against a color chart or by measuring locally with a colorimeter. With these methods, however, the complexity of the chromatic pattern is partially lost. This limitation can be overcome by using spectral imaging, by recording both the spectral and spatial data over an extended area. Two sets of samples of Portuguese Roman mosaics were digitalized by hyperspectral imaging over the range of 400-720 nm at 10 nm intervals and the spectral reflectance estimated. The color of each pixel was computed from the spectral reflectance assuming the CIE Illuminant D65 and represented in the CIELAB color space. For the chromatic analysis they were then divided into cumulative bins of 10% of the volume assuming a JND of CIEDE=1. It was found that the colors of the mosaics show large variations in lightness, low saturation and a tendency to the red-yellow on all sets. On the first set 50% of the volume includes almost all the chromatic information and on the second set only about half. Such results are made possible by resorting to spectral imaging and may be applied on the conservation or display of the mosaics analyzed.

1. INTRODUCTION

Chromatic characterization of Roman mosaics is typically done by observation and comparison against a color chart or by measuring locally with a colorimeter (Palomar et al. 2011). With these methods, however, the complexity of the chromatic pattern is partially lost. This limitation can be overcome by using spectral imaging, a technique that records both the spectral and spatial data over an extended area (Liang 2012). The digital recordings obtained by this technique can produce the chromatic representation of each pixel over an extended area enabling further color analysis and visual simulations (Linhares et al. 2010).

2. METHODS

Figure 1 represents the thumbnail of some of the 10 Roman mosaics that were digitized using a hyperspectral imaging system. Mosaic m2 represents the first set of Roman mosaics obtained at the Roman Villa of Rabaçal, Penela, Portugal. The fragments b1, b2, b6 and b7 represents the second set of Roman mosaics from the Bracara Augusta, Braga, Portugal (Leite et al. 2012). The hyperspectral imaging system consisted of a low-noise Peltier-cooled digital camera with a spatial resolution of 1344x1024 pixels and 12-bit output (Hamamatsu, C4742-95-12ER, Hamamatsu Photonics K.K., Japan) and a fast-tunable liquid-crystal filter (VariSpec, model VS- VIS2-10HC-35-SQ, Cambridge Research & Instrumentation, Inc., Cambridge, Massachusetts, USA) mounted in front of the lens (for more details on the hyperspectral system see (Foster et al. 2006)which appear the same to the eye under one illuminant but different under another, were obtained from 50 hyperspectral images of natural scenes. The degree of metamerism was specified with respect to a color-difference measure after allowing for full chromatic adaptation. The relative frequency of metameric pairs of surfaces, expressed as a proportion of all pairs of surfaces in a scene, was very low. Depending on the criterion degree of metamerism, it ranged from about 10(-6). The system was setup in such a way that the final obtained resolution was at least as good as that of the human eye at the same viewing distance. The spectral resolution of the system was set to be from 400720 nm in 10 nm intervals. The first set of images was acquired outdoors under natural sunlight. Over the area of acquisition, about 0.25 m^2, it was assumed that the illuminant was spatially uniform. The second set of images was acquired indoors under an artificial light source were illuminant spatial nonuniformities were compensated by using hyperspectral measurements of a uniform surface imaged in the same location and under the same illuminating conditions as the fragments (Pinto et al. 2006). In both cases the spectral reflectance of each pixel was estimated from a gray reference surface (Munsell N7 matt (VeriVide Ltd, Leicester, UK)) present in the image at the time of digitalization.

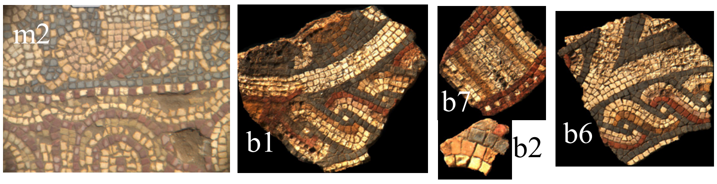

Figure 1: Thumbnails of some of the analyzed sets of Roman Mosaics. The mosaic labeled as m2 belong to the 1st set. The mosaics labeled as b1, b2, b6 and b7 belong to the 2nd set.

Figure 2 represents examples of the type of the recovered spectral reflectance. The reflectances depicted in a) were retrieved from the pixels identified in b). Each pixel of the image as the information of the spectral reflectance. The doted grey line represented in a) is the normalized spectral power distribution of the CIE D65 standard illuminant (CIE 2004).

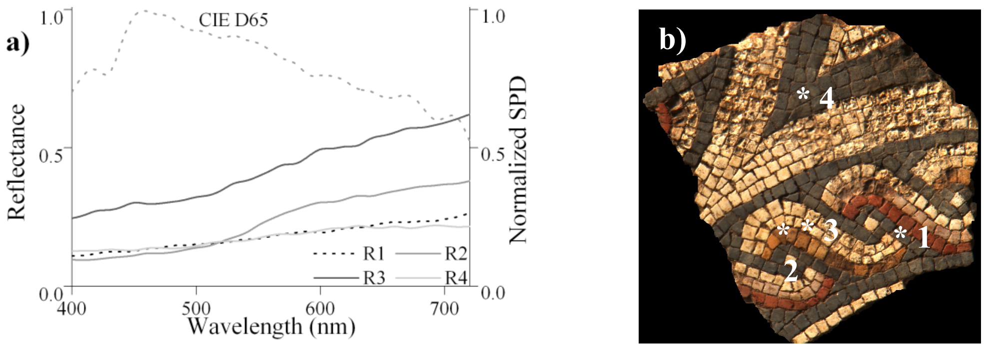

Figure 2: Examples of reflectance spectra (continuous line) obtained from the sample b6 as shown on b). The represented numerals on top of the image have a direct correspondence with the reflectance spectra represented on the plot on a). The normalized spectral power distribution of the CIE D65 is also represented in a) as a grey dotted line.

The color of each pixel was computed from the estimated spectral reflectance assuming the CIE Standard Illuminant D65. The color maps were represented in the uniform CIELAB color space (CIE 2004). To better estimate the color characteristics of each fragment its color space was divided into smaller volumes representing each one 10% of the total volume. The average CIELAB color was used as the center of the color volume. The division in subvolume bins of 10% was done from the center of the color volume to the most extreme color. The number of discernible colors (Linhares et al. 2010) and the number of existing pixels was then estimated on each bin individually and cumulatively. It was assumed a just noticeable difference (JND) of CIEDE = 1. The color difference was estimated using the Euclidean distance formula in a three-dimensional color space.

3. RESULTS AND DISCUSSION

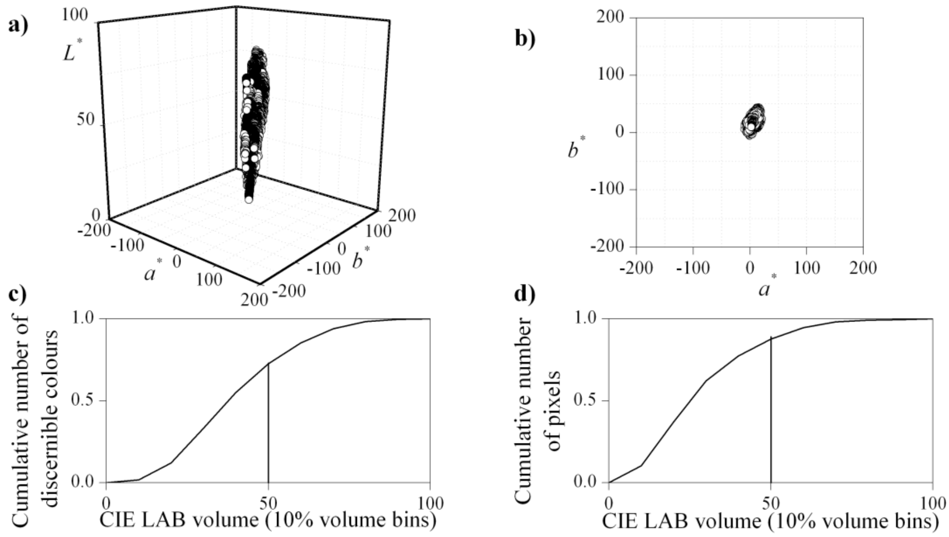

Figure 3: Representation of the CIELAB color volume of mosaic m2 (a)) and ignoring the lightness dimension (b)). c) represents the cumulative number of discernible colors and d) represents the cumulative number of pixels for the same mosaic.

Figure 3 represents in a) as an example the CIELAB color volume were each point represents a pixel from the mosaic m2. b) represents the same set of data ignoring the lightness dimension. It is evident that the variations are bigger in the lightness dimension and smaller in the chromatic dimension. Nevertheless the distributions show a bias to the red and yellow regions of the color space. c) represents the cumulative number of discernible colors in incremental 10% portions of the total CIELAB color volume showing a cumulative value higher than 70% in only 50% of the total volume. d) represents the cumulative number of pixels in incremental 10% portions of the total CIELAB color volume showing a cumulative value higher than 85% in only 50% of the total volume.

Table 1. Cumulative percentage of the number of discernible colors and number of pixels. All percentages were estimated assuming 50% of the total CIELAB color volume. Also represented is the average data for each separated set of images.

Scene name	Cumulative number of discernible colors		Cumulative number of pixels	
	Mosaics	Average	Mosaics	Average
m1	99.76		100	
m2	72.61	90.53	87.63	95.87
m3	99.22		99.99	
b1	64.15		51.57	
b2	59.88		76.45	
b3	59.7		35.91	
b6	70.61	66.16	86.78	60.83
b7	69.35		49.0	
b8	73.34		88.41	
bp	66.11		37.67	

Table 1 shows the cumulative number of discernible colors and pixels for each individual fragment and the correspondent average for each individual set. It shows that 50% of the color volume comprise on the first set and on average 90% of the number of discernible colors representing 96% of the total amount of pixels. On the second set and on average it was 66% of the number of discernible colors and 61% of the total amount of pixels.

4. CONCLUSIONS

The analysis performed here may be used in color comparison in-between the two different sets, that may result lost if more traditional techniques are used (Varas et al. 2008). The use of hyperspectral imaging makes possible not only the study of the chromatic properties of Roman Mosaics in high visual and chromatic details, but may also enable the rendering of visual simulations of the mosaics on different viewing and lighting conditions. This visual simulations may be of good use on the process of restoration or display of the mosaics analyzed (Moro and Pujia 2010).

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Feasibility Study for Textile Colour Simulation with Multichannel Printing Technology

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ABSTRACT

This study has investigated how the growing technology of multichannel printing in the graphic arts could help textile industry to convey accurate colour information. In order to reduce the cost there is an increased need for printed samples that serves for colour judgment and decision in the design process. With the increased colour gamut of multichannel printing systems we are expecting to include most of the colours from textile samples. The results show that with careful control of ink limits and with bypassing the colour management limitations imposed on printing system; we are able to include more than 90% of colour textile samples into the multichannel printer gamut. We also conclude that there must be agreement between used measurement geometries and to account for differences in methodology in order to have a better match. How the texture of such materials influences colour and spectral reproduction is jet to be discovered, and this will be our aim in the future.

1. INTRODUCTION

Every colour management paradigm has the need for ambiguous colour communication. Due to the different physical nature of the materials and colorants used in variety of industries, different colour management workflows have been adopted. In graphic arts industry, the dominant CM workflow is based on ICC based metameric reproduction. This trichromatic based workflow has been enriched by introduction of the multichannel printing. Additional channels (to CMYK) are introduced to extend the colour gamut where conventional printing systems have shortcomings. When “spectral printing” was introduced (Tzeng and Berns, 1998; Taplin, 2001; Gerhardt and Hardeberg, 2006; Morovic et al, 2012) the need has grown for the control and interchange individual colorants (channels). Application areas of the spectral printing are non-commercial products and the addressing fields are: highly accurate industrial colour communication in terms of colour swathes, catalogues (e.g. textile and paint industry), spectral proofing, fine art reproduction, and security (Urban, 2013). The aims of the spectral printing are to increase spectral and colour accuracy, reduce the metamerism and where possible, lower the cost of the final product. All these applications would require optimal colorant set to comprise the gamut of original. The main aim is to have spectral match or at least colour match between original and reproduction under certain set of illumination sources. For achieving this step is to have most of the original’s colours within our printable gamut. Therefore, the aim of this study is to evaluate how much of the textile sample colours we can include into the available gamut of the current print technologies and substrates. The challenge is to reduce the cost that retailer currently incur on one front of the retail colour development process. That particularly involves recurring expenditure on 5 ´ 5 cm fabric samples that are produced to within 0.8 ΔE_{CMC}. This is valid for illuminant UL3000 and 10° observer. Designers use these physical samples when they are deciding which shade an item of garment product will be, or which shade needs to be placed next to each other in a printed or yarn dyed pattern on a garment product. The existing set of roughly 4000 colours is supporting the design process within the colour set that designers are able to pick from. Once their colours for a season and brand are picked, fabric samples are ordered to work with. The possibility of printing these colour samples versus purchasing them from a dyeing company would significantly save in cost.

2. METHOD

We used two 4-channel (Xerox Phaser 6250 laser, Oce ColorWave 6000) and one 12 channel printer (HP Z3200) and 5 different paper substrates. The ONYX RIP was employed to drive our twelve channel printer where we could control ink limits and run each channel to its maximum in order to have real physical capabilities of this device. Colours that are out of the available gamut are mapped in ICC3D utility prior to the calculation of the colour difference. To report results we have been advised to use ΔE_{CMC} formula, but results are also reported using different metrics as well as multiple illuminants. Most important one, where the best match should be established is UL3000 store illuminant. In order to have controlled comparison between textile and paper printed samples we have to compensate for the differences in measurement methodology. In graphic arts the dominant measurement geometry is the 0:45, where in textile industry, standard instrumentation has d:8 geometry. The latter integrates incoming light and effectively neglects the texture of the textile material. Sample preparation for measurement assumes double folded material. Due to the nature of sample preparation for a measurement and the texture of surface, when two textile samples are compared, the mostly used colour difference formula is ΔE_{CMC} where L channel is normalized by factor 2. The same could be applied to the comparison of the coloured textile and paper printed sample. In fact we are referring that the measurements of an anisotropic, porous surface need to be corrected in order to compare with uniformly coloured patch (textile versus paper). Five different papers were employed: HP Heavy Coated paper (130g/m^2), HP Professional Matte Canvas (430g/m^2), HP Artist Matte Canvas (380g/m^2), HP Universal Coated Paper (95g/m^2) and HP Recycled Bond Paper (80g/m^2).

3. RESULTS AND DISCUSSION

The best preliminary results were obtained for the HP Artist Matte Canvas and the worst were given for HP Recycled Bond paper. As the multichannel printer has extended gamut over four channel systems, only the results that are obtained there are acceptable. Therefore, we will exclude from the further analysis four channel printers and all the papers except canvas-like materials as they generally provide satisfactory gamut volume and its surface is similar to texture of the textile materials. The first results (Table 1) represent the possibility of the 12 channel printer in reproducing textile colours.

These measurements were performed under 0:45 geometry, colour management was not disabled and the ink limit control was not applied. In order to make the best comparison between textile and printed paper, we further used d:8, Datacolor 6500 instrument to measure our paper samples. Also, we bypassed the colour management and we regulate ink limits individually by channel to make sure that we are using maximum capabilities of the available inks (Table 2). This approach is more closely resembles spectral printing. Although the ΔE_{00} shows the best results in terms of colour accuracy, we will use ΔE_{CMC} in further reporting.

Table 1. The colour difference under multiple illuminants.

HP Z3200 with HP Artist Matte Canvas paper												
	ΔE			ΔE_{94}			ΔE_{CMC}			ΔE_{00}		
	min	*max*	*avg*	*min*	*max*	*avg*	*min*	*max*	*Avg*	*min*	*max*	*avg*
D50	*0.21*	*11.02*	*2.45*	*0.11*	*10.49*	*1.96*	*0.13*	*9.88*	*2.15*	*0.1*	*7.54*	*1.57*
D65	*0.21*	*10.65*	*1.91*	*0.11*	*10.11*	*1.56*	*0.13*	*9.01*	*1.75*	*0.13*	*7.25*	*1.26*
A	*0.21*	*11.02*	*2.47*	*0.11*	*10.49*	*1.97*	*0.13*	*8.75*	*2.03*	*0.1*	*7.54*	*1.58*
C	*0.21*	*11.04*	*2.47*	*0.11*	*10.50*	*1.97*	*0.13*	*8.98*	*2.09*	*0.1*	*7.50*	*1.58*
F2	*0.21*	*11.02*	*3.31*	*0.2*	*10.49*	*2.50*	*0.28*	*9.35*	*2.1*	*0.21*	*7.54*	*2.02*
UL3000	*0.21*	*10.28*	*1.93*	*0.11*	*9.72*	*1.57*	*0.13*	*8.74*	*2.01*	*0.1*	*6.96*	*1.27*

ΔE_{CMC}			
D50	*0.13*	*5.5*	*1.1*
D65	*0.13*	*4.9*	*1.28*
A	*0.13*	*4.4*	*1.2*
C	*0.1*	*5.6*	*1.2*
F2	*0.1*	*4.2*	*1.05*
UL 3000	*0.1*	*3.9*	*1.02*

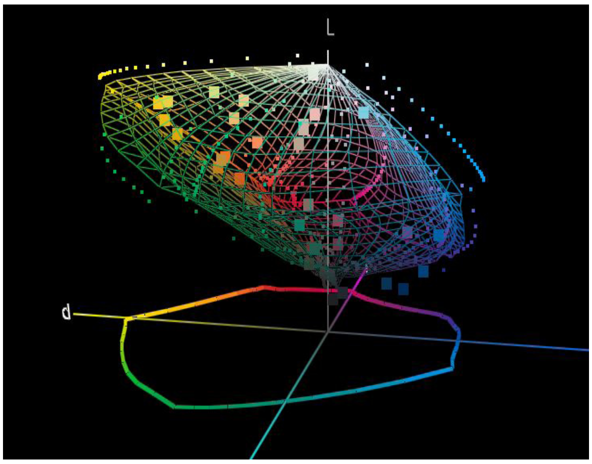

Table 2 (left). Colour difference after adjustments.
Figure 1 (right). The plot of the basic gamut (wireframe), gamut expansion using the RIP (smaller squares) and sample textile colour (bigger squares).

It can be seen from the Figure 1 that most of the colours that are out of printable gamut are located in the section of the low lightness. All the sample colours are within a^* and b^* dimension of the gamut volume but they tend to be out of the printable gamut in lower part of the lightness (L^*) dimension. The paper surface that is used for this evaluation has high scattering properties and low ink penetration. Also, the structure of the canvas leaves some unprinted part of the elevated surface and this can cause the full gamut volume to raise up in the lightness direction. Therefore some of the dark part of the samples cannot be met with this material. Alternative would be to use different substrate for this group of the sample or to meet them with colour dyed paper.

4. CONCLUSIONS

In this work we presented two alternatives of the reproduction of the textile colour onto paper substrates. Conventional colour management does not seem to provide satisfactory accuracy needed for the target application. However, with multichannel ink-jet systems, we are much closer to reproduce accurately the textile colours. To maximize the capabilities of these devices, the full spectral printing workflow should be established. There the maximum potential of the available inks will be used as well as the control of the individual channels. Also the colorant selection process should be performed in order to address the shortcomings that current multichannel systems have for this application.

Another important point that is addressed is to how to communicate colour and colour difference between textile and graphic arts industry. We have found that by using the same geometry we can improve the possible match and we can somewhat include texture information. Although the texture has and its influence to colour perception of the sample is evaluated here, it will be addressed in the future work. The proposed strategy would be to perform distant spectral measurement and to treat texture separately. Also, psychophysical evaluation of the spatial frequency of the texture and its influence for colour perception from the certain distance will be performed.

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Segmentation of Natural Scenes: Clustering in Colour Space v Spectral Estimation and Clustering of Spectral Data

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ABSTRACT

In this paper, we implemented and compared two approaches for clustering-based colour image segmentation of natural scenes: one is finding the best colour space for colour-based segmentation, and the other is segmenting by using the spectral data obtained by estimation from sensor responses. Results show that using estimated spectral data for colour image segmentation of natural scenes can achieve better or equally good results as the best colour space among the tested eight colour spaces.

1. INTRODUCTION

Image segmentation is one of the most important tasks in image analysis and computer vision, and segmentation of natural scenes is particularly challenging due to the complexity of the image content. It is plausible to assume that using spectral information can help achieve better segmentation results than using only colour space information due to the fact that spectral data offers a much more complete way of characterizing the surfaces than colour coordinates (Li 2008). However it is not always feasible to obtain full spectral information unless some estimation algorithms are used to obtain it from a set of sensor responses. Whether using estimated spectral information for image segmentation has the same advantages as real spectral information over colour spaces is investigated in this study.

In this paper, we perform clustering-based colour image segmentation in colour space and estimated spectral space. It is based on the assumption that meaningful objects in a scene correspond to homogeneous colour or spectral information and give rise to separate clusters in colour space or spectral space. Two approaches are implemented and compared in order to determine which one offers the better segmentation quality for natural scenes: one is finding the best colour space among a representative selection of standard colour representation systems, and the other is segmenting by using the spectral data obtained by estimation from sensor responses. In practice, segmentation using the best colour space usually involves the process of colour space selection, which is a process very challenging and data dependent, while using estimated spectral data avoids the selection scheme and requires a training process.

2. METHOD

2.1 Data Set, Segmentation Benchmark and Segmentation Evaluation

The set of colour images used in this work are from the study described by Foster et al (Foster 2006). The spectrum for each pixel has been sampled at 10-nm intervals over 400-700 nm, so there are 31 bands. Figure 1 shows a colour rendering of the six 31-band spectral images tested in this paper. The segmentation benchmark is created by manual labeling. The quantization by mean-shift algorithm will be introduced in sector 2.4. The segmentation results are evaluated by measuring the degree of matching with the benchmark using a similarity metric based on Jaccard index (Polak 2009). The range of the evaluation metric value is from 0 to 1, and 1 indicates a perfect segmentation.

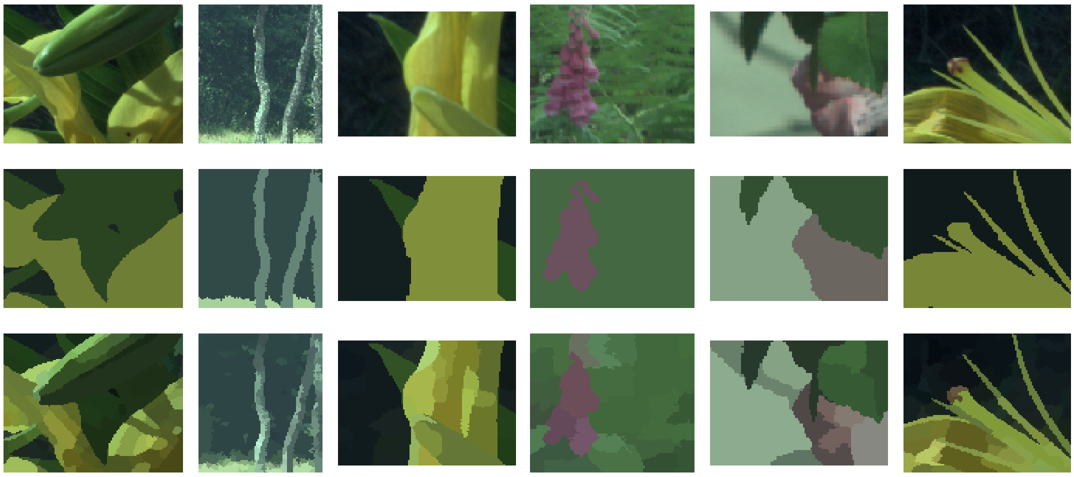

Figure 1: Test images (first row), segmentation benchmarks (second row) and quantized images by mean-shift (third row).

2.2 Colour Spaces

The huge variety of colour spaces that have been developed over time can be classified into a four categories according to their definitions and properties (Vandenbroucke 2003). We selected eight colour spaces as representatives of these four categories: the primary spaces (R,G,B), (r,g,b), (X,Y,Z) and (x,y,z); the luminance-chrominance spaces (L*,a*,b*) and (L*,u*,v*); the statistical independent component spaces (I1,I2,I3); the perceptual spaces (H,S,V). The colour spaces are calculated by linear and non-linear transformations from (R,G,B) sensor responses, which are simulated from spectral reflectance data using a set of spectral responsivities corresponding to a commercial CCD camera and the scene illumination is always assumed to be the standard illuminant D65.

2.3 Spectral Estimation

In this work we use Pseudo-Inverse (PI) algorithm for spectral estimation, which is the simplest linear regression estimation method (Nieves 2005). The performance of original spectral data (SP), normalized spectral data (NSP), estimated spectral data (ESP) and normalized estimated spectral data (NESP) are used for image segmentation and compared with the eight colour spaces in this paper. For NSP and NESP, the reflectance vector is normalized by its Euclidean norm so that the reflectance vector has unit Euclidean length. The normalization reduces the effect of brightness change in the same way as the normalized primary colour spaces ((r,g,b) and (x,y,z)) do, while at the same time preserves the spectral signature of the surface and has the same advantage as using spectral information over colour spaces.

2.4 Clustering based colour image segmentation

In this paper, we perform colour image segmentation using clustering based methods. The mean-shift algorithm is used as a preprocessing step to perform an adaptive quantization on the image (Comaniciu 2002), which helps reduce insignificant information in the scene while preserving the edge information, as well as speeds up the computation (Xing 2009). K-means (KM) and spectral clustering using Nyström approximation (SC) are used for performing the segmentation on the quantized image (Steinhaus 1956, Fowlkes 2004). The number of desired clusters is specified in advance as prior knowledge.

3. RESULTS AND DISCUSSION

Partial results of segmenting two images using SC are shown in Figure 2, and the average results for all the feature spaces over the six test images using KM and SC are shown in Table 1.

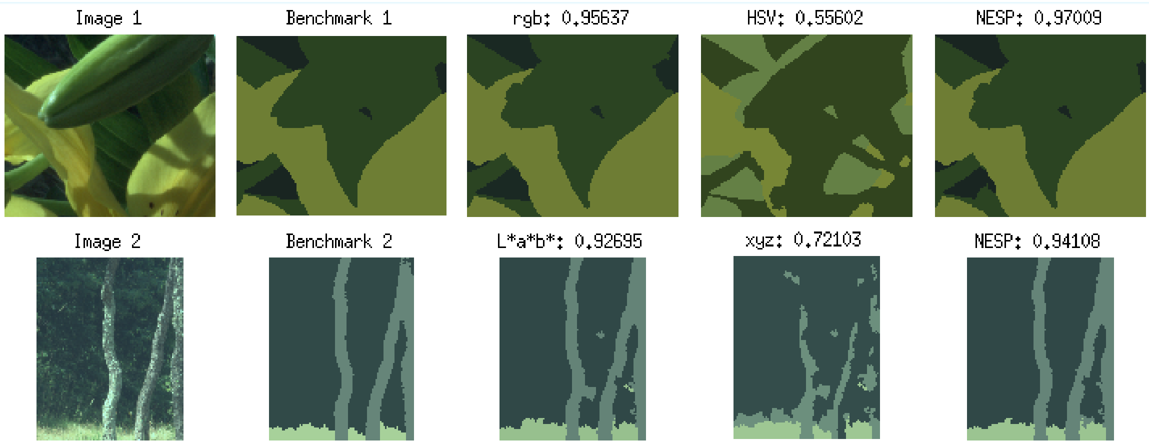

Figure 2: Segmentation results of two sample images using SC. (The first column is the image. The second is the benchmark. The third is the result of best colour space. The fourth is the result of worst colour space. The fifth is the result of NESP.)

Table 1. Average segmentation results of all the feature spaces using KM and SC.

Feature	(R,G,B)	(r,g,b)	(X,Y,Z)	(x,y,z)	(L*,a*,b*)	(L*,u*,v*)
KM	0.7398	0.9220	0.6934	0.8981	0.8635	0.8771
SC	0.8386	0.9497	0.7731	0.8740	0.9322	0.9490

Feature	(H,S,V)	(I1,I2,I3)	SP	NSP	ESP	NESP
KM	0.7839	0.7441	0.7638	0.9544	0.7381	0.9379
SC	0.8349	0.8047	0.8226	0.9676	0.8195	0.9665

From the results we can see that different colour spaces have different performances, and there does not exist a colour space that has the best performance in segmenting all the images. On average, NESP performs better than the best colour space (r,g,b), and SC performs better than KM. NSP and NESP perform better than SP, ESP and other colour spaces who are sensitive to brightness change. For example in the first image in Figure 2, (H,S,V) confuses the shadows on the flower with the leaves, while (r,g,b) and NESP could successfully distinguish flower from leaves. NESP performs similarly but not as good as the NSP, and we assume that its performance could be improved by increasing the spectral estimation accuracy.

4. CONCLUSIONS

Using estimated spectral data for colour image segmentation of natural scenes could achieve better or equally good results as the best colour space among the tested eight colour spaces. Based on the findings of this paper, we can perform spectral estimation on the RGB image data and use normalized estimated spectral data for segmentation to achieve a better result in average without the need of performing colour space selection. As using the full spectrum for clustering based colour image segmentation may include redundant information and is less efficient, future work will focus on the development of a feature selection and spectral data processing strategies for colour image segmentation of natural scenes.

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the colour of culture

Color and Altruism: the Architecture of Background

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ABSTRACT

According to E.O. Wilson, human evolution comes from progress in activities that support groups of individuals rather than those solely centered on kin. Altruism is the tendency to make sacrifices for the survival of the group at a sacrifice to individual gain. Individual gain is a characteristic of architectural culture today. The attention given to originality, visibility, and recognition by the architectural institutions and media, the 'kin' in Wilson's paradigm, is a prime motivator in the design professions. Re-focusing this attention to work that is still creative and exciting, but has altruistic value is indeed the challenge. This study proposes two paths for achieving this goal. The first involves giving more attention to the contextual factors in building projects relative to larger communal and civic goals. This involves bringing a new attention to the role of background architecture, as well as giving more status to the design of interior space. Color and form are co-dependent in these pursuits. The second would include experimental research into the role that color can play in achieving new altruistic goals in the built environment. These studies could include any facet involving color and background including camouflage, color constellations, color field analysis, gaming strategies involving color fragmentation, and color mapping and modeling of urban environments. In all of these the relationship between color patterns and ordering strategies would be the emphasis.

1. INTRODUCTION

In *The Social Conquest of Earth*, Wilson argues that the tendency toward cooperation and collaboration that has powered our spectacular success as a species is explained not by kin selection in which evolution favors the genes of individuals who sacrifice themselves for the sake of relatives - but by group selection, the tendency of evolution to favor groups that work together altruistically beyond what might be predicted by simple genetic relatedness. Humans, along with ants, bees and mole rats are eusocial species that divide labor in what appears to be an altruistic manner. Among many advances, this led us to the establishment of permanent home bases or 'nests'. Specifically, the contention that the force of individual selection pulled us toward selfishness, while the force of group selection pulled us toward altruism and selflessness. We live with a divided psyche as a result. As Wilson explains the matter, the dilemma of good and evil was created by multi-level selection, in which individual selection and group selection act together on the same individual but largely in opposition to each other Wilson (2012: 287-297).

The nest becomes the city in advanced societies, and abstract thought in the visual arts becomes the basis of artistic expression in architecture. Looking at historic cities, the element of protection and survival was always present. Hierarchy within these cities was represented by the architecture. In most there was strict control of the structure and planning, but as individual wealth and power increased and security became less of a factor the individual self-centered impulses became evident in the visual appearance of built environments. Modern cities also have strict organizational requirements that determine their survival. Some of these have distinctive visual appearance based upon a notion of aesthetic unity, such as San Francisco. Other American cities have no visual control of color and form except for massing and height, and these cities are non distinctive and appear like many other contemporary cities. Formal strategies are essential in the appearance of the built environment. Accepting Donald Judd's idea that color and form are inseparable, Poetter (1989:23) color becomes a significant factor in the visual appearance of the built environment.

2. ARCHITECTURAL CULTURE

The Pritzker Prize is the most esteemed award in the architecture profession. It is often referred to as the Nobel Prize of architecture. The buildings by these recipients are usually visually arresting and sculpturally dynamic objects that serve as inspirational role models for not only students in architecture but architects in the profession as well. Image and visibility are highly desirable in the commercial world of architecture. The design of large structures is one of the most effective ways to achieve this. The capability of digitally based fabrication to produce custom structural systems of extraordinary scale and complexity, innovations in structural skins, skeletons, and cantilevers, and advances in all of the material and equipment industries in the building field facilitate the design, engineering, and production of these sculptural mega structures. All of these factors enforce the temptation in architecture to build the figural object. Beyond individual expression, visual design does contribute to the larger communal and altruistic goals of the built environment. Some of these bring order and comprehension to complexity, define public spaces, establish hierarchies such as the signification of center, celebrating institutions of value, and creating the relationships and connections that make all of these strategies possible. The role of color in achieving these goals is altruistic color.

3. THE ARCHITECTURE OF BACKGROUND

In democratic cities is there an aesthetic that will satisfy the majority? There are many opinions about this issue, and the laissez-faire attitude of anything goes seems to be the easiest way to satisfy multiple points of view. Many cities in the United States have figural buildings in their center, usually high-rise towers competing for attention and unrelated to one another or the city as a whole. Many of these cities are indistinguishable from one another. The downtown cores of Denver, Albuquerque, and Houston all appear similar yet are dominated by these highly visible towers. Color is sometimes used to create high visibility, but usually for no other purpose, and in many cities that have predominantly neutral colors in beige and gray, the very light or very dark buildings stand out as figural. All of these cities, however, have older districts and neighborhoods that have a distinctive fabric which gives them unity and cohesion. Color is a factor. Massing, street definition, and a variety of repetitive colors and forms give these districts their visual unity.

What is background? In urban contexts background is that median color/form of the built environment which most conforms to the overall urban fabric and contributes to its visual unity. Background is also the structure or matrix that forms and defines the spaces of importance within the city. The color of this background fabric is a component in the overall visual field. The color of building surfaces comprise a large portion of this field, and these colors can be a powerful means for defining unity. A variety of figural form and color can exist as background in a city if there is repetition. Models that abstract these colors for large areas of an urban environment would allow designers to experiment with color patterns and clusters that support holistic strategies. Rice University in Houston, Texas is an example of background architecture. The campus buildings become the defining walls for open spaces, quadrangles, streets, and hierarchical relationships. Rice has employed famous architects to make additions to this campus. These architects have been challenged to exercise their creative talents within the context of the architectural guidelines of the university. Of these, one of the most interesting is Brockman Hall, by Kieran Timberlake where the imaginative use of color, materials, and a focus on interior architecture demonstrate that beautiful spaces within a controlled context can be as exciting as sculptural exterior form. The altruistic goals of the university are satisfied yet creative individual expression is also possible.

4. ALTURISTIC COLOR

Altruistic color refers to the color choices architects and urban designers make that satisfy larger communal and civic goals. Within this context form and color can be conceived as co-dependent in the visual appearance of the physical environment. The position is taken that color as both figure and ground is a powerful tool in defining unity and variety in an urban context, and one of the most versatile and cost-effective means for changing the perception of a city. This position combined with attention to the potentials of background in this context, aligned with strategies that bring purpose and unity to the urban environment, support the importance of color research and experimentation in architecture and urban design. Altruistic color as a discipline will involve new programs in architecture schools related to visual design and interior architecture. The investigation and documentation of cities that effectively use altruistic color, the study of color through the eyes of painters like Giorgio Morandi, Banders (2008), and photographers like Thomas Struth, Struth (2012), would bring these disciplines into the curricula. Exploring the means for representing and modeling color in built environments as fragments in large color fields is a challenge. In these models urban design strategies might be expressed through manipulation of these color fragments. Of particular interest would be the inclusion of camouflage and color constellations in these studies.

5. THE COLOR GAME

There are many representations of a city where there is a structured (ordered) relationship between fragments of color and larger form. Maps of cities, land-use and comprehensive city plans, quantitative data from census tracts shown as color fragments on a city plan, Wurman (1966). Experience maps show color and pattern of buildings in plan, Minah (2005: 403). A map of this type would should, in some instances, a discernible order (predictable), but many would appear chaotic (random, unpredictable). Where order is apparent there is most likely a 'rule' that provides the basis for an orderly arrangement. Where there is no order apparent the color is random and chaotic. Complexity is used to describe a state that is not totally orderly and not totally complex. The color of cities might be put into this category. The questions then arises as to whether a system can be orderly and chaotic at the same time, is there a continuum between chaos and order, and are there systems that combine order and chaos. Inspired by the Chaos Game, the Color Game might be based on a system where both strict rules and random events are prescribed. The representation of the fragments of color in a city, a strategy or rule that determines an outcome, and a means for manipulating the color fragments to create order would be the challenge.

6. CONCLUSION

Background architecture as a subject of interest and building type would be the starting point for changing the motivation for designing individual self-expressing figural objects to realizing the altruistic role of architecture in urban design. Recognizing this work as well as outstanding achievements in interior architecture would value creative achievements that contribute to larger communal goals. Finally, there needs to be a new facet of study and research within the architecture and urban design curriculum which looks at color and background in built environments as a serious discipline. Subjects for future study, research, and experimentation will include color modeling and representation, color fragmentation studies including color field analysis, camouflage, color constellations and other perceptual phenomena. Theoretical and gaming strategies related to complexity in color fields could be explored, as well as putting a new emphasis on visual design and interior architecture in design education.

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Color me Happy

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ABSTRACT

This paper derived from a comparative study on the relationship between color and the "material culture of happiness" in two large Brazilian cities: Rio de Janeiro and São Paulo. Those are, in the current representation, opposite cities: Rio, exuberant in nature and, hence, a more laid back, relaxed and outdoor way of life; São Paulo, the most important metropolis in the country, cosmopolitan and indoor. In this study, utilizing the data base and, more importantly, the photographic records of a study on the "Material culture of happiness" conducted by the Observatory of Behavior and Consumption of SENAI CETIQT, we sought to analyze the distance between the colors involved in the daily happiness of the inhabitants of these cities. Serving as basis for the study, individuals from both places were asked to capture, through writing and through photographs, at least three everyday moments of pleasure, well-being or happiness experienced in each day of the week. From approximately 1600 moments of happiness described and photographed, we intend to enrich the debate, through the perspective of anthropology of emotions and of the study of colors, about the relationships between local material culture, happiness and colors.

1. INTRODUCTION

The objective of the research that gave rise to this paper was to analyze the "material culture" of everyday happiness in Brazil, from the analysis of "daily happiness" produced by men and women, aged 15 to 65 years, residents in seven (7) major capital of the country. We sought to survey men and women belonging to so-called "urban middle classes", the main targets of the project officers of happiness in modern-contemporary complex societies (VELHO, 2010). Were selected, for this cut, the two largest cities – Rio de Janeiro and São Paulo – for the attention of all catalyze both positive, and negative, forming a peculiar duality in the Brazilian imaginary. The participants were asked to record in writing and through photos, moments of daily *happiness*, lived over a week. We sought to explore the situations, times, environments, objects and products promoted in the daily lives of respondents, feelings of pleasure, well-being or happiness. In a second stage of the research, in-depth interviews were conducted with participants, based on the diaries produced. In every city were surveyed 64 people, divided into 4 age groups (15-18, 20-25, 30-45, 50-65), which produced the "Daily Happiness" and 40 of them were interviewed later. Among the types of moments of happiness, there are situations linked to: domesticity; care for the body, promoting health and well-being; daily responsibilities at work or achievements, activities leisure; community and territoriality of the city where they live: contact with nature and contemplation of scenery and the extraordinary events (birthdays, weddings, parties, etc.). It is noteworthy that the research that led to this study adopts the perspective of the "anthropology of emotions" in the study of "material culture of happiness", understanding emotions as discursive practices, i.e., instead of subjective states, socially shared codes, product of relations between individuals in specific sociocultural contexts (KOURY, 2005; RESENDE & COELHO, 2010).

The study of the colors contained in the photographic records pertaining to the daily analysis was guided by what leads to differences in brightness, predominance of shades and intensities for each city. The significance of color in architecture, urbanism and landscape of a city expresses also the culture of a people. In the observations, we clearly note differences in photographic records that scored the diaries about daily life of each individual and their happy moments. Color and shape simultaneously arise in connection between the middle and the man and they have an active character. The color, when in a context, reaches its goal when it stimulates cravings, projected the images chosen (ARAÚJO, 2006).

2. STUDY OF THE COLORS IN THE CITIES

The method used for the analysis of the colors of the two cities was structured by steps for a better visualization and systematic approach was: 1- The images were taken from the "Daily Happiness" in Rio de Janeiro, and in São Paulo. 2- The photographic records were divided into two categories: interiors and exteriors. 3- The images were arranged in collages that led to two subcategories. Those are: interiors (objects, people, food) and exteriors (landscaping, streets, buildings). 4- The prominent colors were removed from each of the images. 5 -The colors were grouped by "temperature" - hot and cold, lightness and hue (ALBERS, 2009). 6 - The analysis of images and colors was made considering the symbolic aspect (MAHNKE, 1996).

The photographic fragments found in the diaries ride an emotional *psychogeography* of places of conviviality. In them we find important eye-catcher aspects observed during the analysis of the images. For this, we used Barthes (2010). He speaks on the *punctum*, which appears as a detail, a partial object, and becomes a force of expression. The *punctum* paradox is that, while remaining a detail, fills the whole image. Barthes calls attention to the *studium* as a theme applied; as a taste for someone or something – a kind of an ardorous general investment on the photo. He mentions that, recognizing the *studium* is finding the intentions of the individual who made the record, understanding them and discussing them. At a certain point, we can say that in Rio de Janeiro, the *studium* is sunny and prioritizes the sky, having the sea as an ally, so the blue is gorgeous, despite the also strong presence of vegetation.

Figure 1. Exteriors: Rio de Janeiro and São Paulo.

In São Paulo, we feel that the *punctum* of the records reveals frames of buildings and streets emphasizing these elements and their colors. The exception remains with the image of a pasture beside one of the highways connecting the city to other places but, even in it, we can notice that the sky is not the *studium*. We can say that, in São Paulo, what motivates the outside registers are the links and the passages where eventually a blooming tree or a building mark the intentions of the record. Because of the mild climate, in this metropolis, we understand better the green urban landscaping and the less saturated, grayer colors.

Collages made with indoors present a greater number of records in the diaries collected in São Paulo. We see scenes with family or friends, always around the table and with a good food for interspersing the conversations. The warmth of home and intimacy represented in this case the amount to the *studium*. The colors that stand out tend to warm yellow hue: they represent the woods, sauces and beverages. In addition, artificial lighting distorts the color of objects toward the yellowish, due to differences in uptake of color temperatures recorded by the photographic device. Also, the walls of the houses, both in São Paulo and in Rio de Janeiro, are usually clear or white and play a neutral role for the *punctum* arise in objects and people.

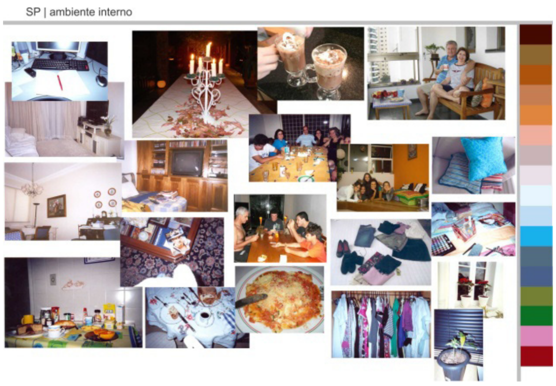

Figure 2. Interiors: São Paulo and Rio de Janeiro.

Rio de Janeiro interiors revealed not as numerous as the externals, but portray equivalently festivity and meeting with friends and family. Just as in São Paulo, the warm tones predominate and represent furniture and food. The difference is that in Rio we have a deeper color, orange, which has a higher strength – saturation – and becomes *studium*.

3. CONCLUSIONS

In Rio de Janeiro, we see the predominance of blue of the sky and sea and in the "indoor" category, warm tones predominantly orange. In São Paulo, we see urban green and gray colors and bumping into buildings and inside, the warm colors also end up being cooler, tending to yellow tint. In Rio de Janeiro, because it´s the color that forms the *studium* landscape, as we saw, we understand the motivation of people to contemplate the horizon. In São Paulo, the color yellow has come up with a positive sense, predominating in the interiors where the family gathering around the table is the focal point. Specifically São Paulo has a large living with gray, mainly due to its buildings, pollution and drizzle, which can sometimes give an impression of melancholy. But we notice it gains a positive, modern and even a fashionable sense. It is felt also that orange color is a source of contagious energy. Because it is a color that appears in Rio de Janeiro interiors, due to the tropical intense and sunny light, it reflects the contagious energy of its inhabitants who have a passion for the sunset.

On the significance of the colors, we detected points of intersection that appears on the form, allows rooting emotional subject and place indoors or outdoors. The energy factor belonging to each color in the environment can define a line, of both city and its particular environment. The meanings that emerge from the colors define the shape of the world. This statement, however, does not end in itself, the truth about the symbology resulting of the emanation of the colors encourages research on the construction of different meanings, which vary according to different sociocultural, physiological and psychological individual factors. It is worth questioning about different points of view to understand the colors of Rio de Janeiro and São Paulo, and how they relate to the moments of happiness. The images formed in the social imaginary about the two cities have reason to be. The issue that mobilized us to examine such photographs for this study was *to determine whether the analysis of the predominant colors in moments of happiness experienced in these two cities reveal significant differences between them*, as current representations is assumed.

Although those cities are considered "identity images" on almost opposite lifestyles, the analysis undertaken here seems to show *more similarities than differences between the colors of "Happiness" in Rio de Janeiro and São Paulo*, revealing similar notions about the sources of pleasure, well-being or happiness searched daily for the two cities. About the images of indoor environments, in both cities, they are warm, full of warm colors, plentiful and juicy food, surrounded by people, furniture and portraits. In the end, although São Paulo tent to milder temperatures in relation to Rio de Janeiro this study on colors shows that, for Brazilians, regardless of city, social relationships are important, and especially the family, which makes the warm inviting colors conviviality.

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Colourful Stories: Exploring the Transformative Potential of Colour Culture in a Northumbrian Mining Town

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ABSTRACT

2014 will see the opening of a new £100m factory in Ashington, a former mining town in Northumbria, UK. The global paint manufacturer AkzoNobel wants to ensure its investment creates not only regeneration through employment but also broader, long-term health and wellbeing improvements, through the life-enhancing qualities of colour. Committed to transforming lives through colour, they are continually striving for innovative ways to engage local communities in transformative application of colour to the built environment. This paper describes successes of the firm's global Let's Colour programme, as well as the Northumberland project, its methodology, preliminary findings and proposals. The best will be developed and implemented over three years from 2014.

1. COMPANY CONTEXT AND PROJECT ORIGINS

AkzoNobel Decorative Paints company believes that making our surroundings more colourful has a positive effect on how people live and feel. By adding colour to people's lives, both physically and metaphorically, the company integrates their economic, social and environmental ambitions. Through their Let's Colour program, paint brands such as Dulux, Levis and Coral transform the communities by renewing the spaces and uplifting people's skills. It expresses a commitment to build a sustainable business model, and inspires people to join in making the world a better place. Since launch in March 2009, the Let's Colour project has come a long way. With nearly 250 projects in more than 25 countries the firm has added colour to lives of thousands. Approximately 16000 people from the communities were trained in painting and decorating while participating in the projects. Charleroi, Belgium and São Paulo, Brazil are just two examples.

1.1 Let's Colour: Charleroi, Belgium

The Belgian industrial city of Charleroi was once regarded as the 'ugliest city in the world'. Paint brand Levis and Let's Colour worked with the local community to add colour to key places in the city. The old symbolic factory was transformed with art and music into a lively and fashionable house of creativity and expression. The old water tower, a symbol of the past and of the future, was painted in bold, vibrant yellow. Colours were added to the impoverished area of Ville Basse and a fertility hospital. In Place du Nord, where many different cultures live together, community members were happy to see an event of this kind, and it was a good opportunity for them to meet their neighbours. Now they organise events on the square, such as barbecues and parties, of their own accord. All of the approximate 1000 volunteers from the local community were very proud of what they had achieved and very happy with their new colourful environment. The project has encouraged others in the city to continue to add colour to Charleroi.

1.2 Let's Colour: São Paulo, Brazil

The traditional community of Bixiga in São Paulo was the first to be visited by the Coral project *Tudo de Cor Para Você* in 2009. Many other projects followed, including a huge urbanisation in Santa Marta favela in Rio De Janiero. *Tudo de Cor Para Você* project aimed to inspire people through the preservation and injection of colour that was given to the community's houses. To thank the many youngsters for all their hard work in the project, they were treated to a lesson in SENAI**,** a national network of secondary level vocational schools. The activity of painting generated a change in people's habits and gave a feeling of pride and ownership of the job at hand. In total approximately 6m people were reached in Brazil by the Let's Colour projects, and the projects will continue.

2. ASHINGTON PROJECT

Since Woodhorn Colliery was closed in 1988, Ashington has struggled with high unemployment, a fragmenting community, and economic decline. As part of AkzoNobel's commitment to transforming lives through colour, and to celebrate their new factory in the town, they challenged Northumbria University Master's students to come up with innovative means of community engagement and impact, involving a transformative application of colour to the built environment.

AkzoNobel's prior experience and research was combined with that of Northumbria University's faculties of Arts, Design & Social Sciences and Health & Life Sciences, to provide a background of colour science and demographic, social and economic data for the region, with past examples of community arts and colour projects.

A recent Council survey, which polled almost 2400 (19%) of Ashington residents, found that despite a certain pride and community cohesion, they are pessimistic and dissatisfied, describing their town in "very negative terms" as "a town which is forgotten, neglected, shabby and dirty, and with a bleak future" (Ashington Town Council, 2012).

> 36% are dissatisfied with their local neighbourhood. Many request cleaner streets, free of litter and dog fouling, accompanied by road and pavement repairs, increased job prospects and improved shopping facilities.
>
> Only about a fifth of residents feel they can influence decisions at a local level. Younger residents feel more able to influence change than their older counterparts.
>
> Only12% of residents are members of a local community group or organisation.
>
> Over 30% have a long-term, limiting illness, health problem or disability.

This background then set the context for a catalyst project, carried out by 23 Masters students studying Multidisciplinary Design Innovation (MDI) at Northumbria University.

Process, Tools and Methods

MDI students are mostly graduates from three general discipline areas: design, business/marketing, and science/technology/engineering. They worked in teams of four or five, including members of all three disciplines. Students engaged in a rapid ideation phase followed by deep-dive research including observational and experiential fieldwork, as well as interviews and surveys, with the aim of understanding the hopes and fears of the community, then translating these into viable enhancement opportunities. Intervention ideas were generated using techniques such as concept mapping, visualisations (sketches, photomontage, CAD renderings and short films) for discussion with stakeholders, and enacting concepts in short videos.

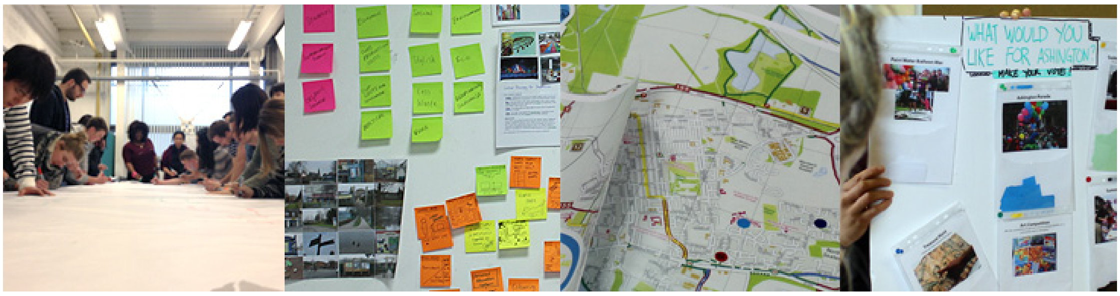

Figure 1: Group ideation; team research; exploration and consultation.

Insights and concept highlights

The project outcomes included many valuable insights and proposals; some had an explicit theme of colour, while others were less literal interventions, with varying degrees of brand visibility. Broadly they can be categorised into five main themes: Enterprise (drop-in centres and business mentoring, high street and market revival, Space to Sell); Education and Training (scholarships, prizes, mentoring); Pride and Identity ('Made in Ashington', red squirrel 'Grey to Red' campaign, allotments and gardens); Community collaborations (film-making, theatre, annual events); Town landmarking (paths, signage and public art). Students made valuable insights in just a few weeks, through immersive fieldwork and intensive ideation phases. Sponsors and students alike were surprised at how much was accomplished in such a short time, with deep insights and radical but achievable proposals. The best of these have been pursued in a second, 10-week phase.

Figure 2: Concept examples. Made in Ashington, Race, Colour my street, On the Map.

Phase two

In this phase, teams explore three main areas of intervention: community events, an education & training programme, and colour in the Ashington landscape.

Public events (such as festivals, contests or performances) will be devised to bring together the community and wider public, bringing colour in all senses of the word. They must tap in to heritage and traditions of the local culture, yet must feel modern, optimistic and forward-looking in its content and themes, and through bold use of colour.

Education and mentoring schemes aim to engage with and nurture local talent, enabling young people to realise their potential in employment related to AkzoNobel products and brands. Projects explore how best to find and recruit such candidates, especially from hard-to-reach parts of the community, and how to connect and inspire through colour. Two tiers of engagement are pursued: firstly, sponsorship in higher education through mentorship, prizes and scholarship awards. Eligible candidates will be studying subjects relevant to employment in chemical manufacturing industry (eg physical sciences, chemical engineering, marketing, management). Secondly, vocational guidance and training will be offered in related trade skills such painting and decorating. Both strands aim to help break the cycle of unemployment, bringing back a sense of hope, ambition and aspiration to Ashington's next generation.

Colouring Ashington follows the more typical format of a Let's Colour project –community collaborations that bring colour to the public landscape, reviving and energising key areas and focal points. Targets for exploration include Ashington bus station, high street and market place, cycleways and footpaths, garden allotments, and traffic roundabouts. Student projects identify suitable sites and mechanisms for participation, and propose designs for consideration in co-creation events.

CONCLUSIONS

Student work has served as stimuli for the sponsors, inspiring and challenging AkzoNobel and the County Council to take bold action. For the students, this project provided valuable experience of multidisciplinary, multi-stakeholder engagement (including the public), working with and presenting to an industry client, and applying design methods to a real social challenge. New and valuable relationships were established between Northumbria University, AkzoNobel and the council. For the community itself, impact will be significant once the final projects are implemented. Let's Colour projects demonstrate the transformative power of community collaborations around the globe that resulted in bold, colourful, large-scale and highly visible change. They set a precedent for Ashington, and expectations are high for the positive impact these projects will bring in 2014 and beyond.

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Colour Culture Preservation of the Historical City

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ABSTRACT

Artistic appearance of the city is closely connected with the preservation of the colour culture of the past and its development at present. Moscow as a polychromic city unifies colours of various historical styles. In order to preserve cultural and historical heritage of the city, we have studied facade colour palettes typical of different construction periods and developed basic palettes for each architectural style. These palettes are divided into five colour areas. Thus, it makes it possible to compare the same colour area in different style palettes and give recommendations on their colour differences and interpretation. This analysis helps identify a hue of the same colour in different style palettes and show the colour evolution from the historical point of view.

Features of façade colours depend on cultural progress in society, tastes of customers, financial potential and, of course, building and finishing materials used in construction. It is vital that those materials could contribute to the preservation of the historic city colour identity. This can be achieved by creating new palettes considering special features of historical colours. For this purpose modern palettes, matching traditional façade coloring, have been developed for ceramic granite and architectural glass.

1. INTRODUCTION

The city is a constantly changing space system bearing the traces of continuity in the colour culture and unity of the historical process. For eighteen years the author has been studying historic palettes of various architectural styles and their interaction in the street space. Development of the style palettes is particularly important in the context of three aspects:

- preservation of the colour culture and colour identity of Moscow;
- practical use of the palettes of each style for the colour scheme design for the building façades;
- use of the palettes in order to select colours for new construction and finishing materials.

Nowadays there is a wide range of such materials available. They include minerit, marmarock, krastan, ceramic granite and, of course, glass. However, it is very important that all those new materials will have adequate artistic and aesthetic features to match organically traditional façade colouring in line with the architectural style of buildings and streets.

2. ARCHITECTURAL STYLES

It is essential to view the historical colour environment as the national aesthetic wealth, which should be preserved and serve as a basis for recreating and maintaining a city colour identity (in the given instance – Moscow). Moscow is an eclectic city, in particular in terms of colour. Restoration of historical polychromy helps to comprehend the history of this city and to see the aesthetics of its past, tastes and financial potential of its citizens, the state of the society in the given period of time. It is possible to correct this or that colour design if the historical colour which is to be recreated conflicts the existing colour environment. Colour of a historical building doesn't need to be same as the original one but it must certainly correspond to the palette typical of this specific architectural style.

The study of facade colouring typical of different periods in the Moscow history has led to the development of basic colour palettes for each architectural style. Palettes of each style are divided into five colour areas including coloring of details in every period and this approach constitutes the primary merit of this research and considerably differs from previous ones. Thus, it makes it possible to compare the same colour area in different style palettes and give recommendations on their differences and interpretation. This analysis shows the colour evolution from the historical point of view.

The study has established the following styles and their basic colour palettes:

- baroque (17-18 century)
- classicism, late classicism, Empire (late 18th – mid 19th century)
- neo-Russian style, eclecticism, Art-Nouveau, neo-classicism (mid 19th – early 20th century)
- constructivism (1920s – 1930s)
- "neo-academism" of the Stalinist period (mid 1930s – early 1950s)
- soviet architecture (1960s - 1980s)
- architecture at the turn of the 20th – 21st century

One can find monuments of the baroque architecture in the center of Moscow of today. They usually have red, yellow-orange, blue-green colours in combination with white and colour details.

Architecture of the Classicism and the Empire periods was regulated by the 1817 Act that prescribed to paint buildings with light colours ultimately allowed architects to achieve certain colour uniformity in the city. Moscow of that period is amazingly harmonious with soft ochre, pastel pink, green, blue and grey-pearl facades with white details and high white-stone basements.

Eclecticism and Art-Nouveau in Moscow show a rich colour palette ranging from red-brick industrial buildings to multicolored private houses. These buildings feature polychromy. Many commercial apartment buildings and mansions demonstrate examples of active colour evolution ranging from terra-cotta brick to greenish-olive tones, emerald-green details of glazed tiles and expensive stone decors. Many pieces of architecture of that period characterize, in a way, the image of Moscow.

Simple forms and palettes are typical for the Constructivism of the 1920s - early 1930s. Although initially their design envisaged bright colours for details and window sashes, in the end these period buildings with plastered walls have all shades of grey, dark-grey, cement-grey colours and black and brown window sashes.

The Stalinist architecture of "neo-academism", represented by multistoried buildings, massive apartment blocks on the main Moscow main streets, demonstrate a rich ochre and ochre-grey palette, often accompanied with dark details. Façades of that period features the "sgraffito" technique brought from Italy and Spain with a pattern in red-brick, less often in dark-green and blue colours. The technique involves scratching of the upper layer of plaster to reveal the differently coloured underlying layer. Buildings on the Garden Ring Road, in Tverskaya street, Leningradsky, Leninsky and Kutuzovsky avenues present striking examples of that period. Mass panel and large-block construction with reinforced concrete and glass, popular in the 1960s - 1980s, have brought to Moscow inexpressive grey-beige colours and dark tiles on basements.

The current period at the turn of the 21st century is the time of social change. Much like at the turn of the 19^{th} century, it has brought about the revival of polychromatic architecture with quite a number of coloured buildings. It is worth noting that the modern colour schemes incorporate colours of all stylistic trends. However, new construction and finishing materials get modern colour interpretation.

3.CERAMIC GRANITE

Today, ceramic granite tiles are widely used for the facing of façades in Moscow. In fact, the return to the former types of finishing, traditional for Moscow, has taken place due to development of construction technologies. Thus, plaster dominated the finishing of building facades for a long time while ceramic granite has become a successor of ceramic tiles and white-stone slabs used for façade finish in various architectural styles in the history of Moscow.

Combination of two different materials, plaster and ceramic granite, on the same site was a demanding task for our team. We did a practical research to develop a new single-texture palette for ceramic granite that would match the approved colour palette used for painting of Moscow's buildings. The palette represents a system of tinted media for the main colours such as red, yellow, brown, green as well as achromatic range. This allowed, as with façade painting, to create the same pattern in different colours on facades of identical buildings united in a local group. The complexity of creating the colour palette for ceramic granite was first of all in the necessity to select the same textured surface similar in all colour regions and have the same colour saturation in every linear range of tints.

Building cladding, made with the use of ceramic granite, whose palette was developed with due consideration of the colour characteristics of historic buildings, has demonstrated wide opportunities for using ceramic granite without destroying the colour continuity of the façade finish in Moscow.

4. ARCHITECTURAL GLASS

Invention of the framework and the elevator in the late 19^{th} century radically changed the appearance of building facades – the stained-glass appeared, the glass lost its utilitarian function. Therefore, it is essential to ensure that the architectural glass can be sufficiently varied in colour and artistic characteristics to wed with the historical environment of the city. There are four trends that we consider particularly important for work with architectural glass:

- variety of the glass colour palette;
- use of silk-printing technique and application of a pattern on the glass surface in a different way;
- development of the assortment of glass types depending on their various reflection coefficients including reflectivity;
- use of modern transparent systems.

A significant role is played by the architectural and artistic characteristics of materials contacting the glass on façades and having influence on its perception, as well as the methods of glass fixing, its area in the building's facade structure and, undoubtedly, the colour. The team of authors have obtained a Russian Federation patent on their method for optical property measurement of glass and selection of glass colour.

The new developments in many cities are represented by a wide colour range. This is easy to explain: not disturbing the uniqueness of cities, maintaining the colour culture of the past and converting it into contemporary shapes and materials, architects create truly artistic ensembles. The Potsdamer Platz complex in Berlin, consisting of high-rise buildings with coloured glass, La Defense complex in Paris with Tour Gan made of glass panels in black casements and Tour Manhattan faced with mirror glass, the new centre of Shanghai and the colourful skyscrapers in Dubai are very expressive in this sense.

In this context, various methods of applying template matrices creating inimitable visionary effects on ufacades and inside the buildings deserve special attention. The Art Gallery in Stuttgart made of silk-printed glass and representing one of the most original variations of the theme of "metal and glass" is a demonstrative example. In spite of its impressive dimensions, the building looks very lightweight as if dissolving into the surrounding historic district.

Here is another example. The unique decorative ability of silk-printing is represented on the facades of Cologne's Media Park office and hotel complex. It should be noted that silk-printing is not only a decorative, but also a functional element of the contemporary architecture. It helps solve the issues of decreasing sunlight action, mark the visual borders of a building, and increase the lifespan of glass and many others. Glass with reflecting effects can create truly fabulous panoramas and images on the facades. This technique is similarly suitable for creating large reflected panoramas on extended faces of buildings and for harmonious spatial solutions on historic streets and squares when fitting new buildings in the existing architectural fabric of a city. Smartly placed in terms of urban planning, they merge with the surrounding buildings.

We observe various examples in many cities of the world. An office and commercial centre building made with dark glass is arranged favorably on a pedestrian street in Vienna. An ancient church reflects in its stained glass windows. The reflection serves as a guiding point on the street, as the church is not visible in the street's perspective at all. A reflecting silhouette of a historic building on the embankment of the River Themes in London creates an illusion of a wide square opposite to a recently built complex, thus, expending the urban space. Wonderful effects of buildings reflected in adjacent buildings inside one district can be observed in La Defense, in Paris. All those examples invariably support the necessity of studying glass in terms of its architectural and artistic value, as more and more contemporary buildings with glass facades are emerging on the streets of the cities all over the world. And a city must be beautiful!

5. CONCLUSIONS

Every historic city is unique in its own way. It is important to identify the features of its uniqueness and preserve them in a new construction rather than destroy and throw away what has been accumulated over the centuries; to find new modern architectural tools in order to develop and ensure identity of the city in the future. It is necessary to show all possible development trends of the colour culture as a research and applied area present in every line of architectural activities and defining aesthetics of the city of the future.

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One island, Three Neighborhoods, Three Identities, Three Colors

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ABSTRACT

This study explores the relationship between chromatic atmospheres and territorial identity in three neighborhoods in Isla Teja, Valdivia. In spite of their shared island nature, they have different features, including unique ways to practice space. Such differences are expressed in the color patterns of the facades. The practices are explored based on the perceptions of the dwellers, revealing the deep differences in the ways they understand their neighborhood.

The research establishes a dialogue among architecture, design and anthropology, developing a case study that combines ethnographic background information and chromatic comparisons. The findings suggest a relationship between materiality and territorial identity, revealing chromatic patterns that –from an apparently technical view– constitute a much less visible dimension in discourses, strongly remitting to elements that are typical of the construction of a neighborhood identity. We hope to contribute to the further analysis of topics of interest for color and urban space researchers.

1. INTRODUCTION

Color is part of any cultural space and considers designed elements and the embedding of natural resources, material culture and populations in a historical perspective, as "organic landscapes" in constant construction (Pizano and Cortés, 2002). Beyond the presence of color in these scenarios, it is often an undervalued element, expressed spontaneously and relatively unconsciously in discourses, keeping an irregular status at the urban planning level.

Addressing it as part of the landscape assumes the presence of chromatic atmospheres, which according to Lenclos (1999), correspond to a "general palette", where the architectural elements (facades and roofs) and the pavement, make the most visible area of the urban space. This is added to changes in colors due to light, vegetation, water and the sky. Such an interweaving results in a local atmosphere, which, influenced by a shared materiality, achieves a unique character (Muñoz, 2009).

Based on several authors (Barela, Sabugo et al, 2004, Martínez, 2004, Segovia, 2002, Gravano, 1988), we assume that the "neighborhood" is a particular form of territory, alluding to perceptions which –interacting with the surroundings– gradually gain physical reality, leaving marks that often dilute external characterizations. These are zones "…where the observer can enter with thoughts (…) They could be recognized from outside and, sometimes, they could be used as an external reference when a person goes towards them" (Lynch, 1989 [1960]:84-85).

We speak, hence, of a suitable space when exploring the relationship between chromatic atmospheres and perceptions, assuming the "chromatic identity" notion as a complex junction. Along with offering an enclosed object, the neighborhood is the space par excellence of identity projections (Delgado, 2007). Thus, it is useful for the early study of the relationships between colors and local groups. This research focuses on such relationship, discussing the chromatic identity of three neighborhoods in Isla Teja, Valdivia (Chile). These districts have different origins, spatial arrangements, architecture, and socio-cultural traits, which call for a cross-functional approach.

2. METHODOLOGY

In a first moment, three neighborhoods were chosen in Isla Teja: the Anwandter district (industrial origin, established as from the 1900s); Teja Sur (results from the efforts of a group of university professors during the 70s); and Lomas del Cruces (recent establishment and under consolidation).

The study required simultaneous research, considering existential and physical aspects. In addition to collecting the historical background of the island through literature revisions, the neighborhoods were analyzed in their physical dimensions, considering photographic records, sketches (watercolor), planimetry, index cards and chromatic comparisons (NCS card). Simultaneously, the existential aspects related to local history and assessments were analyzed, collecting historical files and testimonies from key informants. In addition to a simple questionnaire, eight interviews were conducted in each neighborhood (in-depth and semi-structured).

3. RESULTS AND DISCUSSION

Although the differences are clear in terms of the chromatic atmosphere, colors stay in the background when local dwellers are asked to characterize their neighborhoods. Overall, the reflection around material aspects and colors was induced in all the interviews, accounting for an actual naturalization of these elements at the discourse level. When directly asked, the respondents often made the following assertions "I like it (…) because all are almost the same …I mean, they are normal colors for a house (…) just plain and simple colors, yellow, light blue..red" (E.S., Población Anwandter, 2011), or, in one of the other districts assessed, "(white) is a color that …I don't know... What other color could be used? The wood was already too much" (H.S., Teja Sur, 2011).

However and only after insisting on the topic during the interview, certain elements that point to differences –which arise from local history and class identity– emerge.

In the Anwandter district *(originally, a neighborhood for brewery workers),* titling is an issue that marks the consolidation of the physical intervention of houses, including their color, and is considered a signal of individuality and ownership. In the Teja Sur quarter, on the other hand, keeping a restricted palette is connected with the adherence to a common vision about dwelling, which in turn is linked to the professional character of the neighbors *(mostly academicians at Universidad Austral de Chile, UACh),* in contrast with other districts in the city. Notably, in Lomas del Río Cruces, *(the original project was also developed by academicians of the UACh)* there is great stylistic diversity in terms of house designs, while keeping a chromatic unity that integrates neutral tones part of an international style (Figure 1).

Figure 1: Left, the workers neighborhood; middle, the TejaSur quarter and right, the new district.

In terms of specific practices, some colors like yellow, light blue and turquoise are a family heritage, conditioned by the access to household resources and at present, by the imposition of colors under social intervention programs that promote the homogenization of the color pattern in the district (issue that prompts differing assessments among neighbors). Simultaneously, the other neighborhoods react strongly against some of the colors used in this district, like light blue, turquoise and aquamarine, as they are associated to lower-income groups. Colors like yellow and white, however, are accepted in all three districts, as they are part of the city's shared German tradition (Cordero, 2010). Along with getting a specific palette for each neighborhood (Figure 2), the study helps in the analysis of color as a particularly useful variable when exploring local perceptions. By keeping an implicit link with the dwellers' sense of ownership, it promotes the development of identity elements that are not apparent at a first glance, but which allow for the deepening of the construction of territorial identities.

Figure 2: The cromatic palette of the workers neighborhood, based on the NCS colours.

4. CONCLUSIONS

This study aims at highlighting color in architecture and urban space, considering its presence in the daily lives of dwellers. Beyond its implicit character at the discourse level, color is an element that conveys traditions and local assessments. Therefore, exploring the relationship between color and the construction of territorial identity becomes a valuable tool to further investigate architecture and urban development topics or, in a more practical level, for the preparation of appropriate chromatic proposals for public urban projects, focused on the planning of cities that are in tune with those who inhabit them. In the targeted districts, along with establishing differences at the color pattern level, light was shed on the ways through which they link with the dwellers' assessments, so as to address a rooted sense of neighborhood ownership. This is a first analysis, but also an invitation for similar projects that contribute to the development of cross-functional approaches on the topic.

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Red and White as Expressions of National Identity: A Study on the History and Meaning of Polish National Colours and an Attempt at Recording Them in Selected Systems of Colours

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ABSTRACT

My presentation is aimed at seeking the origins and historical conditions of particular symbolism of white and red in Poland. It is also an attempt at answering the question: to what extent may such a common and universal combination of colours as white and red become an expression of specific values and the history of one nation? The following factors will be analysed: the meaning of colour in heraldics, the symbolism of the national emblem and coat of arms of the Polish state, traditional methods of obtaining various shades of red in Poland, the colours of a national costume of a nobleman and military uniforms, the role of white and red during famous historical events and attempts to formalise the notation of Polish national colours by the Polish authorities.

1. INTRODUCTION

White and red is a legible, symbolical colour combination which is easy to remember and bears aesthetic values. All these characteristics were decisive for it being used in visual communication since time immemorial, even when visual communication was not known by its present name. Cave paintings, customary outfits, talismans, writing characters, pictorial symbols, emblems and coats of arms, banners and flags are just some examples. A high position of white and red in the hierarchy of primary colours resulted in them being often used as an emblem reserved for representatives of the highest social strata, or even rulers. In the history of Poland their symbolism was closely connected with the history of the nation and state while the attachment of the Poles to white and red was the manifestation of identity and national community, especially during the times when Poland lost its independence.

2. WHITE AND RED IN EUROPEAN FLAGS

The popularity of the red colour in the European culture is traced back to the Roman times. Used during the triumphal return of the victorious chief to Rome and as a combative and distinguishing symbol of the legions in the form of vexillum – a square crimson piece of material put on a spear, it functioned as a symbol of victorious power, blood shed, triumph and peremptory power. Handing in a spear with a banner attached to it was a symbolic act of granting power. The banners of European rulers originate from *vexillo roseo imperiali* (imperial red banner) and owe their colour to the imperial right of blood, a principle of deciding about the life or death of subjects. A high position of red had its roots also in heraldics in which the colour under the name of GULES appeared in many countries as third after gold OR and silver ARGENT. The heraldic red symbolised the blood of the Redemeer, sacrifice, generosity, bravery and love. White in heraldics was the colour substituted in various situations by silver (e.g. on flags) and its meaning was equivalent to the meaning of silver symbolising chastity, eternal glory, honesty and innocence (Znamirowski 2003). The combination of white and red was a sign of bravery in heraldics, as an emblem of many families. National colours of European countries most frequently originate from the coats of arms of ruling dynasties while their symbolism was often an issue of secondary importance. Red appears on the flags of 36 out of 46 countries on our continent while white is present in 28 countries; yet the exclusive combination of red and white can be found in 7 flags only.

3. POLISH NATIONAL EMBLEM

The first insignia of power were given to the Duke of Poland, Boleslaus the Brave, in Gniezno in 1000 during a symbolical coronation by Emperor Otto III. They included St. Maurice's Spear with the red banner, later kept at the Wawel Royal Castle. Also silver coins with the image of an eagle, which later became the crest of the Piast dynasty, were struck on this occasion. The depiction of the eagle was extremely popular in Central Europe (sometimes also referred to as the aquila zone) while in Western Europen a lion was predominant among coats of arms. Both the lion and the eagle were the symbols of gallantry, strength and bravery. In this sense, the symbolism of the heraldic red colour of the background was supposed to emphasise the features of an eagle.

The symbol of an eagle as a sign of statehood appeared on the emblems of Poland, Germany, Austria, Moravia, Silesia or Russia. Yet it should be emphasised that these eagles differed by both form (single- and double-headed eagle) and, more importantly, colour. This fact was highlighted in the legend on the establishment of Gniezno, the first capital of Poland, in the place where a nest of a white eagle was found, as noted for the first time by chronicler Jan Długosz. The symbol of a white eagle on the red background was shown on the coronation sword of Polish kings called *Szczerbiec* (Jagged Sword). Subsequent iconographic sources demonstrate the description of the Polish royal banner at Grunwald, during the largest medieval battle that took place in the Polish lands in 1410. It was bloody red, with an emblem with a crowned white eagle. Such an emblem was to remain the universal sign of the Polish statehood for centuries to come.

However, it must be stressed that the importance of white and red in medieval Poland was not greater than in neighbouring countries. The Danish and Austrian flags are older than the Polish one and their appearance is associated with famous legends. Red and white were the colours of federated states, German cities and Swiss cantons. Red and white were specific for cities belonging to the Hanseatic League: Hamburg, Bremen, Lübeck, Rostock, Elbląg, Gdańsk, Tallinn, Riga.

One may risk stating that the combination of red and white was a characteristic element for the countries of Central Europe, which was evident in the national colours of Poland, Czech Republic, Austria, Switzerland and to a certain extent also Slovakia, Slovenia and Croatia (Pan-Slavic colours).

4. POLISH COCHINEAL

The etymology of the name of the red colour in Polish is attributed to the word *czerwiec* meaning Polish cochineal – *Porphyrophora polonica,* an insect which was the source of a crimson dye used to change the colour of fabrics in the Middle Ages. The name of June, which was the month of collecting larvae used to produce this dye, also originated from the name of this insect. In the 15th and 16th century, Polish cochineal was one of the major exported goods (along with salt, grain, wood and amber). The red colour obtained as a result of dying with Polish cochineal had an intense crimson hue, at that time considered to be the most precious one. It was the colour of knighthood and later of rich noblemen. Peasants used madder *Rubia tinctorum* to dye their own clothes; this dye gave fabrics warmer colours but with much poorer intensity and durability (Tokarski, 2004).

Trade in Polish cochineal collapsed in the first half of the 17th century in consequence of the importation of cheaper cochineal giving faster colour – *Dactylopius cacti* brought from South America. However, the attachment of the Polish nobility to crimson red remained unshaken, which was also connected with the development of a specific style of Polish national costumes that differed considerably from European ones in the 17th century. At that time, the Polish nobility tried to prove its descent from the mythical tribe of the Sarmatians living in today's Ukraine and Moldavia in the Roman times. The colourful Sarmatian outfit consisted of a long buttoned garment called żupan and an outer robe called *kontusz*. This attire, usually red, was recorded on numerous portraits. It was worn by the richest representatives of the nobility called "Crimsons" (*karmazyni*) in contrast to petty "grey nobility" (*szaraki*) and burghers (łykowie) (who wore straw-coloured attires). In 1776 the Parliament (*Sejm*) sanctioned civil uniforms which included żupan and *kontusz* in colours determined for each voivodeship. In most voivodeships, various shades of red, combined with dark blue and white, were chosen as basic colours for *kontusz* (Sieradzka, 2003).

5. PATRIOTIC COLOURS

In the second half of the 18th century, Poland found itself in a difficult political and economic situation. Numerous wars and the anarchy destroying the country led to the disaster of partitioning the territory of Poland by its three neighbours: Germany, Russia and Austria. Before losing independence, the Polish parliament tried to save the country from the fall by proclaiming the Constitution, the first one in Europe and the second one worldwide (after the American Constitution). It was supposed to lead to the reforms necessary for the state: improvement of the situation of burghers and peasants. Attires: women wearing white robes with red sashes tied around and men wearing white and red sashes became the visual sign of patriotic moods. Unfortunately, the joy of proclaiming the Constitution did not last long and soon after Poland lost independence for the next 123 years. But the red and white colours remained the symbol of Polishness in successive national uprisings: the November Uprising (1831), the January Uprising (1861), the Warsaw Uprising (1944), appearing as ribbons, armbands, sashes or flags. Foreign authorities prohibited wearing these colours and failure to observe this ban resulted in a range of repressions. The symbolism of white and red, first of all, emphasised the elements of struggle for liberty; red meant blood shed and suffering while white denoted innocence, honesty and purity. After the defeat in the January Uprising, national mourning lasted for several years and it was expressed by wearing common black outfits and patriotic oxidised iron jewellery.

5. NATIONAL RED AND WHITE

In 1919, the Parliament (*Sejm*) of the restored Second Republic of Poland determined the appearance of the national flag. In the brochure published in 1921 titled *Emblem and Colours of the Republic of Poland*, Stanisław Łoza described the Polish red colour as the "colour of venous blood." (Łoza, 1921) This was particularly important in the situation of conflict with Bolshevik Russia that also used the red colour. However, in case of Russia it was 'communist' red, with the fiery, aggressive tint. Unfortunately, the next decree of the President of

Poland of 1927 changed the red colour from the carmine to the scarlet hue, which inspired protests of some Polish specialists in heraldry. After WWII, the scarlet version of the red colour was maintained, which was justified after the take-over of power by the communists. In 1980, the Polish Parliament passed the ordinance specifying Polish national colours in the CIELUV system (Dziennik Ustaw RP, 1980). After the collapse of the communist system in 1989, there was a spontaneous comeback to traditional Polish symbols: crowned eagle and crimson red. But the problem was treated by the Parliament as marginal and the system adopted in 1980 was maintained.

6. SPECIFICATION AND NOTATION OF NATIONAL COLOURS

The development of colour systems and various methods of measuring and systemising colours in the second half of the 20th century caused that many states adopted the notation of national colurs in several different colour systems. This resulted from the fact that while in the past national colours appeared mainly on fabrics (flags), the contemporary development of printed and electronic media makes their application much simpler and common. In 2011, in the course of preparations for the Polish presidency of the European Union, the Ministry of Foreign Affairs took efforts to find equivalents of Polish white and red in RGB, CMYK, Pantone and NCS systems. The task turned out to be extremely difficult, both due to the discrepancies between individual systems and too great a difference between the statutory notation of colours and their equivalents. The finally adopted arrangements were restricted to the notation in CMYK and RGB systems, and their character only approximate to the original was emphasised.

6. CONCLUSIONS

The problem of a distinct specification of the shade of national colours remains a significant element of respect for the national history, in spite of the fact that it was disregarded by successive authorities and institutions. As the history of the Polish national colours shows, a specific hue of red and white may both be important from the semantic perspective and differentiate individual countries which use these colours to mark their identity.

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Colour Expectations of Fiction Genre Book Covers

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ABSTRACT

This research identified the colours people expected to find on the book covers of three fiction genres: Romance, Science Fiction, and Mystery/Thriller. A survey of 180 participants assessed their colour expectations. The results confirmed a number of popularly-held colour-genre associations, while also highlighting some unexpected associations. The colours nominated most often for Romance covers were in the red to pink range leaning towards purple; these colours were inversely related to the colours most often chosen for the Science Fiction colours. The colours nominated for the Science Fiction and Mystery/Thriller covers were very similar: black, white, greys and dark blue. Significantly, the nominator's gender appears to have no bearing on the colours nomination for each genre. Additionally, there was no link between whether the nominator read the genre or not.

1. INTRODUCTION

The cover of a book serves two roles: to protect the inside pages, and to indicate the content; it is like a miniature poster. Moreover, it is a promise made by a publisher on behalf of an author to a reader (Haslam 2006). While the old adage "never judge a book by its cover" is a true statement, Bhaskaran (2006) argues that, when it comes to publication design, first impressions last. Indeed, whether in an e-bookshop or on a shelf, the cover is the first thing you see. The cover may entice you to open the book or walk away. For designers, authors and publishers the cover is crucial; it provides the one opportunity to sell the work to a reader.

A well-designed cover communicates, clearly and succinctly, what the publication is about. Therefore, the cover of a fiction book should be a gateway into the tone and content of the text. It should link the author's words and imagination with the reader's love and enthusiasm for escapism, adventure, romance, and a different world to the one in which they live (Haslam 2006, Pite 2003).

A colour can convey a myriad of emotions and feelings, which instantly capture attention or give out a warning. It appears that people recognise and react to colour from a very early age and in many settings. Associations are made with certain colours that stay with us through our whole lives. Consequently, colours can have a variety of meanings and can be linked to different emotions (Bhaskaran 2006).

Colour is, therefore, one of the most important tools a graphic designer has when creating a book cover. Within graphic design, including cover design, various paradigms of colour usage have developed and evolved. While there is little overall agreement, Bonn (1982) suggested that the primary colours of red, yellow, and blue are the most favoured by designers, and Western book covers often have brown backgrounds. In contrast, horror and gothic tales tend to have black and dark blue backgrounds, with purple and green being seldom used.

This study examined the popular expectations of book cover colour for selected genres through a survey of university staff and students from a wide range of ages and a variety of cultural backgrounds.

2. METHOD

A two-part survey was used to collect the data. The first part surveyed participant's relevant details (gender, age, etc.) and reading habits; the second collected data specific to colour and genre expectations in regard to fiction books.

Part 1 sought to obtain an overview of the participant's characteristics, and to see if their colour expectations were related to their background. Thus, any relationship between the nomination of colours and characteristics of the readership were determined.

Part 2 required participants to select colours that they associated with each of 3 genres (Science Fiction, Romance, and Mystery/Thriller). From a palette of 25 colours and they circled up to five colours they associated with each genre. If no exact colours were available they circled the nearest colour/s (without ranking).

The colour palettes consisted of 18 pure hues (with 100% saturation and 50% lightness); these included the recognised primary colours of both additive and subtractive mixing (red, green, blue, cyan, magenta, and yellow); and 12 other pure hues separated by distances of 20° or 30° around the colour wheel. The colours yellow and purple, where the distance was only 10 degrees, revealed a greater apparent difference in these colours for a given offset around the colour wheel. A set of 4 colours crossed the spectrum from white to black in equal steps. The last 3 colours included impure hues, such as brown and maroon.

Each survey had three palettes, one for each genre being tested (with the colours arranged in a square array of 5×5). While the palettes colours consisted of the same colours, they were in a different randomised sequence to avoid bias.

2.1 Conduct of the Survey

The survey was conducted in April and May 2010, on Griffith University campuses in south-east Queensland, Australia. Both cold face-to-face contact and familiar face-to-face contact were used to recruit the 180 participants, from various age groups and cultural backgrounds.

3. RESULTS AND DISCUSSION

3.1 Colour Selections

The participants nominated their colour expectations for genres with which they were familiar. Science Fiction received a total of 793 votes, Romance 785, and Mystery/Thriller 788 votes. In each of the genres, all colours received at least 1 vote. As some participants nominated more (or less) than 5 colours for some genres, the number of responses, in total, was not 2700 (180×5×3), but 2366. In the Mystery/Thriller genre black received the most votes (154) of any colour for any genre. In Romance the top 6 voted colours were in the red-pink range, and white. Science Fiction and Mystery/Thriller colours were similar, both having black, white, greys, and royal blue in the both of their 6 top-voted colours.

A rank analysis of the order of nomination of the colours, using correlation and other analyses, showed a significant inverse relationship between nomination frequency for Science Fiction and Romance ($p < 0.05$), and a significant positive relationship between the frequency of nominations for Science Fiction and Mystery/Thriller ($p < 0.01$). There was no significant correlation between colour nominations for Romance and Mystery/Thriller.

3.2 Analysis of Concordance of Colour Selection Preference

An analysis using Kendall's coefficient of concordance rank correlation coefficient indicated that the participants ranked the colours as more similar than would be expected if the choices were made at random (Siegel 1956). The analysis yielded a W of 0.31, which for the 25×3 table yielded χ^2_{24} of 22.1 ($p = 0.57$) i.e. there was little or no overall commonality between the rankings of the three genres. Next, the pairwise commonality ranking was computed (Siegel 1956). The results showed that for the pair Science Fiction and Romance, the values obtained were $\tau = -0.374$, $z = -2.619$, $p = 0.0088$ (i.e. Science Fiction and Romance had significantly negative rankings); for Science Fiction and Mystery/Thriller $\tau = 0.419$, $z = 2.939$, $p = 0.0033$. Thus, Science Fiction and Mystery/Thriller followed similar rankings); the pair of Romance and Mystery/Thriller values were $\tau = -0.078$, $z = -0.544$, $p = 0.59$ (i.e. the similarity in the rankings was little better than would be expected if the colours were nominated at random).

As the ranking of the little-nominated colours could be seen as of little importance, when comparing the rankings more weight might be given to the rankings of the commonly-ranked colours. Therefore, Top-Down Concordance was used to estimate the similarities in ranking (Zar 2010). The concordance score was $C_T = 0.436$, χ^2_{24} = of 31.4, $p = 0.14$. Hence, there was no significant similarity in the ranking of the commonly-nominated colours between the three genres. Thus, a paired comparison was again undertaken. The comparison of Science Fiction and Romance yielded $r_T = -0.295$, $z = -1.435$, $p = 0.15$; i.e. there was no real association in the rankings. Evidently the negative association found earlier can be attributed to the inclusion of the lesser-ranked colours. This outcome was not entirely unexpected.

If there was a strong negative relationship between the rankings, then the infrequently nominated colours in one genre were the frequently nominated colours in the other. However, paying little regard to the infrequently nominated colours will weaken or hide this negative association. In the comparison between Science Fiction and Mystery/Thriller, there was a strong commonality in the rankings of colours ($r_T = 0.799$, $z = 3.912$, $p = 9.1\times10^{-5}$). Thus the ranking of frequently-nominated colours was strongly similar in these two genres. In the final comparison between Romance and Mystery/Thriller ($r_T = 0.042$, $z = -0.207$, $p = 0.84$), there was no ranking commonality.

While the number of participants surveyed was sufficiently large that analysis of the sample partitioned was viable, the wide range of cultural backgrounds meant that such groupings were too small for any confident analysis. However, the results are generalisable across a multicultural population. Further analysis indicates that the popular conceptions in relation to fiction book cover colours and genre were not influenced by gender or reading avidity. Hence, the participants' exposure to such genres, no matter what format, may have helped to establish such colour perceptions or expectations.

4. CONCLUSIONS

This study examined the popular perceived expectations of the colours used on the book covers of the three genres: Science Fiction, Romance, and Mystery/Thriller. The findings show that the colours nominated for Science Fiction and Mystery/Thriller covers were very similar, particularly for the most-often chosen colours: black, white, greys and dark blue.

In contrast, the colours nominated most often for Romance covers resided in the red to pink to purple range, and white. Interestingly, the colours chosen most often for Romance were directly inverse to the colours most often chosen for Science Fiction. Therefore, the highly ranked colours in Romance were the lowly ranked colours in Science Fiction. Unexpectedly, the gender or reading avidity did not influence the participants' colour genre expectations.

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Colour Harmony or Not?

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the colour of culture

ABSTRACT

When studying colour combinations you always ask: What is a beautiful colour combination and what is not? Can anyone tell? This question is of interest to almost everyone today but especially for architects and designers creating environments or products for people whether at work, in public spaces or in our homes. Choosing the right colour combination is a necessity to achieving desired effects in colour-scheming and design. There are of course no given rules concerning what is right or wrong and what is beautiful or not, but some guidance can still be offered on the subject of colour-scheming. There is knowledge to be gained from our colour research and theories. A lot of different theories have been developed to find the beautiful colour combination. Some of them have their background in pigment mixtures like Goethe, Itten, Chevreul and some in visual properties like Kobayashi, Nemcsics, Munsell, Ostwald, and NCS. However colour harmony or not depends first of all on the actual context.

1. INTRODUCTION

Studies of human opinions of individual colours are of limited usefulness, in that a colour is never seen in isolation. Colours always occur together in one form or another. Our sense of vision is constructed in such a way that it demands variation in colour stimuli in order to give us colour perceptions that tell about the environment.

The "laws of harmony" have mostly been based on colour mixing and the complementary colour theories, as for example: "Colours which are opposite each other on a colour circle must (for this reason) be beautiful together"; "Colours which are each other's after-images must together form a whole and thus be beautiful together, because the eye is so constructed" (Sällström 1996, Itten 1969). The colours in these different theories, like Goethe, Itten, Chevreul, are not defined other than by colour words, pigment names and printed pictures. This makes it difficult to know exactly which colour they actually meant. It is not simple to get that beautiful grey by mixing red and green.

An harmonious combination has parts which go well together and are in proportion to each other. If two or more colours harmonize with each other they fit in well with each other. The different colour harmony models analysed in this paper are Itten, Le Corbusier and NCS.

2. ANALYSES OF DIFFERENT COLOUR COMBINATION MODELS

The NCS system has been used as a language between the different colour harmony theories and methods. A visual colour system gives possibilities of identifying characteristic similarities and relations between colours and referring all the colours of the colour space to a limited number of categories. The structure of the NCS System affords great opportunities for testing and analysing different colour compositions by ordering and compiling the colours and studying similarities and relations between them. The system will help to study expressive potential of different colour constellations. The concept of colour categories indicates that a number of colours in one way or another are perceived as similar, though they may in another respect be supremely different. The colour space enjoins a division onto colour categories according to which of the elementary colour properties constitutes the main property, the absolutely dominant property, and which are subsidiary properties, the main and secondary attributes. The partition of the three-dimensional colour space into primary colour category areas in relation to nuance and hue can be illustrated in two dimensions in the NCS Colour Category Scheme.

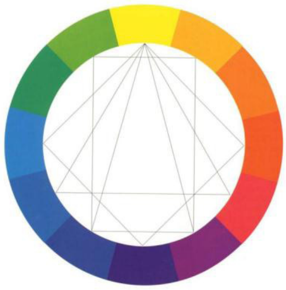

Figure 1: Itten's 12 colours analysed and defined in NCS. Starting with yellow 1. G88Y, 2. Y24R, 3. Y47R (orange) 4. Y77R, 5. R05B (red), 6. R42B, 7. R58B (purple), 8. R64B, 9 R78B (blue), 10. B75G, 11. G01Y (green), 12. G33Y.

2.1 Itten

Itten´s theory of colour harmony (Itten 1969) has its starting point from the three primaries yellow, red and blue which are placed in an equilateral triangle. He developed a colour circle with 12 colours by mixing the three primary colors. In the circle geometrical figures can be turned to different starting positions for a harmonious colour combination. The colour circle was developed by mixing the colours with white and black to achieve the contrast between light and dark. The twelve colours are only defined with the colour names and the printed pictures. An attempt to analyse these 12 colours (Fig. 1) has been done by measuring the colours in "The art of colour" from Fifth printing1969.

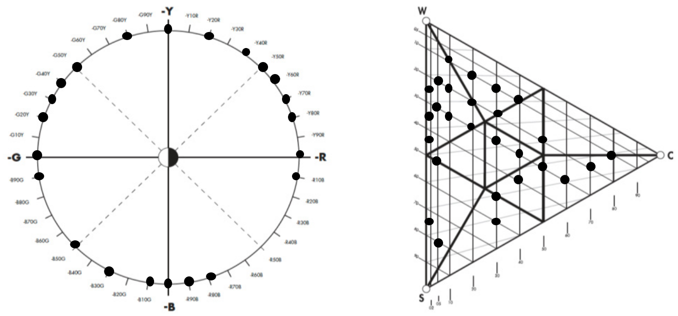

Figure 2: Le Corbusier Chromatic Keyboards in NCS colour areas.

2.2 Le Corbusier

Le Corbusier is probably the most influential and important architect during the 20th century. The colour palette of Le Corbusier is today an inspiration to many colour designers. At the time that Le Corbusier presented his colour palette only traditional and natural pigments were available. The Le Corbusier Chromatic Keyboards 1931/1959 has been analysed by Daniel Tobler (2003) in NCS and CMYK. This collection includes 43 different colours and they are arranged in 12 different colour palettes named: Space, Sky, Velvet I and II, Masonry I and II, Sands I and II, Landscape, Checkered I, II and III.

2.2 The NCS Colour System and Colour Similarities

Studying the NCS Colour Space, one finds a number of properties which are easily identifiable as similarities of hue, nuance, blackness, chromaticness, whiteness and saturation. One can easily study how these similarities between the colours affect the expressive quality of a colour composition. These visual colour attributes have become important tools in the colour design process.

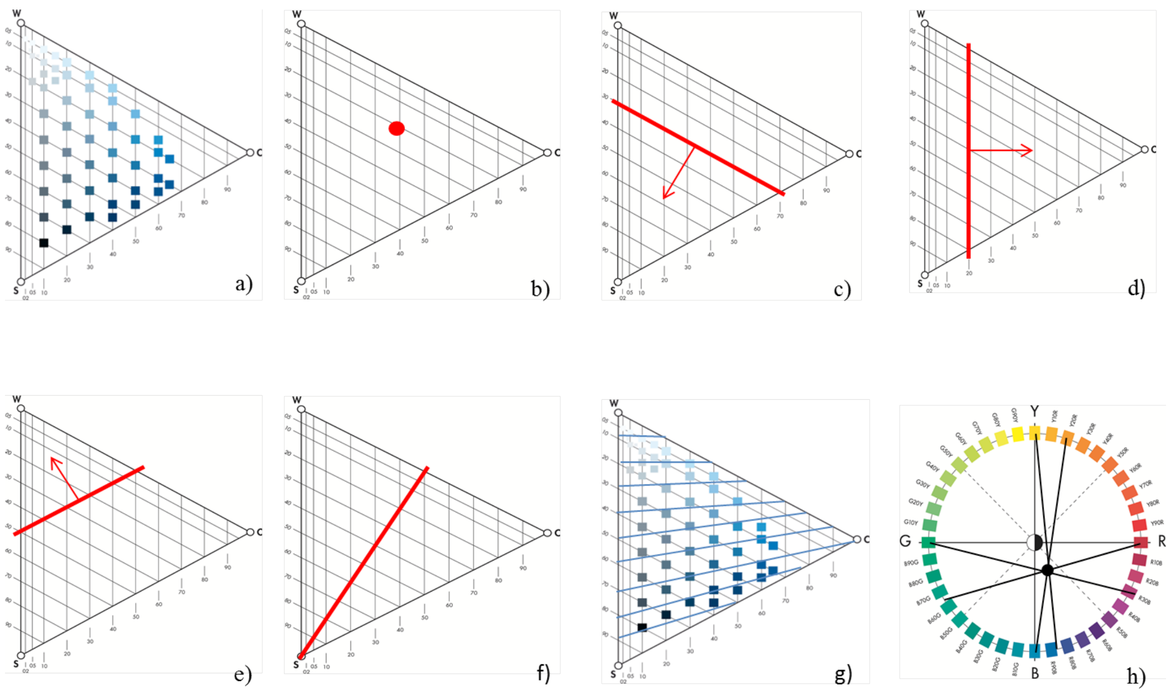

Figure 3: NCS Similarities: Same hue a), Same nuance b), Same blackness c), Same chromaticness d), Same whiteness e) and Same saturation f). Colours with the same lightness g), Perceived hues of complementary colour stimuli h).

Studies by Hård/Sivik (1989) suggest that compositions of colours with one or more of these formal similarities, figures 3a-f, also tend to be more highly appreciated. A further similarity between colours which can be illustrated in the NCS descriptive colour model concerns lightness, figure 3g. Compared with other colour difference parameters, it is lightness differences which are of the greatest importance when working in a patterning context. Great contrast in lightness gives a clearly distinguishable pattern and a small difference in lightness makes for an indistinct pattern.

Complementary colours is a concept which is considered to play an important role in colour aesthetics but which is defined in many different ways in literature and reference works. Opposite colours as per NCS is an alternative definition of the term (chromatic) complementary colours based on simultaneous presence in a colour gestalt of all four chromatic elementary colour properties – yellowness, redness, blueness and greenness. In the NCS Colour Circle, figure 3h, straight lines are drawn between the pairs of perceived hues of complementary colour stimuli, they all intersect in a point with the approximate position chromaticness = 20, hue = R75B. The lines indicate areas where the perceived hues of the complementary colour pairs are identical with opposite colours according to NCS, opposite colour ~Y20R will be ~B.

Three main dimensions to be able to describe and analyse a "colour gestalt" has been identified by Hård/Sivik (2001) in a Colour Combination Model related to the NCS Colour System. The three main dimensions, each with three sub factors, to categorize colours are; 1) Colour Interval with Distinctness of border, Interval kind and Interval size; 2) Colour Chord with Colour complexity, Chord category and Chord type; 3) Colour Tuning with area relations, Colour relations and Order Rhythm. The Colour Chord describes the complexity and concordance among the colours, how they visually "sound together" in analogy with a musical chord. The different complexity grades are shown in the Colour Hexagon.

4. CONCLUSIONS

A visual colour system describes how a colour looks like. Colours that have some elementary attributes in common tend to be more harmonic. A visual colour system like NCS is helpful to find these combinations. It is a professional tool for the colour designerto quickly find harmonious colour combinations and can bring some order to the infinite number of possible combinations of colours. It does not take away intuition and creativity which needs some systematically way of working when investigating different colour combinations.

A colour system does not necessarily give pretty colour combinations, but it does provide a tool for experimenting with different colour harmonies. With a visual colour system it is possible to test and investigate the effects of different colour combinations and document and analyse them. This will give an overview of the different choices and facilitates which evaluations of combinations lead to a new content and which are less important.

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fashion

Cobalt or Cerulean? Interpreting Colour Trends for the Fashion Industry in Smaller Markets

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ABSTRACT

The Canadian apparel industry faces many difficult decisions during product development, and selecting a colour palette for an upcoming season can be a significant challenge. With no specific Canadian colour forecasting services available, Canadian trend directors must rely on European and American forecasts for their colour trends. This study on colour trends and preferences demonstrated how colours that are forecast for the United States and Europe are adapted for Canada and the diverse target markets within it. Six case studies based on interviews with trend directors from Canadian retailers explore the methods used to develop seasonal colour palettes. These case studies reveal each retailer's customers' attitudes towards colour trends and colour preferences, and then compare them to the rest of the retail market. The results will allow Canadian fashion professionals – and those working in small markets anywhere – to better understand how to develop seasonal palettes for their customers, thereby increasing sales and profit.

1. INTRODUCTION

Fashion trends and customer preferences are very important elements in the development of fashion products. Fashion trends are a reflection of what is current, and they are influenced by factors that include social, political, economic and cultural changes as well as pop culture and technology (Cho and Lee 2005). Fashion forecasters pull emerging trends out of public information by becoming sensitive to directional signals, and are always looking for new, fresh and innovative ideas (Brannon 2010). Fashion forecasting indicates what the influential trends will be for an upcoming season, and can extend across various categories of fashion products, including textiles, accessories and colour. Forecasts are usually presented in a book or online, and designers purchase them for use both as a guide to creating marketable products and as a source of inspiration. As these trends are just suggestions, it is up to designers, buyers and other industry professionals to interpret the predictions and tailor them to their target markets (Wilson, et al. 2001). The research discussed in this paper addresses the development of colour palettes for target markets based on colour trends.

Colour indicates the mood of a season and is one of the most visible signs of change within the supply chain; therefore, a well-developed colour palette is essential to product development (Grove-White 2001). It sets a standard throughout the supply chain, and ensures that all the various components and materials will match within the product, and with the other products on the sales floor. For example, textile production sits at the beginning of the supply chain and fabric producers must anticipate consumers' needs well in advance in order to complement a designer's final product. The textiles can be produced as early as two years before the designer's final product is sold to the consumer, which means that colour forecasts must be available before textile production begins (Rinallo and Golfetto 2006).

2. METHOD

The current research is an empirical study of colour forecasting in the Canadian fashion industry. Using qualitative methods, the study explored designers' interpretations of a trend publication's suggested colour forecast in order to understand how a colour is adapted to fit the needs of various specific target markets' needs. Six case studies facilitated understanding of how these palettes had been adapted by a variety of Canadian retailers.

The population sample included major Canadian retailers that had a large vendor base. This selection process was used because in a department store or major retailer, the final decisions on product attributes are made by the buyer (Wilson et al., 2001). Such retailers also set a colour palette for their private label products that many different vendors follow. Department stores act as gatekeepers, deciding what products are available to consumers, and one retailer often services a few different target markets.

The Canadian retailers that were included in the study have several stores nationwide and cover a variety of price points, demographics and psychographics. This study therefore provides many examples of different target markets within the whole sample. As there are no trend-forecasting publications targeted for Canadian consumers specifically, this study provides insight on how colours that are forecast for the United States and Europe are adapted for Canadians. The principal research methods were semi-structured, face-to-face interviews, and visual analyses of colour palettes. The interviews were done in person at the corporate offices of each respective department store, and audio recordings of the interviews were transcribed. Interviewees all signed a consent form that was approved by the Ryerson University Ethics Board. Interviewees were asked to describe their customers, customer preferences, how they interpreted the forecast from the trend publication they use, and how they adapted it to their target markets. They were also asked specific questions about the additional resources they use for trend information, their merchandising strategies, and how their market segments compare to the global marketplace. Gaining a thorough understanding of how these retailers developed their own palettes provided useful information on how each market segment responds to colour in women's and men's apparel.

Based on the responses from each retailer, common themes were detected within colour preferences and market segments. The methods of colour palette development were compared and contrasted based on the way that retailers interpreted trend services and their retail success with particular colours. Each retailer showed their colour palettes for their market segments, and explained where the colour standards came from and why they chose that particular shade for the final palette. If a retailer had more than one market segment, they discussed the differences in tones between the palettes for each market segment. The end results will provide guidance towards colour preferences for different types of consumers, and help vendors work within their supply chains more effectively.

3. RESULTS AND DISCUSSION

The results from the six case studies consisted of three themes that influenced the way that Canadian consumers responded to colour trends. Canadian retailers have noticed an increasing trend towards menswear becoming more fashion-focused (Naderi, 2013), which in the past has tended to be conservative when it comes to innovation. Retailers that are not as fashion-forward may choose to mute the colours from the trend service or introduce the fashion colours one season later. However, it has been found that vendors that do business in both Canada and the United States sell more colourful product to Canadian retailers than they do to American retailers. For the womenswear market, Canadian retailers have not had much success with navy blue but have better sales with shades of dark blue that go well with black. The results from the case studies show that suburban middle-aged female customers, regardless of how fashion forward, prefer clean, brighter colours. Due to the loss of pigment with aging, those cosmetic shades have the ability to enhance a woman's appearance. Research has shown that younger consumers are more likely to purchase colours because they are trendy while older people will choose certain colours because they feel that it will compliment them (Kim, Fiore and Kim 2011).

A retailer from the case studies receives colour palettes from its American division to use as a reference but it still develops its own palettes to suit their Canadian market. From past experience, some of the colours that are on the American palette do not work for the Canadian population because the ethnic mix is different. The U.S. has a higher Latin and African American population whereas Canada has a higher Asian, Eastern European and British population, for example. The differences in the skin tones between the two countries can change which colours are more flattering. The American colour palettes often have a mustard and peach family of colours which has not sold well in Canada. Canada is multicultural, so they will include a bit of those colours in its seasonal palette but not offer as many products in those colours. Research has shown that 40% of the Canadian female population looks best in cool and intense colours, 22.5% in cool and soft, 22.5% in warm and soft and 15% in warm and intense colours (Chu and Nemeth 2010).

The results from the interviews showed some commonalities in colour preferences and their customers' responses to colour trends. Each retailer had a unique approach to developing its colour palettes with its target customers in mind. Almost all retailers were faced with fashion trends having a shorter lifespan than in previous years, a demanding customer and a constant desire for newness. These challenges applied to many different target markets, making these issues almost universal. Fashion trends are a reflection of society which explains the homogenization of colour across retail at all price points, as well as the limited number of trend services. What makes each retailer distinctive is its interpretation of the colour trends and the way that these trends are customized for the retailer's target markets. Retail success in Canada is dependent on the proper prediction of colour trends for the Canadian market, and retailers' ability to drive sales through effective merchandising that satisfies customers' desire for innovation.

4. CONCLUSIONS

Colour trends represent a symbiotic relationship between retailers and customers that reflect customers' aesthetic and satisfy their desire for innovation while offering high profit margins to the retailer. Colour trends represent the consumer's current taste and what the consumer will want to purchase in the future, while also reflecting fashion's ephemeral nature. Fashion is both a high profile and economically important industry where fashion and colour trends heavily influence sales. The consumer's involvement in the industry plays an important role in maintaining interest and spending. Regardless of whether they are innovators or late adopters, all consumers play a vital role in supporting the industry and the diffusion of fashion (Naderi, 2013).

Canada faces many struggles with its industry catering to such a small market. The lack of trend services for the Canadian market specifically leaves trend directors and other fashion professionals debating between an American and European aesthetic. In addition, most retailers need to appeal to a broad demographic in order to create a large enough market share to support their business. There is vigorous competition among retailers and the infiltration of foreign retailers, particularly American, dilutes the amount of product that is targeted towards a Canadian audience. Canada's small industry and the limited amount of domestic manufacturing may be the reason for the lack of academic research on its apparel industry (Campaniaris et al., 2011). However, two of the retailers in this study still manufacture some of their products domestically, as do other Canadian companies that produce higher quality goods that sustain the local manufacturing sector.

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Sustainable Colours and Biotechnology in the Fashion and Textile Industry

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ABSTRACT

Textile sustainability problems are often associated with the dyeing methods applied by the fashion and textile industry. These issues are strongly related to the usage of non-renewable resources as well as the effluents of such finishing processes that present high levels of toxicity and risk for the entire ecosystem. Through an extensive study on various fields such as Biotechnology History, Ethnography, Biology, Archaeology, amongst many others we gathered information regarding natural coloured compounds, colour sources (plants, animals and microorganisms), ancient and modern techniques of extraction and application as well as advantages and disadvantages of dyes (natural and synthetic), etc. This study shows the evolution of colour in the textile industry. It also reveals that the revival of natural dyes in addition to cutting edge technologies such as biotechnology allows for an industrial feasibility. Results indicate significant reduced environmental impact and strategies for sustainable development.

1. INTRODUCTION

Since young age we are surely conditioned to react to colours in both emotional and psychological ways. Aware of colour influence over the consumers, textile and fashion industry explore this aspect in great detail, spending massive amounts of energy and money in the pursuit for the perfect colour. This is crucial so the product successfully sends an intended message in order to increase sales. Fashion wouldn't be such a major phenomenon without dyeing development and its techniques. By reconstructing its history and evolution we can better evaluate their sustainable potential as well as realize if they contain key answers for current or future issues that seek resolution in the fashion and textile industry (Hamburger, 2002).

Natural dyeing was always of major importance until the middle of nineteenth century when the first synthetic dye was discovered (Garfield, 2002). This encounter led to the gradual abandoning of natural dyes usage due to their high prices and rather complex technologies involved (often characterised by lengthy procedures and a higher level of difficulty regarding methods of extraction and limited shades and fastness). Synthetic dyes offered industry a great variety of colours, great fastness properties, plus they were cheap. This innovation made possible the usage of textile dyes in bulk, however, the production and application of some of them represent severe ecological and toxicological risks. This aspect is certainly one of the most serious problems in the textile industry, seeking for an urgent answer. Alternatives must be discussed.

2. METHOD

For deeper understanding on relevant subjects, the methodology used for this study consists essentially on the analysis of scientific papers and books (primary and secondary research).

Documents include articles on many subjects in fields of knowledge as different as design, history, ethnography, anthropology, chemistry, biology, among many others; these documents were imperative for the identification of different dyes; by crossing different topics we were able to gather data regarding dye's bio resources, provenience, extraction methods, ancient techniques, procedures of application, possible shades and evolution. This research covered developmental stages of many different civilizations (until the 21st century) and reflects upon many technologies applied involved in dyeing procedures or its evolution and enhancement.

3. RESULTS AND DISCUSSION

Guidelines for textile industry by the pollution control boards question their sustainable practices. As a highly competitive business, the prime concern of textile industry is to develop greater awareness of quality and sustainability while effectively responding to industry and consumer's demands. Innovations in its procedures are imperative for sustainable strategies to be implemented.

The production of dyes is an indispensable process within the textile industry success. Besides the print and pattern, consumers demand for basic characteristics in textiles. These must resist to the agents that cause colours to fade. Textile dyes must then guarantee colourfastness. They must, simultaneously, be cost-effective. Despite the many benefits, the production, application and usage of certain textile dyes are not safe for consumers (Clarke and Anliker, 1980) and for the environment (Clarke and Steinle, 1995). The effluent textiles derived from their usage contain chemicals are harmful, toxic, carcinogenic, mutagenic, corrosive, and irritant; some are known hormone disruptors, whilst others can affect the reproductive system. Many don't break down in the environment, but instead build up into the bodies of animals and humans, generating mutations (Dirty Laundry, 2011). The use of some synthetics dyes carries severe risks for consumers. These are related to length of exposure, oral ingestion, skin and respiratory tract susceptibility (Clarke, Steinle, 1995). Recent changes in legislation plus emergent awareness of consumers triggered a preference for natural quality products (Luxury Fashion, 2009), which led to an awakening interest for natural colour compounds.

Natural dyes are perceived as less harmful for the environment due to its biodegradable nature, therefore safer for consumers and ecosystem in general. Studies reveal certain natural dyes are of great efficiency regarding to colourfastness and UVR protection (Kozlowski, Zaikov and Pudel, 2006). Furthermore, some possess antimicrobial (Prusty, Trupty and Das, 2010 / Singh, et al. 2004) and anti-inflammatory properties (Hamburguer, 2002). Their application is more frequent within brands that embrace principles of *Slow Fashion*; initial problems related to the scarce usage of natural dyes are often associated with lack of knowledge on resources, extraction processes and dyeing methods (Shamim and Karmakar, 2006). Naturally, these compounds are still limited in quantity and thus remain expensive.

Biotechnology is particularly important when analysing the evolution of dyeing. By allying ancient knowledge and innovative methods, dyeing processes may be improved; research indicates positive results of great quality considering the purposes of industry regarding colourfastness (Vankar et al. 2008). Additionally, through genetic engineering, it is possible to enable an organism to produce large quantities of a certain coloured compound of interest (Ratledge and Kristiansen, 2001/Hasseloff, 2012) reducing the incidence of ecosystem damage caused by dyeing and finishing procedures. Also it is possible to produce natural dyed fibres with much more convenient colour shades for the industry (Chen et al., 2007) eliminating the dyeing process (Santos, 2010). Furthermore, experiments still need to be made in order to quantify and understand the dye potential of these bio-dyes, though ethical questions are likely to be raised (Ginsberg, 2012).

4. CONCLUSIONS

Both natural and synthetic dyes possess advantages and disadvantages when applied industrially. Natural coloured compounds do not always guarantee infinite shades of colour and large quantities of material. They are also expensive due to their rather complex extraction methods. Therefore, natural dyeing cannot be applied on a large industrial scale. Some synthetic dyeing substances are related to toxic and ecological issues, which must be contained. Some authors defend that these are issues that can be circumvent by the use of sophisticated technologies such as modern biotechnology.

Natural dyeing is associated with green methods. They possess a biodegradable nature and less toxicity and fair fastness properties. Additionally they hold UVR protection and medicinal properties. Surely natural dyes need to be explored in greater depth. Biotechnology's application in the textile and fashion design sectors suggests methods that result in less waste for the ecosystem and use less energy and water. Despite being such a radical form of approach, it is a promising technology to pollution's prevention and decrease, biodiversity conservation and cost reduction. In sum, this means that the application of natural textile dyes could be done in bulk and would be, therefore, feasible on an industrial scale.

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Colours in Nature as a Source of Fashion Designers' Inspiration during the 21st Century

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ABSTRACT

Colour is one of the most important elements in Fashion Design, It affect in the consumer's first response about the fashion collection. Colour in Nature is one of the most important sources of inspiration for the Fashion designers. This research based on studying the colour in nature as a rich source of inspiration; how fashion designers adopted the colours in nature in their collections during the 21st Century, what are the common colour schemes in Fashion Design, Also how can we create illusion by colours to increase or decrease the visual size to the body, and to show the aesthetic features of the body and draw the eyes away from the body defects. The research also presents how we can use colours to achieve the principles of design like Rhythm, Contract, Harmony, and Emphasis in the apparel. The research presents some of the fashion designers collections who depends on colour in Nature as a main source of inspiration; analyze the fashion collections for the international fashion designers and define the colour schemes which they used and how it relates to the source of inspiration. The research also includes applied study, by inspiring Haute couture collection contains of seven (7) outfits ; using different themes from Nature and use their silhouettes and colour schemes as sources of inspiration, and applies colour schemes to find out the most successful schemes for consumers.

1. INTRODUCTION

Colour in fashion design is very subjective. It is a fundamental consideration in the design process. Studying how colours affect different people, either individually or as a group, is something some people build their careers on. Colour schemes are the ways that colours are used together, and different results are achieved by using different combinations of colours. I believe that, the way to choose the collection colours is generally depend on the source that we inspire the collection from. The natural world provides a vast and diverse source of inspiration for gathering primary information; a lot of fashion designers inspired their collection from colours in Nature.

2. METHOD

The Methodology of the paper depends on studying and analysing the items: Colour Schemes- Create Illusion by Colour – Fashion Inspired by Nature.

- **Colour schemes**: Colour schemes are the ways that colours are used together. This part of the paper interested in studying and analyzing the combinations of colours in fashion such as: Monochromatic colour scheme – Analogous (Harmonious) colour scheme – Complementary colour scheme – Split-complementary colour scheme – Triad colour scheme – Accented neutral colour scheme. And give examples for each kind of it (Mary 1998, Pamila 2006, Sue 2002).
- **Fashion Inspired by Nature (Analytical study):** Nature has always been a fine inspirer for fashion designers. In the recent years, a lot of fashion designers collection's

theme were concerning about the environment issue, like the global warming, a society of jungle. The natural sources of fashion design include: flowers, leaves, birds, shells, insects and animals.

- **John Galliano in Christian Dior label:** He depends on the mix of the brightness of the flowers colours and uses it in the designs as printed motives. The colour palette was the extended harmony colours; it consisted of lime green, bright orange, red, fuchsia, black and purple. And the prints were mesmerizing.

John Galliano in Christian Dior label, Fall 2008
(www.hipgirlie.com)

- **Kate and Laura Mulleavy:** Kate and Laura Mulleavy interacted with one of the environmental issues; a Siamese fighting fish, The Mulleavy sisters depends on brightly extended harmony coloured combination including white, yellow, orange, red, pink, blue, green, turquoise, brown and black.

Kate and Laura Mulleavy, Fall 2008
(www.fashionmagazine.com)

- **Custo Barcelona:** He always use combinations of stunning, unusual bright and colourful designs and themes; in the collection which presented here, he inspired it from the lion fish, and his colour palettes were gray, shades of red, lavender mauve, taupe, ecrus, beiges, pale pinks, orange and brown with bright combination.

Custo Barcelona, Fall 2011
(thefabulousreport.com)

- **Giles Deacon:** He used the silhouette and the colours for some insects and made the dresses, and used the mono-chromatic colours (black, blue, green, orange, and red) with metallic colours.

Giles Deacon, Fall 2008
(www.fashionindie.com)

- **Nicole Miller** Nicole took inspiration for the element of water and ocean for her upcoming collection; she opted for the storm and the boldness of the ocean. She used the best colours for her theme; charcoal gray, black, white, blue, green, and blue-green.

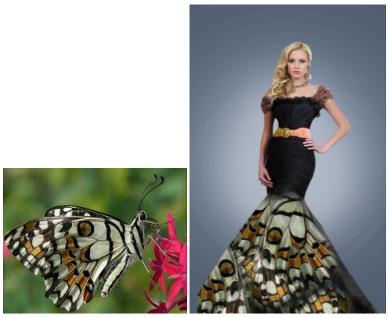
Nicole Miller, Spring 2010
(sachika.com)

The applied study: It depends on innovating haute couture collection contains of (7) outfits, inspired from Nature, firstly I defined (7) themes from nature and used the colours and silhouettes of it as a source of inspiration with defining the colour scheme for each design.

The Design	The Theme	The Colour Scheme
Design (1)	The colours and silhouette of a fish	Accented neutral colour scheme
Design (2)	The colours and silhouette of a butterfly	Accented neutral colour scheme.
Design (3)	The colours and silhouette of a peacock	Extended Analogous colour scheme
Design (4)	The colours and silhouette of a worm	Accented neutral colour scheme.
Design (5)	The colours and silhouette of a “bird of paradise”	Complementary colour scheme
Design (6)	The colours of tortoise	Monochromatic colour scheme
Design (7)	The colours and silhouette of a snake	Accented neutral colour scheme.

Here I present six (6) pieces from my collection.

Design (1)



Design (2)

Design (3)

Design (4)

Design (5)

Design (6)

3. RESULTS AND DISCUSSION

The natural world provides the fashion designers with vast and diverse sources of inspiration. A lot of fashion designers depend on Nature elements and colours in their collections during the 21st century, in some cases we found some of fashion designers interacted with the environment problems and try to remind us about changing the world and improving the environment problems. There are differences between the colours schemes which be used by each designer, according to the source which he inspired his collection from. It will be great success for the fashion designer if he is so close from the colours of his inspiration source and use the suitable colour scheme. Colour can be used successfully to create some illusion for the body proportion; we can increase or decrease the visual size of the body; by defining colours we can make body looks smaller, larger, taller, or shorter. We can also use colours to achieve Rhythm with repetition, gradation, and radial arrangement of colours in the apparel; also we can achieve Contract, Harmony, and Emphasis in our collections to draw attention to the body features or draw the eyes away from the undesirable feature. Finally using some themes from Nature as a source of fashion collection inspiration can give us very innovative ideas, and help us to enrich the fashion design field.

4. CONCLUSIONS

Colour grabs the customer's attention and makes an emotional connection with them, It is so important to understanding the psychology of colours and the colour schemes when we plan to design a collection, It depends on the source which we will inspire from; A lot of Fashion designers depend on colours in Nature to inspire their collections, so they were care to understand the colour scheme for each source and use it in their collections.

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http://aic-colour-journal.org/

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Dedicated Follower of Fashion

Victoria WALKER

ABSTRACT

The Kinks created a hit single with a "Dedicated Follower of Fashion" and they aren't the only pop group to realise the importance of fashion. The Rogue Traders' song became synonymous with the Gok Wan's Fashion Fix series. If you think of the likes of Madonna and Lady Gaga who were voted style icons by Time[1], they have both had hit songs about fashion. When clothing designers set the scene for what colours and textures grace the catwalk and ultimately the high street, do they realise just what an impact they are making on other industries? The seamless flow from designers creating clothing that influences colour cosmetics is in no doubt; top fashion magazines Vogue and Cosmopolitian glamourize fashion whilst highlighting the beauty industry. The connection between other industries may not be so obvious. However, if you think of the cupcake craze and the use of them as wedding cakes then the link to food becomes apparent. The colour scheme of bridesmaids dresses is often coordinated with the detailing on the cake. Producing stunning cakes often requires relying on niche icing suppliers whose specialism originates from a broad spectrum of technologies from industries as diverse as Pharmaceuticals.

1. INTRODUCTION

Colour initally draws us to a item of clothing then the factors of texture, form and shape begin to play a part in the puchasing process. So when the latest Elle collections magazine showed a myriad of colours on the front cover then it may seem like having a Pantone of the year may be a little too restricting for one season. The indication is that 2014[2] will reflect a passion for colour. This will no doubt delight designers like Nanette Lepore who is renowned for working with bold colours when creating clothing.

This paper will look at a sample of designers that are famous for their dedication to colour. The industries that are directly affected by the events that occur on the catwalk will be explored. Firstly the impact fashion has on colour cosmetics, the valuable support of the cosmetic professional bodies and the research that they conduct.

Another industry that is influenced by the fashion industry is food. With the recent economic situation there has been a shift from elaborate tiered cakes to pretty delicate cupcakes for the wedding market. This trend doesn't seem to be exclusive to the wedding industry and an increase in sugar decorations and colourings has been obseved as a result. It will look at colour manufacturers and how changes in regulations have shifted the emphasis towards the use of natural colours over synthetics. It will look at how the cake decorations market has changed over the years. It will also delve briefly into the Pharmaceutical industry.

2. DESIGNERS

The effect of colour was dramatised in 1999 when Alexander McQueen spray painted Shalom Harlow's white dress as she was stood on a platform that spun her slowly around in

1 Skarda E. 2012. All TIME 100 Fashion Icons
2 Prescott J. 2013. International Dyer: Colour and Novelty are the themes for 2014.

a circle. Covered in yellow and black ink the dress was brought to life. According to the Metropolitian Museum Of Art Alexander McQueen took inspiration from the artist Rebecca Horn. We can not help but wonder if the colours of the ink were selected to reflect the artistic element of the design, as yellow and black date back to Egyptian drawings. The striking effect that colour creates isn't a recent phenomenon; Elsa Schiaparelli created a sensation when she is said to have invented shocking pink in 1937[3]. This was soon after her hat range was launched, so her hat boxes reflected her signature black and magenta colourway. More recently; Chris Benz self-proclaims himself as the Prince of colour after his first catwalk collection was neon. The Cambridge Satchel Company has been linked to neon colours so collaboration with Chris Benz to produce a small range of limited edition satchels[4] for the Spring season 2013 was a logical progression. Zandra Rhodes is also a distinguished designer who is synonymous for her palette of bright colours. The theatrical influence of her work makes it no surprise that Lady Gaga became an enthusiast for her work. It is Lady Gaga's love of drama that inspired the unveiling of the Philip Tracy's long awaited Millinery show at London Fashion when she wore a pink veil[5]. Recognised for her intense style using glitters and extravagant eye make-up she teamed up with MAC cosmetics to produce a lipgloss and lipstick. Product endorsements by celebrities is a beneficial marketing tool for companies, especially when it is associated with the beauty industry as it is accessible to a wide customer base.

2.1 Colour Cosmetics

Designers realise the significance of using colour cosmetics to accent their designs. Coco Chanel who was quoted as saying "The best colour in the world is the one that looks good on you" launched the cosmetics part of her business in the late 60s. If you look at the recent catwalk trends; Anna Sui exhibited stunning blue overstated cat eye strikes, Christian Dior focused on colours with embellishments. The eye makeup trend is bold, resonating elements of th 80s where Boy George and Cyndia Lauper excelled. We have definitely left the nude makeup styling from the 1990s which suppressed the beauty industries sales. Euromonitor International's primarily data for 2012 valued the colour cosmetics market at $55bn[6]. In 2010 Topshop lauched its cosmetic range almost certainly in response to Mintel reporting that beauty products sales rose by 30% in the UK (Aidin B 2011). The nail market is growing, a trend that was observed in the London 2012 Olympics. Whenever you saw a female swimmer stretching her fingers out towards the end of the pool you would be reminded of the colours of the nation that they were swimming for. Colouring cosmetics for a world wide market becomes fairly complex, so manufacturers of cosmetics rely on the valuable support of the professional bodies like Cosmetics Europe (formerly known as Colipa) and the Cosmetics, Toiletry and Perfumery Association (CTPA). The main reason for this is that colours can be permitted for different applications depending on the country that the product is marketed in. Generally countries follow the requirements for the European Union or the Regulations enforced by the USA. However, this isn't always the case, China has its own Chinese Hygiene standards and they run these in parallel with EU requirements (CTFA 2007). Even when you know that a CI number is allowed in cosmetics then you have to be

3 http://www.vogue.com/voguepedia/Elsa_Schiaparelli

4 Lomrantz Lester, T., 2012. Glamour: Chris Benz for Cambridge Satchels: The Spring '13 we can wait to get our hands on.

5 12.09.2012. The Telegraph: Lady Gaga open Philip Treacy show at London Fashion week

6 www.cosmeticsbusiness.com. 2013.Colour Cosmetics: The colour of Money

aware of restrictions upon its use. The CTPA has also been instrumental in starting the "Colour with Confidence" campaign alongside Mark Coray, President of the National Hairdressers' Federation and hair stylist when they found that research showed that people don't carry out a patch tests before colouring their hair. [7]Josh Wood is legendary for hair colouring and his partnership with the likes of Jean Paul Gaultier is an enviable way to display hair designs.

2.2 Cake Decorating

On 19th July 2013 the Victoria & Albert Museum is celebrating the 25th anniversary of Jenny Packman as a bridal and evening dress designer. One hope of a bride is that the theme of the wedding colours is carried throughout the day, whether that is inspired by navy blue Jenny Packman design or another designer. Each year Pantone releases wedding season colours in conjunction with the wedding stylist Dessy. Dessy then produce coordinating bridesmaids dresses, accessories and menswear. The emphasis is put on the cake manufacturer to produce decorations that follow this wish. Therefore, there has to be a vast array of colours available to realise an incredible cake to remember. It is here that cake designers turn to niche cake decorating suppliers such as Knightsbridge PME and Sugarflair to produce an astonishing palette of colours in their products. Conventionally, synthetic colours have been used to achieve the shades required in icing applications. The benefits of these colours are that they have a long shelf life and are stable in a huge amount of applications. However, as a result of the Southampton study the use of natural colours has become prevalent. The study identified six colours that may cause an adverse effect of children's behaviour. As a result any products that contain the colours; Allura Red E129, Ponceau 4R E124; Tartrazine E102; Sunset Yellow E110; Quinoline Yellow E104; and Carmoisine E122 now have to be identified by name and carry the statement "may have an adverse effect on the activity and attention in children" (Baynton C.2008). The nature of natural colours means they are not as vibrant as synthetic colours and are complex to deal with, so the cake maker has to be aware of factors that will affect the stability of the colour as they can be sensitive to pH and temperature. In cake manufacture dusting powders are used to achieve subtle colour to fine decorations. It has become fashionable for these dusting powders to be enhanced with a metallic or glittery sheen. With such ingredients available it is no surprise that cupcakes with varying colour, texture and flavour became such a craze. Supermarkets have realised the size of this market and the home baking aisles have expanded a carry a wealth of different sugar decorations they look to colour manufacturers such as WILD Flavours Inc. with specialist knowledge of colours to ensure that their business provides cutting edge products to the mass market. Niche cake decorating suppliers utilise the technologies from other industries, stencils and cutters that are used use elements of the craft of card making. For example, some glitter inks have been created using technology that was developed for tablet coating in the Pharmaceutical industry.

2.3 Pharmaceuticals

The Pharmaceutical industry generally likes to keep its products white to convey the sense of purity. It also prevents any misconception that the products are for anything other than the medical purpose that they were intended for. If you colour a product it immediately draws attention to it, which excites and motivates us. This is obviously seen as a negative reaction when it is associated with drugs, especially when seen through the eyes of a child. However,

7 National Hair Federation, 2012. http://www.nhf.info/news/colour-with-confidence-campaign-launched/: Colour with Confidence campaign launched.

sometimes it is essential to colour tablets for identification purposes. Colouring within a Pharmaceutical product is a complex issue for the manufacturer and there are very definite regulations, guidelines and rules to be obeyed. Therefore, a link to fashion and fashion seems farfetched given the regulations that these products are categorised under in this industry. However, it can depend on the market and how a product is being defined. Take for instance toothpaste, it is considered as a cosmetic in Europe. However, in the USA it can be an Over the Counter drug (OTC) if it has an ingredient such as Fluoride in it. So, the trends for colours can be seen. When Aquafresh was first launched by GlaxoSmithKline (GSK) in 1973 it was striped with blue and white. In the 1980s the product was refined to fight plaque and that's when the red stripe was introduced.

3. CONCLUSION

When fashion designers show their collections for the season the colours they inherently affect other industries. When consumers buy an item of clothing they make sure they have the makeup that compliments it. Hair is a form of accessory even though it doesn't change as readily as other methods of decoration. The wedding colour scheme can be progressed on from the bridesmaid's dresses to the table decorations. It may influence the confectionary range that is developed. How designers use colour evokes a reaction to the consumer, if they see a colour or a colour combination that they adore they may think that's just the colour that I need for my lounge. How many other industries are fashion followers?

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product design and branding

Dimensionality of the Perceived Value of Product Colour

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ABSTRACT

Scholars agree that product colour is an important factor in product success, yet colour is an under-studied element in marketing research. In particular, there is a paucity of research on the perceived value of product colour, although studies show that product colour is important in consumer perceived value. This paper addresses the issue by showing that 1) the perceived value of colour is three-dimensional and 2) the outcomes of consumers' colour consideration processes fit to at least one dimension at a time, but are likely tradeoffs between two or all three dimensions.

1. INTRODUCTION

Up to 62-90 percent of a consumer's product assessment is based solely on colours (Singh, 2006), yet colour is an under-studied aspect in marketing (Labrecque, Patrick and Milne, 2013). Typically, when choosing colours for product lines, companies rely on intuition, anecdotal evidence (Gorn et al., 1997), personal preference and hunches (Trent, 1993), when, in fact, regarding product colour as an important element of total quality management could give companies a distinctive competitive edge (Trent, 1993). Even relying on consumer research to predict which colours consumers are likely to purchase is not necessarily productive, because consumers actually are poor predictors of their future feelings (Wilson and Gilbert, 2005) and behaviour (Wilson and LaFleur, 1995).

There is a paucity of research on the perceived value of product colour, although scholars have found that product colour is an important component in consumer perceived value (Barbu, 2011). Consumers' immediate reactions when exposed to colours are studied widely (e.g. Bellizzi, Crowley and Hasty, 1983; Gorn et al., 1997; Middlesatdt, 1990), yet we know little about how product colour is perceived after the immediate exposure. Studying the perceived value in or after use is important, because consumers perceive value differently in the purchase (immediate reaction) and in use (long-term perception) (Gardial et al., 1994). Understanding the perceived value of colour is essential because value determines consumer loyalty and profitability (Woodall, 2003). This paper addresses the previously neglected importance of perceived value in colour literature by empirically studying how consumers perceive the value of the colour of their cars and mobile phones.

2. METHOD

Due to the lack of previous insight into the perceived value of colour, it is appropriate to conceptualise the effect through a qualitative study, because qualitative methods are suitable for addressing complex phenomena and conducting preliminary studies to develop theories (Soafer, 1999: 1101). Interviews support the data collection for this study, because they disclose consumers' insights and opinions (Parkhe, 1993) and otherwise non-traceable facets of consumer behavior (Qu and Dumay, 2011: 246). The main question the interviewees were asked was "Tell me about the colour of your car/mobile phone". The aim was to have the interviewees talk freely about the colours without limiting their mindsets to any pre-fixed aspects of colour. Cars and mobile phones serve as the explored product categories because their functional characteristics cannot be determined by the colour. To avoid other effects, such as colour's influence on perceived product features, these products do not guide associations through colour, which leaves room for free interpretation.

The empirical study includes 39 loosely structured interviews. The interviewees are selected through purposeful sampling in order to learn from information-rich individuals and understand the phenomenon in depth (Patton, 2002: 46). The sample included 22 women and 17 men, aged between 25 and 67 years. The average length of an interview was 23 minutes, the shortest being ten minutes and the longest 47 minutes. The analysis started by transcribing all the interviews and inductively coding the data in order to find patterns without any *a priori* assumptions. The data was then grouped according to words that the interviewees used when they described colours. The groups were then categorised into larger themes that are internally homogenous and externally heterogeneous.

3. FINDINGS AND DISCUSSION

The findings revealed that 1) consumers perceive the value of colour in three dimensions: experiential, symbolic, and functional, and 2) consumers often prefer different colours in each dimension, which leads to tradeoffs between the dimensions.

The experiential dimension covers the individual attractiveness of colour; what the interviewees like and dislike. The interviewees did not express any specific reasons for desiring colours or finding them unacceptable, but rather, they expressed their subjective taste. Most of the interviewees did not describe their overall favourite colour in relation to the desired colours for their cars and mobile phones, but instead, they favour one colour generally, another on cars, and a third in relation to mobile phones. *The symbolic dimension* refers to culturally determined value perceptions of colour; symbolic reasons for finding colours desirable or unacceptable. The symbolic reasons mirror meanings, associations, cultural elements as well as needs for group membership and ego-identification. *The functional dimension* represents how the colour of an item adds value to the underlying usage purpose of the item. The interviewees expressed the functional value of colour by describing how well colours are able to perform functionally and by explaining that perceived value stems from superior functionality. Table 1 presents example quotes on each value dimension. Similar dimension are found, for example, in brand value literature (Berthon et al., 2009), customer value literature (Smith and Colgate, 2007) and product appearance literature (Creusen and Schoormans, 2005).

Table 1. Example quotes on experiential, symbolic and functional value dimensions.

	Experiential value	Symbolic value	Functional value
Desired colour	I really like the white colour [of my phone]. Although red has been my favourite crayon since childhood. But, it doesn't translate to a mobile phone.	I would like to have a green car because it [the green colour] represents my values. Green values.	I am very satisfied with the grey colour [on my car]. I don't have to wash it all the time. ... You can't really tell if it's dirty or not.
Un-acceptable colour	I would never buy a green car. Or a yellow car, or an orange car. They are not beautiful. And I feel that the car turns into ugly if the colour is not beautiful.	All bright colours [on mobile phones], they always make me think that a person cannot be taken seriously.	I will never buy a white phone again, because white shows every little scratch on it.

The interviewees often prefer different colours in each dimension. That is, while one colour, for example, is desired experientially it can be unacceptable symbolically or functionally. This leads to consumers facing conflicts between the three dimensions, and the outcomes of consumers' colour consideration processes fit to at least one dimension at a time, but are likely tradeoffs between at least two dimensions. The interviewees feel very strongly about unacceptable colours; if a colour is unacceptable in any dimension, they may not make a purchase at all. Therefore, a tradeoff can occur between 1) experiential and symbolic dimension, 2) experiential and functional dimension, 3) symbolic and functional dimension, or 4) unacceptable colour in any dimension and not making a purchase. Table 2 presents example quotes on the tradeoffs.

Table 2. Example quotes on tradeoffs between the three value dimensions.

Experiential/ symbolic tradexoff	Experiential/ functional tradeoff	Symbolic/functional tradeoff	Unacceptable colour / not making a purchase
I really would like to have a pink mobile phone, but I can't because pink mobile phones are something that teenagers use to vote for their favourite *Idol*.	I wish I could have a black car, but because it's always dirty, I won't.	My favourite car colour is black. I get an association of a secretary of state, or a high level executive. But black is always dirty, you have to wash it constantly.	Dark green on cars is an old man colour. I actually test drove a dark green Audi but I didn't buy it because of the colour.

4. CONCLUSIONS

For marketers, it is important to learn how consumers perceive the value of colour in order for them to learn how to offer right colours which, in turn, leads to reduced manufacturing costs and increased sales (Trent, 1993) and prevents companies from wasting time and energy in trying to chase the latest trends (Grossman and Wisenblit, 1999). Moreover, if marketers are aware of the colour consideration processes of customers, they may be able to participate in the purchase decision and assist customers in their choices, which will increase customers' purchase intentions (Kolesar and Galbraith, 2000) and customer satisfaction (Du, Jiao and Tseng, 2006). For example, eliminating tradeoff by offering colours which are desired in all three dimensions would save the customers from having to compromise. Satisfying customers is likely to increase customer loyalty, positive word-of-mouth and repurchase intentions (Chitturi, Raghunathan and Mahajan, 2008). Finally, it is crucial for marketers to understand what makes a colour unacceptable for a consumer and offer colours which are acceptable in each dimension, because offering unacceptable colours may make a consumer to walk away instead of making the purchase.

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Colour Words in Everyday English

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ABSTRACT

Colour words bring day to day language to life often as adjectives, sometimes as nouns, less frequently as verbs and rarely as adverbs. Data has been obtained from approximately 200 dictionaries and other sources such as newsprint and the media in general. Such words are used for different purposes, most commonly as a general descriptor of colour appearance, as an immediate identifier recognisable to a specific human population, and as a symbolic descriptor.

Sections of the assemblage will be devoted to black, blue, red, white, green, yellow, brown, grey, pink, orange, metal colours and purple with violet and indigo. The proposed work will not be a dictionary as data will be presented in themes for each colour. These themes include fauna, flora, food, colours, sayings, dress or oral tradition. For example, the section devoted to blue presently consists of 18,000 words containing approx 700 blue terms in 38 such themes. It will be possible to access individual entries using an index. In this paper examples will be given from the compendium with examples of the many colour word order systems used in daily life, together with examples of colour word perversity and colour patterns.

Key words: colour names, English language, terminology

1. INTRODUCTION

Use of colour words in the English language has attracted many scholars who have approached the topic from a number of directions. For example, Biggam of the University of Glasgow has discussed the basic principles of modern colour semantics within an anthropological framework. Steinvall of Umeå University Sweden has carried out studies of colour word frequency in English dictionaries. He also deals with the interpretation of and meanings attributed to colour words very much in context within the sentences they are constructed. He uses the eleven basic perceptual colour categories derived from Berlin and Kaye: black, blue, brown, green, grey, orange, pink, purple, red, white, and yellow.

Colour words are used to bring day to day language to life and such words are used for different purposes. Work reported in the present paper describes progress towards a compendium of colour words used in vernacular English. Approximately 200 dictionaries have been consulted as well as numerous non-fiction books, newsprint and other media sources. Excluded are titles of books and musical compositions, except perhaps where they contribute to the understanding of a particular colour term or phrase.

The final work will not be a dictionary as, for each colour, entries are presented in appropriate themes. These may include fauna, flora, colours, food, medical and veterinary, sayings and similes, dress, and oral tradition. For example, the chapter devoted to blue presently consists of 18,000 words containing some 700 blue terms in 38 such sections. Each theme may, if necessary to complete a story, contain references to the place occupied by other colours within the theme. It will be possible to access individual entries in the compendium using a comprehensive index. This paper contains brief accounts of the principles and examples of colour word use as well separate sections on colour word order sequences and special words used to describe colour patterns.

2. COLOUR WORDS IN USE

Colour words are used in common language as adjectives, nouns, occasionally as verbs and very occasionally as adverbs. They are used for different purposes:

1. as a general adjectival descriptor of colour appearance – 'this red wall'.
2. as a noun, an immediate identifier to a specific population e.g. in relation to association football 'the blues' in London are Chelsea, in Liverpool they are Everton.
3. as an arbitrary symbolic descriptor - 'he is green with envy'.
4. as a verb – 'to green' intransitive 'the plants have greened already this spring' transitive 'I blued the washing'.
5. as an adverb – 'in spring the tree grew greenly'
6. as an interjection – 'by all that's blue!'

Care must be taken when interpreting the sense of colour words within the context of the sentence in which they are used. In all categories except 3, interpretation is safe and meaning is usually beyond doubt. However, when colour is used as a symbol we may be on more dangerous ground. The word 'green' means the colour 'green'; it does not mean anything else. Hence, we can attribute to the word 'green' whatever emotions, beliefs, feelings, associations, symbols we want to attribute to it. These may be contradictory. For example, Shakespeare on different occasions uses 'green' to emphasise the very different emotions of freshness and fertility, ignorance, immortality, expectation and hope, envy and melancholy (Hutchings 2013).

Although we may be able to distinguish millions of colours when they are adjacent, there are very few colours upon which we are all agreed and which therefore can be used as safe descriptors in general conversation. Those most often used comply with the Berlin and Kaye list with the addition of metal colours.

The word count for each chapter of the compendium stands at present as:

black 28,000	blue 18,000	red 16,800	white 16,600
green 15,000	yellow 6,500	brown 5,000	grey 4,600
metals 4,600	pink 2,200	purple, violet and indigo 2,200	orange 1,500

Other chapters, perhaps for example dealing with colour pattern words and colour word order systems, will also be included.

2.1 Colour words as adjectives

Most names for animals and plants are probably those used first by local communities when describing local fauna and flora. Examples of a colour name used to describe the whole animal include the Newfoundland name *white bear* for the polar bear; *white bear* is also the Chinese name for the panda. The *scarlet tanager* and the *snow goose* are North American birds, and the *sooty tern*, is from the tropics, all adjectives denoting colour. Colour names applying to specific parts of the animal include the *white-tailed deer* and the *black browed albatross*. Geographical isolation of communities leads to the same animal being called different names. In parts of Africa the *white-tailed gnu* is also called the *black wildebeest* after the colour of its body. The same name can be given to different animals. The *snow mouse* is applied to *Arvicola nivalis* as well as to the American arctic lemming *Cuniculus torquatus* which is white in winter. Sometimes the wrong name becomes applied to an animal by mistake. The *white rhinoceros* is brownish-grey not white. The Boer in South Africa called it the wide-nosed one (*wijd*), but the English mistook this for white.

In a similar way colours describe the whole or part of the plant. A tree may be named from its appearance or from that of its wood and examples are the *red beech* of Europe and different varieties of *red pine* found in North America and Australia. *Red dye woods* yield red dyes, for example, the brazil, peach, sappan contain brazilin from which the dye is obtained. The country Brazil was named after the East Indian *red wood tree* long used as a source of red dye. Names are also derived from the colour of the flowers and fruit they produce – the *red jasmine* has red flowers and the *red mombin* is called after deep red fruit of the spanish plum.

2.2 Colour words as nouns

To those following football in London the *Blues* refers to Chelsea, if in Liverpool *Blues* are Everton. On rare occasions a modifier is used. Glasgow Rangers FC are the *Light Blues* – Queen's Park an old football club in the city has a dark blue strip. *The Blues* or the Royal Horse Guards originally in 1690 were called the *Oxford Blues* after their then commander the Earl of Oxford. The name distinguished them from a Dutch regiment of horse guards also dressed in blue. In Flanders in the mid eighteenth century it fought under called the name *Blue Guards*. The regiment merged with the Royal Dragoons in 1969 to form the *Blues and Royals*.

The colour of the northern Union Army uniform during the American Civil War was blue and hence the troops were called *Blues*. A northerner or Yankee was called *blue belly* by southerners. On the other hand the grey uniform of the Confederates led to them being called *boys in grey* and *Greybacks*. The name given to the 29th USA Infantry Division was the *Blue and Grey*. Formed in 1917, the division quickly gained the nickname symbolising the fact that it comprised soldiers from states on both sides of the American Civil War.

2.3 Colour words as verbs

In the eighteenth century navy *to blackwash* was to use *black wash* and *to black-down* is to use tar and *lampblack* to blacken rigging or the ship's side. *To blacken* and *to black mouth* is to injure a reputation perhaps by slander or libel, but also refers to a person noted for using foul language. A *blackguard* is a villain hence *to blackguard* was used meaning to insult. *To black* or *to black lead* was to colour or clean or brush over with *black lead*. Among end of the nineteenth century tailors *to blackleg* was to make life so uncomfortable for a person that he was forced to leave the district. *To black* is to ostracise or ignore people or machinery as in a Trades Union dispute and *to blackleg it*, is for trades' union members to return to work before the strike is over. *To blackleg*, from the same period, still refers to a worker who continues to work during a strike, or one, not a union member, who works for less than union rates and more generally is someone refusing to join in or who breaks the rules of that group.

2.4 Perversity

Colour terms themselves may be individually interpreted. For example, the term *purple patch* is given to an individual who is doing very well. This arises from the equating of purple with royalty and richness. To others the opposite applies, that is to someone who is doing very badly, from the equating of purple with the colours produced by bruising and physical harm.

A more extreme example arises in Australia where red haired individuals are called *blue*. The *blue doe*, also *blue flier*, is the female of the *red kangaroo*, said to be so called from the colour of its greyish pelt. Other examples include the *blue heeler* or *bluey* the reddish dog used to control cattle, while *bluey* is also used for the draught bullock which has a bluish reddish coat. More recently in the same vein the Australian *Virgin Red* airline which has red planes is called *Virgin Blue*. Not only Australians are contrary, the railway term *blue* referred to the green line clear light. In the USA blue on the railways is a colour of caution.

2.5 Colour pattern words

Domestic animals require more detailed descriptors and specific words are used to describe specific patterns. Cattle having belts or bands of colour also those mainly black but with a middle-band of white are said to be *belted* or *sheeted. Riggie,* or *riggy*, is a cow having a white stripe along her back. *Brinded*, or *brindled*, or *brandit* in Scotland derived from the Middle English, *brennen*, to burn, applies mainly to dogs of a grey-brown colour, barred or spotted with a darker colour. Also, *merle* dogs have a grey coat with black markings. *Menald* refers to spotted or speckled animals, specifically to deer, a dappled chestnut colour.

2.6 Colour word sequences

Colour orders are used in sporting activities such as archery and billiards, where colour indicates score. Because colour names are immediately evocative they act as very convenient identifiers of particular states within any system of coding especially where severity of a condition is defined. For example, teas are classified according to the severity of fermentation. *Green tea* is made from unfermented leaves, while the lightly fermented white tea is unique to China. *Yellow tea* is similar to white tea being 10 to 12% fermented giving the infusion a yellowish hue. *Teal tea* is half fermented until the leaves are green with red outer rims, giving it the aroma of green tea and the flavour of red. *Black tea*, called *red tea* in China, is heavily fermented, yielding a reddish infusion. Confusion may occur when doctors cross borders. In the USA triage colour sequence *black* indicates death; in the UK it is *white*.

3. CONCLUSION

Colour words are richly used in language because they can be immediately visualised, special words being used to describe colour patterns. Not only do colour words describe in an evocative and recognisable manner, they can be given a 'meaning' solely defined by the user.

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Color Communication in Brand Revitalization

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ABSTRACT

The brand is constantly making efforts to communicate with consumers. This is because the brand is an evolving organism, with the goal of being 'customer-oriented'. The brand revitalization is required due to the influx of new customers. Therefore, the brand is faced with dilemma in balance between sustenance brand heritage and refreshment of brand. This study seeks the clues to the dilemma focusing meaning and color of package design. The perfect pair of meaning and color shows a customer the way to access to the brand identity. After the formula of brand and color (like a Coca-Cola Red), brand identity can move flexible, and finally retain brand freshness.

1. INTRODUCTION

A number of brands try to extend brand life to overcome decline. A majority of these brands have disappeared into oblivion, while others have been revitalized. In today's competitive market, new products are faced with high cost and risk. It is therefore critical to design a longer product life span by flexible identity. In this context, brand revitalization can be used to trade up a brand in a less risky way. While there have been studies to measure the financial value of brand, literature concerned with brand extension within the framework of design has been lacking.

In an image age, the visual logic itself is important and visual communication palys a comprehensive role in the market. Visual information rather than the language is immediate (Seward Barry 1997). The color is due to the efficiency of information delivery focused and more powerful communication tools. The simplified forms of the brand symbol mark, and elimination of brand name is probably going to reflect this trend. Package design itself has prompted commucation in the standardization of function, quality, and price. It is provided information as well as engendered symbolic meaning and emotion (Gage 1999). Therefore package design is considered important as a communication tool. This paper is an attempt to provide an understanding of how they mutually affect meaning and color of package design in brand revitalization gradation.

2. METHOD FOR A CASE STUDY

The product was selected due to its longevity, over thirty years in the market. Data has been collected from the website, in-house periodicals, and video collections.

A qualitative research method was used in this correlation between design management strategy and color communication. Color was analyzed via CMC Munsell converter.

We utilize a single case in this study due to its uniqueness in terms of the concept and the package changes over the years.

A case in discussion is a real example of snack cake brand. It is an excellent example to demonstrate the process of successful brand revitalization: it has been revitalized to become among the most respectable brands in the category of confectionery in the region. The case described situations within its market context and how marketing strategy repositioned the brand in parallel with its package design.

The Choco Pie is a snack cake consisting of two small round layers of cake with marshmallow filling with chocolate covering. The concept of Choco Pie origins from Moon Pie whose prototype was first launched in 1917 in Southern Tennessee. In 1929, Moon Pie was created by Chattanooga Bakery for local miners in Chattanooga, Tennessee. In 1958, Morinaga in Japan released Angel Pie, similar to Moon Pie. Orion Confectionery began to sell a similar product known as “Orion Choco Pie” in 1974. In 1979, Lotte Confectionery, Haitai and Crown Confectionery entered into the market by releasing a product very similar to Choco Pie. Since the early 2000s, Orion began an aggressive expansion into overseas markets notably China. Overseas sales of Orion Group outnumbered domestic sales in 2009, thanks to the sales in China broke the 1 trillion won (approximately $10 billion).

3. RESULTS AND DISCUSSION

This study investigated the historical account of the brand revitalization process over the past 40 years. From 1974 to the present, a stage of development is divided into three parts and analyzed on this basis. When the first changed occured from luxury snack to casual bites in 1989, the package did not change significantly. Despite the lack of evolution in the outward sign of the brand, it has long tried to communicate with the consumers with the concept of ‘情 (JEONG)’, meaning pure heart in Korean. The proper metaphor surrounding ' 情 ‘ has it that when a friendship matures between two people. After having stably repositioned the brand meaning through emotional communication, package design underwent drastic color change away from blue towards red. The blue and the red color on the color wheel are complementary to close. Consumers accepted the radical change of color, Choco Pie brand equity with ‘Red’ and ‘ 情 ‘ was settled consequently. The two main causes led to the acceptance of this radical color changes. The first, the packaging design sweeping change was required due to enter the Chinese market. Second, cultural factors have created an atmosphere of acceptance of the change. In the Korean blockbuster movie JSA, Choco-Pie was the carrier to share the minds of the North and the South soldiers. In 2002 World Cup held in Korea and Japan, Red Devil wearing the red t-shirts drove the country into the crucible of red. (Red Devils or Bulgeun Ahgma is the official supporting group for the Korea Republic national football team.) Brand identity strengthened without vacillation (Tables 1 and 2). Interesting to note, the change in meaning preceded the change in visual design, notably color.

After having changed the color concept from blue to red, the shape of the total package has been more refined and the package has changed to much shorter life cycles. Using a large area of strong tone red enlarge Choco Pie Red Power.

Table 1. Stages of Growth of Choco Pie.

The first Growth 1974 ~ 1988 Domestic	**The second Growth** 1989 ~ 2001 Regional	**The third Growth** 2002 ~ 2012 Globalization
Monopoly Staple substitute Nutrition and calories Rapid growth Similar Products Rival brands Overcoating package	Two-way Communication Negative growth Slowdown in growth Humanism 精 concept Trademark Registration Contemporary image Future-Oriented image Overseas markets	精 concept of stabilization Red package design Product of globalization Sophisticated transformation Rapid development Innovative corporate image Emotional Communication
10 million dollar (1998) 	1 billion dollar (2001) 	10 billion dollar(2012) 

Table 2. The trend of meaning and color change in Choco Pie brand.

Key Issues						
Red Taboo (Communism)				Movie'JSA'(2000) World Cup Red Devils (2002)		Social & Culture
		IMF Economic Crisis (1998~1999) Competing Brands				Economic & Technological
Cold War (1950~1980)		Diplomatic Relations (1993, Korea-China)				Political
Originality *Quality-Oriented*		**Differentiation** *Export-Oriented*		**Brand Equity** *Emotion-Oriented*		**Key Concept**
						Change Occur Line
No ne	Blue	情	Blue	情	Red	
The first Growth		The second Growth		The third Growth		Story / Color

4. CONCLUSIONS

We can identify two main points in the brand revitalization process of Choco Pie. To begin with, Orion pursued incremental changes with a focus on the repositioning of brand image. After the repositioning, Choco Pie underwent radical changes in color.

In the global market, companies need communication tools to go beyond language. Color has gained more importance as the first means of cognition. Brand strategy to focus on color is a must for immediate communication with the consumers. The color deeply-rooted in human senses can effectively communicate with the bottom of heart. Color without meaning is just an image. Yet, color with meaning is a very strong communication tool for emotional expression. Color that represents a brand, once recognized, can accommodate broad value. That is, corporations can communicate with consumers with its flexible identity.

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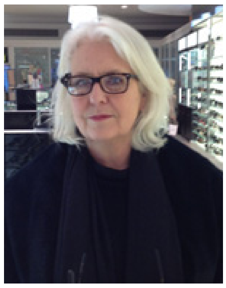
hilary dalke

Colour: Influence on Environment, Behaviour, Well-being, Sensory Design and Special Needs



keynote

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BIOGRAPHY

Professor Dalke is Director of the Design Research Centre at Kingston University London and a leading designer in the fields of environmental and sensory design. Previous experience in the fashion and car industry, and her innovative Colour Design Research Centre at London South Bank University, established Dalke as a leading colour designer. Architects, local government bodies, manufacturers and developers worldwide, seek her professional advice specifically on technical and aesthetic usage of colour design in the built environment.

Dalke is an expert in accessibility, visual impairment and special needs designing for healthcare, retail, long-term care and prison environments. She has pioneered research on contrast and vision, is the founder of CROMOCON Ltd. and is a member of two BSi task groups: BS 8300 to develop guidance for people with neuro-diversity and cognitive impairment, and the built environment, as well as BS 8493 Light Reflectance Values.

Professor Dalke has initiated collaborations with Oxford University Experimental Psychology, Cambridge University Engineering Department, Portsmouth University, UCL, St George's and London South Bank University Knowledge Transfer Centre and is on the Programme Committee at Cambridge University for CWUAAT.

symposium: aesthetics

Symposium: Color Aesthetics
“Cross-cultural color preferences in Asia”

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ABSTRACT

Throughout my research career, the study of human color preferences has been the most central topic. I have conducted a series of studies, which include both social surveys and experiments on cross-cultural differences in color preference. The results have shown two significant findings. First, a strong preference for white is common in Asian areas, which have both geographical and cultural proximity. Not only Japanese, but also Chinese, Korean and Indonesian participants showed a strong preference for white. Second, there are preferences that are common universally, and others that seem to be distinctive to a specific region. For example, blue (especially vivid blue) tended to be preferred very highly in all the regions and in all the years that were surveyed. The reasons suggested by the subjects for preferring certain colors tended to be that these colors were closely connected with feelings of pleasantness and unpleasantness regardless of time or place. Finally, a diagram of the general structure of color preference is proposed, based on cognitive implementation.

1. INTRODUCTION

One of the oldest and most large-scale surveys of cross-cultural color preference suggested that there was a general order of preference for fully saturated hues in the order of blue, red, green, purple, and orange, with yellow ranking last. As this order did not differ between Caucasian and other races, it was concluded that there was no cross-cultural difference in the preference for colors (Eysenck 1941). Another report of the preference among American, Lebanese, Iranian and Kuwaiti university students in Beirut showed that while red and blue ranked highest in preference value for the American subjects, those colors ranked lowest for Kuwaitis. Also, the finding that blue-green was ranked last among the Americans, but was most preferred by both the Iranian and Kuwaiti subjects suggested that cultural variables were at work in determining color preferences (Choungourian 1968). Moreover, similarities in feelings about colors have been found among 23 cultural groups (Adams and Osgood 1973). A study of cross-cultural differences and similarities in color preference among nine cultural groups (Americans, Germans, Danes, Australians, Papua New Guineans, South Africans, Japanese-Americans living in the U.S., non-Japanese living in Japan and Japanese) demonstarated that vivid blue was the only color that was commonly preferred highly by all groups. But the study also showed the cultural variables involved in color preference (Saito 1981). One very significant finding in Saito’s study was the distinct Japanese preference for white. Twenty-five percent of the Japanese subjects selected white as their 1st, 2nd, or 3rd choice, but such high preference for white could not be observed in other countries. Factor analytical and cluster analytical studies of a detailed investigation of color preference were carried out on 1,600 Japanese in four large cities, especially in connection with the subjects’ age, sex, area of residence, and life style. This study also suggested that white was most highly preferred regardless of age, sex or area of residence, thus confirming the high preference for white in Japan 1991 (Saito et al. 1991a, Saito et al. 1991b). To investigate whether this tendency was unique to Japan, if it may be observed in other Asian areas and if the preference is influenced by environmental factors such as cultural and geographical aspects, the studies were replicated in other Asian countries in areas having both geographical and cultural similarity.

2. METHOD

Three consecutive studies were conducted from 1992 to 1993. The Subjects who participated in the cross-cultural study of color preferences were as follows: The first study in Tokyo (Japan) and Seoul (Korea) was conducted on 199 university students (Tokyo:32 male / 68 female, Seoul:28 male / 71 female). The second study in Tokyo (Japan) and Taipei (Taiwan) was conducted on 316 university students (Tokyo:72 male / 88 female, Taipei:54 male / 102 female). And the third study in Tokyo (Japan) was conducted on 175 university students (72 male / 103 female), 158 subjects (89 male / 69 female) in Tianjin (China) were mostly university students, and the subjects in Jakarta (Indonesia) were also 157 university students (82 male / 75 female). The stimulus in all the studies was the same 'color chart' with 77 glossy colored chips: 70 chromatic colors, 5 achromatic colors, and silver and gold. They were selected from the PCCS (Practical Color Coordinate System) developed by Japan Color Research Institute. The colors were pasted on a neutral gray cardboard panel 29.7 x 41.8 cm in size. Each colored chip was 3.5 x 2.0 cm. The chromatic colors were arranged horizontally by tone (seven tones: pale, light-grayish, dull, light, vivid, deep, dark) and vertically by hue (10 hues: R, YR, Y, GY, G, BG, B, PB, P, RP). The subjects were asked to look at the color chart and select their three most preferred colors and three least preferred colors in order of preference and nonpreference, respectively, and to state the reasons for their choices. In most cases, the questions were asked orally either individually or in small groups of two or three people. The color chart was observed under fluorescent light. The results were analyzed mathematically by correspondence analysis.

3. RESULTS AND DISCUSSION

3.1 Tendency of color preference in Asia

The results showed that a strong preference for white was common to Asian areas, which have both geographical and cultural proximity. Not only Japanese, but also Chinese, Korean and Indonesian participants showed a strong preference for white. However, the reasons for preferring white were somewhat different. In Japan, for instance, white was preferred mainly because of its associative images of being clean, pure, harmonious, refreshing, beautiful, clear, gentle and natural. In China, the reasons for the choice were mainly associations with chastity or purity. The Chinese also liked white because it was elegant, clean, beautiful, and "pure white", some of which are common to Japanese. It is also a symbol of sacredness for the Chinese. Several subjects in the survey study mentioned that white was the source of every color, so that it was substantial and unique. In Indonesia, white was preferred mainly for its association with being clean, chaste, neutral and light.

3.2 A diagram of the structure of color preference

During the course of the cross-cultural surveys among various countries, there were preferences which remained relatively unchanged over the years, and others which displayed relative changeability during the years or in the areas surveyed. Namely, there are preferences that are common universally, and those that seem to be distinctive to a specific region. For example, blue (especially vivid blue) tended to be preferred very highly in all the regions and in all the years that were surveyed. The reasons suggested by the subjects for preferring certain colors tended to be that these colors were closely connected with feelings of the pleasantness and unpleasantness, regardless of time or place. Subsequently, a diagram of the general structure of color preference was suggested based on cognitive implementation (Saito 1997). It was presented as a three-layered structure with preference based on feelings of "pleasant" and "unpleasant" forming the nucleus, or the inner-most first layer; preference due to individual factors composing the surrounding second layer; and preference due to environmental factors composing the outermost third layer (Fig.1). The closer the preference is to the center of this diagram, the more stable and universal it is, being relatively unaffected by differences in geographical area of residence or year of survey. The further away the preference is from the center, the more liable it is to change with the individual and the environment surrounding that individual. The idea of the model of the diagram was derived from a structure similar to that of the human brain. The amygdala which is located at the inner-most brain region of the limbic system is closely connected with preference in relation to the feelings of pleasantness and unpleasantness, and it seems apparent that the feelings of "pleasant" and "unpleasant" are intimately involved in the choice of color preference as well.

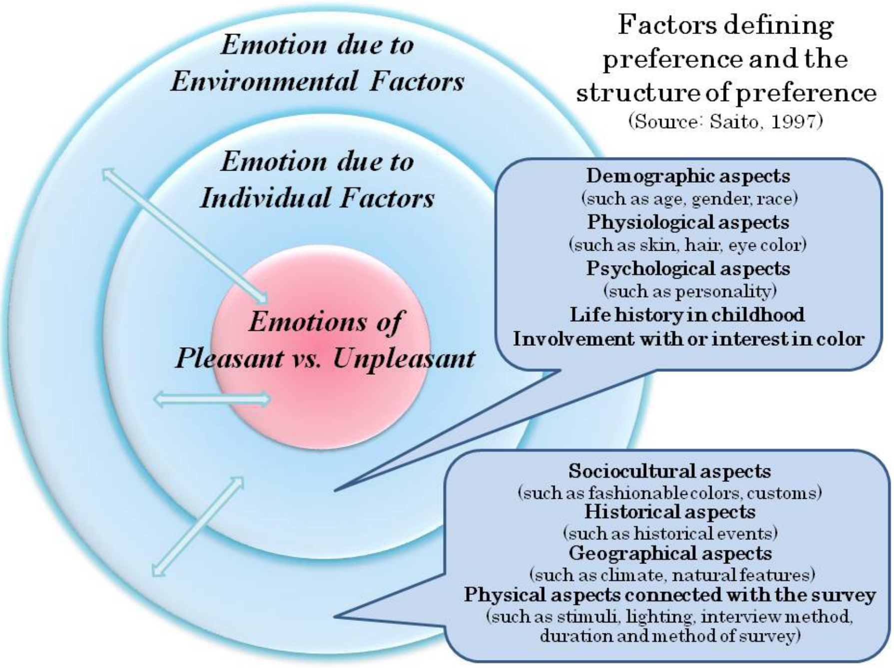

Figure 1*:* Diagram of three layered structure of color preferenc*e.*

4. CONCLUSIONS

The results of the survey of cross-cultural color preferences have shown two significant findings. First, a strong preference for white is common in Asian areas, which have both geographical and cultural proximity. Second, there are preferences that are common universally and those that seem to be distinctive to a specific region. Cognitive implementation leads to the development of the model of a structure of color preference which is similar to the structure of the human brain. Further studies are necessary to clarify the factors which may influence comparative color preference.

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Colour Aesthetics in Relation to Colour Emotions

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ABSTRACT

Aesthetics is a branch of philosophy dealing with the nature of art, beauty, and the creation and appreciation of beauty. It can be studied scientifically to investigate the relationship between sensory responses and physical stimuli, or psychophysics. This paper describes a series of study on colour emotion and colour harmony using psychophysical methods. The methodologies are finally integrated as part of product design process.

1. INTRODUCTION

Aesthetics, in broad terms, can be defined as 'critical reflection on art, culture and nature'. It can be studied scientifically to investigate the relationship between sensory responses and physical stimuli using the methodology known as psychophysics. This discipline is called Affective Engineering or Kansei Engineering. Its aim is the development or improvement of products by translating customer's psychological feelings and needs into product's design parameters. It links customer's emotional responses (i.e. physical and psychological) to a product with their characteristics. Hence, products can be designed to bring forward the intended feeling. The method has been widely adopted in various applications. In the academic field, they are associated with society of ergonomics and KANSAI engineering. They host large conference each year such as International Conference on Kansei Engineering and Emotion Research (KEER).

Recently, researchers have worked on several related topics concerning associations with colour. My colleagues, especially Dr. Lichen Ou, and I have conducted a series of studies in this field since 2000 (Ou et al.; 2004, 2006 and 2012). This paper is aimed to summarise our work on colour emotion and colour harmony and its applications. It can be divided into three areas: colour emotion, colour harmony, and how to apply in the design process.

2. COLOUR EMOTION

Our journey started from the research on colour emotion using single colour patches (Ou et al. 2004a). The thinking behind was to build a solid foundation not to relate with industrial applications by using materials from a particular design such as fashion, interior, packaging, etc. The results showed that a good agreement between Chinese and British, and between male and female on the 10 emotion scales studied. These scales can be classified into three dimensions (colour-heat, colour-activity and colour-weight). The results agree well with the others' findings. The models were also developed to predict colour emotions from the colour measurement data. They subsequently studied colour emotion on multi-colour combinations (Ou et al. 2004b). They again found little culture difference, and most importantly, the colour emotion is additive for different colour combinations. The mean of each individual's emotion values represent the visual results well. However, this does not work well for the emotion of 'preference'. Hence, colour preference was investigated (Ou et al. 2004c). It was found preference is enhanced with moderate colour activity, one of the three main emotion scales. Above three studies built a foundation of colour psychology in our framework. We found them to be very effective in real applications (see later).

During a period of 5 years, a collaborative research project (Ou et al. 2012) was coordinated by our team to conduct a cross culture study on colour emotion including 4 scales (colour-heat, colour-activity, colour-weight and like-dislike) for two-colour combinations. A total of 223 observers over 8 countries were involved. The results confirmed the reliability of the three emotion scales across all cultures. For like-dislike scale, little differences were found between countries. However, Argentinean observers show larger difference comparing with the other observers. The data were also used to reveal the differences between gender groups, between age groups, and between with and without design backgrounds.

3. COLOUR HARMONY

Colour harmony has been extensively investigated by many researchers. Many of them are based upon a particular colour order system. The main theories of colour harmony found from these studies are: equal lightness, equal chroma, equal hue and complementary hue. Our approach (Ou et al. 2006) was to apply 1431 colour pairs to scale its colour harmony, defined as 'a colour pair exhibiting pleasing effect'. The results showed that a colour pair to be judged as harmony have 1) a higher sum of lightness, 2) a lightness difference, 3) equal hue and equal chroma difference, and 4) a hue close to pure blue colour. Note that all the rules disagree with the conventional theories of colour harmony, except Rule 3). A colour harmony model was also derived as a function of CIELAB L^*, C^*_{ab} and h_{ab}.

The experimental work was later extended to use 6545 three-colour combinations and 111 interior images (Ou et al. 2011). The results again confirmed that simple additivity law works not only for colour patches but also for images on colour harmony. Large confidence has gained from this study to apply for the other applications.

Later, various studies were carried out for real applications including decorative, printing, textiles, packaging, museum paintings, and lighting. For each application, the same methodologies were adopted. It includes the accumulation of the terms associated with the product in question, the preparation of the products in real form or image in a selected colour range, the method for psychophysical experiment and the results from the data analysis including factor analysis to reduce the number of terms into few categories, or customer perceptions. Finally, models have been developed to predict from the physical or psychophysical measures to customer expectations. The results confirm that colour has an impact in product design. A harmonised colour scheme predicted by the colour harmony model will frequently be felt more pleasant by the customer. The terms to describe customer expectation could vary according to different applications. However, they are more or less related to the three principle emotion scales found here.

At present, International Commision on Illumination (CIE) realised the importance of the work. A technical committee (TC1-86) on *Models of Colour emotion and Harmony* was established with an aim to recommend universal accepted colour emotion and harmony models to fit well to the existing datasets.

4. GENERIC MODEL TO STUDY COLOUR AFFECTIVE ENGINEERING

This section is intended to introduce how to integrate the earlier findings into a product design process. Figure 1 shows a workflow of product design including 4 components: product variables, physical measures, perceived attributes and customer expectations. This was originated by Engeldrum (2000) for assessing quality of imaging products.

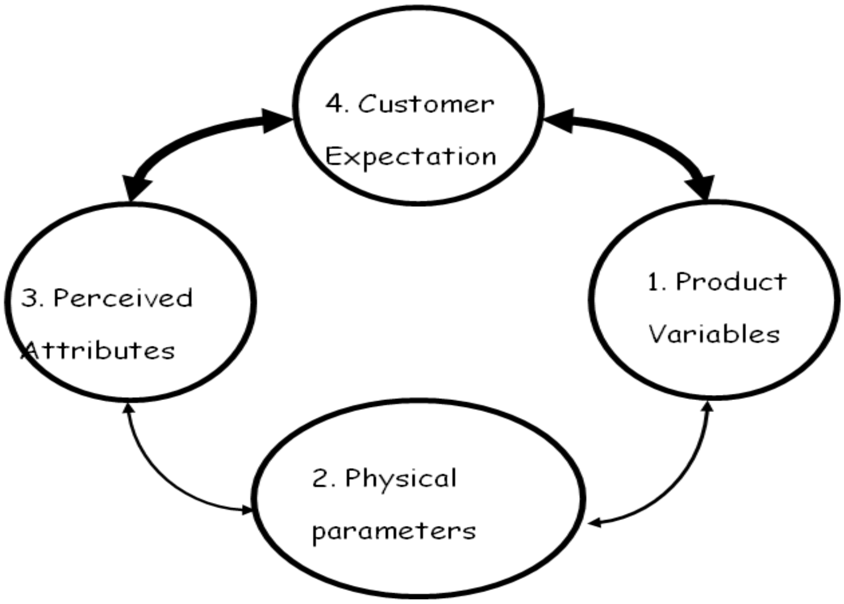

Figure 1 A workflow for product design

Let's take an example for designing a product of LED light source. In Stage 1, there are many engineering variables such as how many types of LEDs, their peak wavelength, luminance, spatial arrangement. In Stage 2, each product will then be evaluated by instruments to obtain 'physical measures' such as spectral power distribution, peak wavelength, luminance, 2D and 3D light distributions. Stage 3 will transform the physical parameters to perceived attributes via vision model such as brightness, chroma and hue for describing colour quality, uniformity to describe spatial quality. Finally, the customer expectations such as cosiness, lively, tenseness and attachment as found by Vogels (2008) which are known as 'atmosphere perception' in a lighting environment. These expectations can then be used to directly adjust product parameter in Stage 1 to reach a particular atmosphere. The methodologies introduced here can be used between Stages 3, 4 and 1 in Figure 1.

5. CONCLUSIONS

This paper introduced a series of study on colour emotion and colour harmony using psychophysical methods. The methodologies can finally be integrated as part of product design process.

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inter-
disciplinary
colour

The Blind and the Interpretation of Colors

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ABSTRACT

A lot has been said about the analysis of the world we picture from our eyes as well as of how we perceive and experience the space, time and action around us. But what happens when, in the midst of this context, we think of those who do not decode visual information? How is their relationship with the universe of colors? They actually have access to them, their meanings and expressiveness, or as a result of their disability, can't they see anything? It is true that our mental images are formed by the information we receive from all our senses. Thus, each one in its own way, we all see. The central discussion of this article relates to the different ways of looking at and dealing with the colors. Underlying this proposal is the tenet that the sense of sight is only one of these multiple paths.

1. INTRODUCTION

In their cinematic dictionary, Aumont and Marie (2003) define the gaze as a model of the subject and it's psyche, or better saying, it is distinguished by the fact that the vision emanating from the perceiver. Addressing the same topic, the philosopher and photographer Evgen Bavcar (2001) seeks in the mythical figures of the Greco-Roman world a relationship that reveals the history of the gaze. He takes the Cyclops, Ulysses, Oedipus and Tyresius to describe it. In his analysis, the Cyclops, archetypal of rudimentary vision instinctual, is provided with one eye and sees the world from one-dimensional way. In mythology, it is rightly defeated by Ulysses and his binocular vision, that can distinguish the name of the thing by blinding the Cyclops strategically naming himself as *Nobody*. Understanding that Cyclops was the victim of *Nobody*, his brothers did not come to rescue him (*Nobody blinded him*), allowing Ulysses to escape.

To Bavcar, with Ulysses monocular gaze becomes unsuitable because in its place comes the gaze connected to the knowing. Ulysses sees what he knows and thinks in what he sees, in other words, he differs signifier and signified, the sign and its object, the name and the person. It is only with the blindness of Oedipus – sticking his own eyes when find himself married with his mother, or "blind" to not have recognized her – and so even more with the nonconformity of Tyresius – the blind seer of Thebes – to accept the world as it is, the visual differentiation will expand to the invisible: the result of the vision becomes a creative process. To unravel the sentence of the oracle ("We must defend the Persians behind the wooden walls") Tyresius did not stop on the meaning contained in a simple sentence. Surpassing the literalness the literalness of "walls" and "wood", he creates a synthesis in a third term: "ships".

It is undeniable that the contemporary world, heir of the Enlightenment propositions and founded on science, emphasizes the gaze of Ulysses: we separate, classify, ordain, and categorize the "real" from what we see. But this does not mean at all that we are hostages of this "dictatorship of vision". Putting it in the words of Wittigenstein (1996): "We could not imagine a tribe of blind people? Couldn't they be able to see under certain circumstances? And don't sighted people should arise as exceptions?" And we can complete: the blind would not be able to deal with the colors, its meanings and feelings? So, it is necessary to extrapolate our binocular gaze to immerse in this invisible world, full of possibilities.

2. THE COLORS AND AUDIO DESCRIPTION FOR VISUALLY IMPAIRED

The short film *The colors of the flowers,* produced by the Spanish organization ONCE, tells the story of a little boy with visual impairments who, like his classmates, need to write an essay about the colors of the flowers. But how would he do that? The blindness make impossible to him perform such a task? Encouraged by his teacher to do the essay for himself, Diego, the little boy, starts to seeking a way to explain the colors he had never seen. It is curious to note that a friend of Diego tries to help him by saying: “Daisies are yellow, roses are red and violets are purple.” Then, when he looks for information about color in a search website, the boy stumbles upon the definition of the “Color is a visual perception that originates in the brain when the nerve interpret signals generated by the photoreceptors.” Diego laughed. After all, said in that way, what could that mean?

The story continues. When Diego goes through a wooded park, the little boy listen a birdsong. Suddenly, an idea comes to him. He writes the essay and present to the class. “The flowers are like colored birds and there are many colors of flowers. That’s why there are so many birds, because there is a bird so that every flower can has its own color. It has also the bee color flower and cow field color.” What Diego shows us is that the aesthetic experience of visually complex phenomena, such as the colors, can become accessible to the public with visual impairments.

We cannot deny that in a society dominated by the sense of sight like ours, people with visual impairment are shut out from access to this information. In this sense, audio description appears as a tool that enables the inclusion of this portion of the population by providing sound data from the visual information.

Audio description is an educational resource for assistive technology, geared to the needs of people with visual impairments, whether partial or full. It is an inter-semiotic translation, where a system of visual signs is converted into sound texts (SILVA, 2009), by presenting a range of extra audio integrated into the product (whether audiovisual, theater, opera, dance, and so on). In audio description, important visual details as sets, costumes, indication of time and space, movement and bodily expressions of characters are presented in a sound in order to contribute to a greater understanding of the product audio described. Preferably, these extra audios should be inserted in between the dialogues and important sounds, so as not to interfere with speech, sound effects and the musical of the product.

From the impact that it has on the feelings and the power that it has to express different psychic states, color creates a varied “sensitive environments”. Thus, a major challenge in the audio description is to make color tangible to the blind. And to avoid to make the same mistake as Diego’s friend (“Daisies are yellow, roses are red and violets are purple”), it is up to the audio descriptor translate this information as open and stimulating as the starting material, equivalent (but not equal, since they belong to different semiotic supports) to the information in the source text. In this thought is implied the idea of preservation of the concept of collateral experience in art, variable from subject to subject. In it, different inputs produce different outputs, or even a single input can produce more than one output. These relations are very important in the open semiositic processes and, consequently, in the audio description.

This simple principle underlies an attempt to think the audio description as something that goes beyond the mere transposition in sound of what we see, centered only on those who produce. Instead, the real focus of the audio description is the recipient, and the recipient is fundamentally different from those who produce it. Thus, to undertake this translation, we wonder if the visually impaired are imagetically naive, or if they cannot establish relations with the colors in their everyday life. Indeed, the answer is negative to both questions. To give a simple example of that, we just need to notice the way that anyone with visual disabilities worries about matching the colors of their clothes.

There is a certainty of a world common to all of us, where are articulated perceptions which are individual and subjective. But for beings living in societies capable of cultural learning, as in our case, the environment is not just physical but physical and cultural: beyond physical space, it includes rituals, rules and standards among others. This category involves the ability to use and interpret conventional signs, where a concrete expression (handshake) is a concept less concrete (a friendship) to community members. While social in origin, this system of meaning becomes internalized by acquisition, and assumes the role of acquired value system, that is mediation between organism and environment. Diego, the little boy in the film, shows us that the translation of colors for audiences with visual impairment follows exactly this way.

In other words, the investigations surrounding the translation of colors for audiences with visual impairments must overcome them to embrace the invisible and creative. Audio description is perfectly capable of moving beyond the mimetic representation of the image displays to become a proposal in which the so-called visually impaired can see how Tyresius. From this relationship, it becomes more evident the role that is shown to audio description: the task of acquaintanceship with the sensitive (colors, in our case), but the sensitive from the point of view of the visually impaired and not from the seers.

3. CONCLUSION

How blind are we in relation to our own senses and in relation to the others? There are many challenges showing up for researches in the field of audio description of colors. To enter in this universe, we must respect the visual culture that already exists in the repertory of the public with visual impairment, understand how they relate and deal with the world of colors. From this, we will be capable to co-construct new and important possibilities of interaction.

As inspiration, becomes valid to mention again the work of Evgen Bavcar – besides philosopher and photographer, Bavcar lost his sight at the age of eleven. His work, very technical and tricky, challenges us to put the picture/colors as something not necessarily visual, but visible: Bavcar sees with his hearing, his tact, with his whole body. And the photographer goes further, declaring that he is "blind" as astronomers, who can only see indirectly – "What can they see with their own eyes?" (Bavcar, 2001, p.12). According Bavcar, we all use the other's gaze, but in other plans. And as we can not only see with our own eyes, says we are all a bit "blind".

> Every photo I take I have to have perfectly organized in my head before shooting. I put the camera at the height of my mouth and that's how I photograph people I hear talking. The autofocus helps, but I can manage without it. It's simple. I measure the distance with my hands and the rest is done by my internal desire for images. I know there are always things that escape me, but that's true of photographers who can physically see. My images are fragile; I've never seen them, but I know they exist, and some of them have touched me deeply (Bavcar).

Figure 1: Photo by Evgen Bavcar.

Taking as a north the claim of Toro and Werneck (1997) that “democracy is a way to build freedom and autonomy of a society, accepting as its foundation diversity and difference” and also observing the tenet that deficiency lies not within itself but in the way society is organized to deal with it (which can be stimulating and accessible in very different levels), it is argued here in favor of the visually impaired also be taken as presupposed receiver of colors.

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Inbetween Light and Shadow: (In)visibility

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ABSTRACT

The relationship of the individual with light and shadow is ancestral and reflects itself in the history of mankind. This relationship, of a collective or personal nature, has meanings which are associated to culture, memory, imagination and the individual's attitude towards life. As the complexity of relationships and referrals increases, these structural, figurative and / or expressive elements of dematerialization and materialization of space tend to create effects, sensory experiences or perceptual codes that lead to the discovery of new spatial dimensions.

Bringing together some examples of works of contemporary authors, we propose an exercise of reflection on new ways of understanding the interaction between matter, light and shadow and the effects produced in the individual, whose sensitivity coexists with spontaneity of colour, movement and image. By alluding to the senses and imagination stimuli, regardless of technological advancement, it appears that many of the old functional and spiritual needs still remain and are crucial in the creative process of formal, functional and perceptual definition of a space.

Keywords: Light.Shadow.Space.Visibility.Invisibility

1. INTRODUCTION

In an era characterized by a variety of expressions that accompany the development of technology, the diversity of visual stimuli and the emergence of new patterns of consumption and mobility, the individual's relationship with space becomes increasingly complex and ephemeral.

In this relationship, the expression of materiality becomes an instrument of production of a "culture" that is revealing of new perspectives and space theories, whose dynamics, as referred by Consiglieri (2007), provides the understanding and manifestation of space perception under various aspects, namely, the concrete, as an expression of the natural world; the sensitive, as creation of subjectivity for each individual or group; and the coded, as a product of the signs that make up languages.

In this context, light and shadow can represent different values, aspirations and needs of a society. They constitute the mediation of a thought, a concept or an action in time, which exerts a strong influence on the design, representation and transformation of space. A "game of intentions" which may comprise, from the basic sense of protection and shelter (social and nature), to the sense of object and desire.

At present, these conditions tend to be more competitive, confused or subverted. The creative agents tend to act in various directions in order to meet the new challenges and the new logic of the production process and, far too often, the search for the beautiful prevails over form. A paradigm shift that, with the advancement of technology, made the act of designing quick and easy to perform, and where some authors tend to risk and project the unknown and unattainable, imagining the relationship between work and human being, and the place in the future, through the use of image.

Accordingly, as stated by Barnabas (2007) and Vicente (2009) “light is the hardest material the architect uses to support his dreams.” If for some authors it is a circumstantial and technical element, for others it is a building material. One way or another, everyone considers it in the design process. However, not everyone prioritizes it as an element of integration and as a generator of an expression that adds “value” to the materiality of the built object, thus transcending the mere random play of light and shadow.

From these considerations, we intend to understand and demonstrate the importance of relations produced by light and shadow in contact with matter (disclosed or hidden) and the man who perceives it.

2. METHOD

As stated by Corbusier (1923 apud Rebouças 2011), “architecture is the wise, correct and magnificent play of volumes brought together in light; shadows and blanks reveal the forms (...)”. Light and shadow, “stable” and “unstable” elements, fundamental for architectural design, can shape and modify reality, affecting the individual’s psyche and the perception of the environments he experiences. In them is an underlying mutiplicity of relationships and factors that define specific aspects of expression of space materiality.

This gives a subjective character to its application because, however identical the methodology and parameters adopted, the solutions or syntheses authors bring are acts reflecting their understanding and appreciation of the principles or possible options governing the project.

Barnabé (2007) mentions, in an interpretation of Plato’s “Allegory of the Cave”, that “in this universe confined to shadows, light gives form and meaning to material entities, connecting them to each other. Light builds and mediates the relationship between space and the psychic dimension of the user, makes movement perceptible, orders and defines all real phenomena. Darkness, the enslaved look, directed to the shadows, can give man a distorted view of the world.”

Imposing itself not only to the eye, but also to conscience, this hypothesis shows us the idea of a critical appreciation of the relationship between poetic and technique, where space is a phenomenon of emotion, in which light and shadow are the “awareness of reality”, rather than an object utility.

Under this assumption and by exploring some of the principles defended by Thenaisie (2007) and Muga (2008) concerning different types of experiences and effects of light and shadow in space, we chose the following case studies: House Brione from Markus Wespi and Jérôme de Meuron (2005); Miami airport installation (2011) by Christopher Janney; Stephen Lawrence Centre (2007) from Adjaye Associates; and Fall in Pop (2012) from Nobuhiro Shimura.

The criteria for selecting these so diverse authors derive from the goal of structuring a critical reflection on the system of relations that rediscover and redefine the inherent and apparent materiality, which is felt and suggested in the space. A clash of realities and different applications that allows us to articulate how light and shadow have contributed to the balance between sensory system and intellectual and conceptual role of space.

3. RESULTS AND DISCUSSION

The use of new materials, the development of new construction systems, the definition of new spacial programs or the reinterpretation of the existing ones, all modified the use of light and shadow. Generally, the definition of an architectural style defines the language for use of these elements. Even when they are not recognized, they appear in a subtle way.

Wespi and De Meuron's work reproduce a plastic representation of feelings and moods which allow the observer to interpret a formal and spiritual message. In the manifestations of natural, artificial and temporality, alongside with the expressive connotations, the careful drawing, the singular materials allow for the subtle changing's to be noted. The space without visual obstacles and excessive ornamentation is condensed in the essence of matter, form, light and shadow and in the naturalness of the visibility of this union.

Figure: 1. Casa Brione, Markus Wespi e Jérôme de Meuron (Photos: Hannes Henz).

Christopher Janney challenges the concept of colour harmonies and materials are allowed to acquire a final form from the changes and alterations provoked by a natural process over time. Light and shadow are the fundamental elements which, by the orientation of the building, the connection to the outside world and the time of day or time of year, transforms space and enhance their use and interpretation.

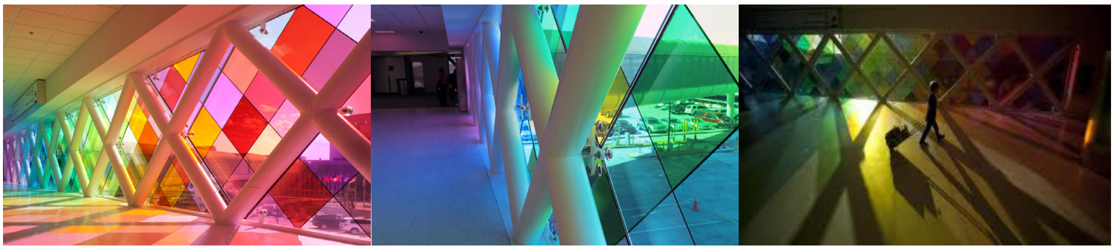

Figure: 2. Miami airport installation, Christopher Janney (Photos: Designboom).

David Adjaye is also an "experimentalist" of the invisible and visible effects of light and shadow. His solutions are never repeated, but are rather worked upon by bringing successive ideas, for which he then creates proposals which communicate natural with artificial light. These either tangent or reflected lights does not harm the eye in order to create a structure that asks to the observer to engage with space on a physical and emotional level.

Figure: 3. Stephen Lawrence Centre, Adjaye Associates (Photos: Dezeen).

Nobuhiro Shimura, with a imaginative audacity expands the experimentation of light, shadow, colour and sound that even ephemeral, enable us to understand and achieve new and ancestral meanings, in reality that is continually changing.

Figure: 4. Fall in Pop, Nobuhiro Shimura (Photos: Margarita Vazquez Ponte).

In this intellectual and cognitive process, light, shadow and colour are emitted through the skin of the installation, making the interior communicate through the translucency and transparency of the atmosphere. A structure that defines: virtual and real, colour and form, representation and image, light and shadow, but also, an interaction with the observer converting materiality into something temporal, evanescent and open to personal and cultural experiences.

4. CONCLUSIONS

The perceptual impression evoked by light and shadow lie in the quantitative and qualitative interactions among the various elements of space. Building a space is building light and shadow, thinking them as elements (or materials) that can participate and influence the conceptual process and the expression of the “visible” and “invisible” materiality. That is relating the space elements with temporal and cultural dimensions and, therefore, with meanings susceptible to change over time. This approach, offer us a reading key to be sensitive to this permanent, unquestionable and inevitable reality.

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Kolormondo: A New Tool for Colour Understanding in Daily Life

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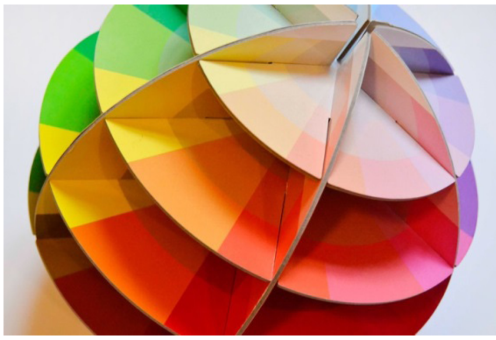
ABSTRACT

The world is not two-dimensional like a flat map. It is a globe, and thus in 3D. The same goes for colours. However, colour is often presented flat – in colour charts or colour fans. And just like a map is not an accurate representation of the world, these colour charts and fans are confusing. This might seem trivial for somebody who is well oriented in the world of colours, but to most people, it is a problem. The subject of colour, although important to everybody, soon becomes very complicated.

Kolormondo visualises colours in 3D; in a globe. It is thereby systematizised, **logical, easy to understand and intuitive**. It gives an **overview** and can be used by **the beginner**. It is **complete** and can hold any number of colours. It facilitates **communication** by enabling use of everyday words like “up/down” instead of “value” / ”brightness” and “in/out” rather than “saturation”. The beginner and the expert can thus talk to each other.

The first product launched is physical; a 3D colour puzzle. It is primarily sold in Museum shops and to schools. It serves as an introduction to the subject of colour for both children and adults. The first digital product is an app for Apple iOS and Android devices. Kolormondo will soon introduce a third product; a web based tool. Kolormondo is patent pending.

1. The box and the puzzle pieces

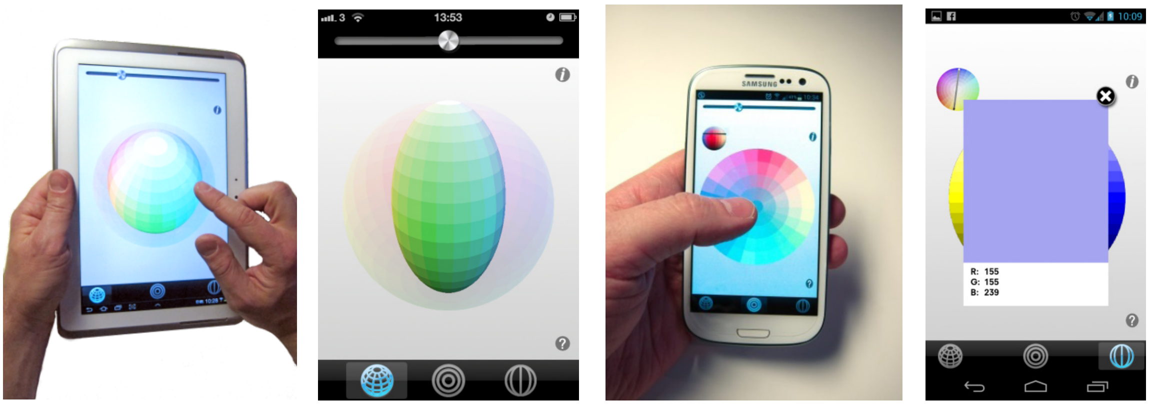


2. The Kolormondo 3D colour puzzle

1. INTRODUCTION

Colour is **important** in many professions but also for the general public. It influences us in many fields of life. However, most people remain ignorant about the subject, and there are **hardly any tools** for learning, understanding and communicating colour, particularly not for beginners. Different **professions use different colour tools** (RGB, CMYK, Pantone, NCS, etc.). **Colour language** is either very precise but only known by a few (like S 0580-Y70R for light orange in NCS) or vague, such as “latte”. Digital 2D colour devices (used in e.g. Adobe Photoshop) are easy to use but hard to actually understand considering colour interrelations.

The purpose with Kolormondo is to create an introduction, an easy-to-use tool for activities like communicating colour, identifying a particular hue, seeing what colours are good matches, developing and inspiring artistry and creativity and to inspire when choosing colours. Once you know the ABC-book, you can advance to more complex reading.



3. The Kolormondo app on various devices.

2. THE CONCEPT

Kolormondo visualises the world of colours in 3D; in a globe. Around “the equator” is the colour circle, with the most saturated colours, as seen in Illustration 1. Going north, colours gradually turn lighter/whiter, meeting at the white North Pole, see Illustration 2. Going south from the equator they darken, and meet at the South Pole. Inwards, the saturation is reduced. The grey scale is a pillar between the North and the South Pole.

Kolormondo is inspired by the theories of Runge, Göthe, Itten and others. It uses the triangles of the CMYK/RGB systems. Thereby, complementary colours are opposite each other and each colours relation to all other colours and what it is “composed of” is obvious. The gradual change from any given nuance in/out to its less/more saturated “relative” is easily seen, as well as the change in value going up for a lighter/whiter version and down for more black. By following relations circularly, one nuance transforms into the next and the next.

3. A COLOUR PUZZLE AND A COLOUR APP

The Kolormondo concept exists, so far, as one physical version, a 3D colour puzzle, and a smartphone app. The puzzle is built from 11 pieces, that can be taken apart and build over and over again. When done, it is an eye-catching beautiful mobile. In the app the user can turn, enlarge, move into, cut the globe and find the RGB-values for each nuance. See Illustration 3.

4. USERS AND USAGE

The main aim of Kolormondo is to make colour understandable and to inspire - in particular beginners - to become more capable in identifying, choosing and matching colours. Obviously this is useful in schools and adult education. But also, a professional (like a designer) can use it to educate clients. Thereby, the quality of the dialogue during production processes increases.

For pedagogical reasons, the first representation of Kolormondo, the 3D colour puzzle, has only a few hundred nuances. But soon after the launching in 2011, semi-professionals and professionals started asking for a more advanced version.

The Kolormondo app is therefore more complex than the puzzle, containing around 1500 nuances. It also has the value of each nuance expressed in RGB.



4. Discussing, building and studying Kolormondo

5. NOW AND ONWARDS

Kolormondo is a **logical, easy to understand and intuitive** way of describing the world of colours. It **is systematic** and **neutral** to various interests. It is for immediate use in daily life by **the beginner**. But it is also **complete** and can hold any amount of colours. It facilitates **communication** by words like "up/down" and "in/out" instead of "value" and "saturation". In particular, it helps the expert and the beginner to communicate.

Knowledge about colour and how to match colours is no longer a secret for a select few. Everyone can understand it. And from knowledge comes ability and passion. Understanding the Kolormondo concept is essential for comprehending colour. Just like knowing that the world is round is basic for understanding the world we live in.

Please see the three-minute film on http://www.kolormondo.com/Film-Kolormondo-Colours-Made-Simple.html and for further information, kindly visit www.kolormondo.com.

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How the Colour Affects System Compares with Other Approaches to Colour Harmony

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ABSTRACT

The successful application of colour psychology depends entirely on colour harmony. In a similar way to music, individual notes or colours are neither 'good' nor 'bad' in isolation and, whilst each has its own individual properties, very little emotional response is evoked until the notes or colours are combined to create a musical piece, or a colour scheme. We are rarely, if ever confronted by one colour, and the emotional response is not necessarily being caused by the colour the observer is consciously considering. Response to colour (and indeed all aesthetic influences) was found, by the late Professor Hans Eysenck, to be 80% unconscious [1]. Disharmonious combinations of colours (or notes) produce generally negative feelings and can create the false perception that the individual colours or notes are innately unattractive.

The Colour Affects System of Applied Colour Psychology includes a systematic approach to colour harmony, borne of a conviction that something as fundamental to life as light (colour) could not be random: there must be patterns. Over several years of searching and empirically testing colour groups, more than 90% of observers consistently agreed that each colour group was harmonious (regardless of preference).Most of the research was original. When the harmony groups were subsequently subjected to serious scientific scrutiny, and scanned into a computer, the colours in each group were found to have mathematical relationships that did not occur between colours drawn from different groups – i.e. the System is algorithmic. Objective colour harmony is now a reality.

Key words: Harmony; Colour Psychology.

1. INTRODUCTION

We have found that people tend to assume that the Colour Affect System is in some way an alternative to traditional colour harmony theory. It is assumed to be another harmony system, to be compared with existing work, such as that of Judd & Wyszecki, or, further back, Johannes Itten and many others over hundreds of years. We are aware that we have not made it sufficiently clear in the past that the Colour Affects System *underpins* classic colour harmony theories and works *with* all other approaches. It works within any colour ordering system – NCS, Munsell, Pantone, etc. The ideal way to produce colour palettes that are universally attractive and psychologically effective is to apply classic colour harmony theory within the Colour Affects colour groups.

In the interests of clarity, this paper describes how the Colour Affects System relates to the two colour harmony/colour psychology systems closest to it: the work of the leading colour scientists in the field: the late Professor Shigenobu Kobayashi, of the Nippon Color & Design Research Institute in Japan, and Dr Li-Chen Ou, formerly at the University of Leeds, in the UK.

In order to evaluate the Colour Affects System, it is important to understand that it bears little relation, beyond the superficial, to existing systems of colour psychology or colour emotion scales.

2. COMPARISONS

2.1 The work of Dr Li-Chen Ou

Li-Chen Ou chose 35 colours as the basis for his system, and produced over 6,500 permutations of these 35 for his research. He asked observers for their opinions about the properties of individual colours, dyads or triads, and also for a quantitative assessment. (For example: “Which of the following words would you use to describe this colour - warm or cool?” “Which of these colours do you consider to be warmer?” “How warm do you consider this colour to be?”) He also draws a distinction between colour emotions and colour semantics. He claims that people do not say “That colour makes me feel warm” but “That colour is warm”.

Dr Li-Chen Ou’s extensive data enabled him to create a model of colour harmony:

- Colours that are similar in chroma
- Colours of differing lightness
- Lighter colours, rather than darker

2.2 The work of Professor Shigenobu Kobayashi

Kobayashi’s system has 130 main colours, and he devised image scales classifying them along Cool/Warm and Hard/Soft axes; he also classified his database of feelings along the same two axes. He ascribed 180 adjectives to specific colours, and presented these adjectives in four quadrants, overlapping in many places.

Kobayashi also maintained that basically the words do not have negative image association.

In the context of the psychological nuances, he has three psychological axes: as well as Warm/Cool (WC) and Soft/Hard (SH) he adds Clear/Greyish (KG)

2.3 The Colour Affects System

In some respects, the Colour Affects System is built on a directly opposite methodology from both these gentlemen’s work – it works ‘the other way around’. Not being a colour scientist, Angela Wright’s initial division of colours into four groups, based on the common idea throughout history of humanity falling into four personality types, was carried out in the 1970s and 1980s,entirely intuitively over many years of looking for patterns, rather than working with a number of specific colours. It was only in the 1990s, when Colour Affects came to the attention of the academic world, that the colour groups she had defined were found to cluster in the same computer space – i.e. there were mathematical correlations between colours within each group that did not occur between colours from different groups – suggesting the patterns she had been seeking.

Trying to evaluate Colour Affects in the context of the work of Kobayashi and Li-Chen Ou is to misunderstand the Colour Affects system. Certainly there are apparent similarities between the four Colour Affects families and Kobayashi’s scales:

Colour Affects groups could be described as

- Group 1 – Warm/Light/Clear
- Group 2 – Cool/Greyish/Delicate
- Group 3 – Warm/Strong/Greyish
- Group 4 – Cold/Strong/Clear

However, Professor Kobayashi developed his system by entirely different methods, and formed entirely different conclusions.

3. FURTHER DIFFERENCES

Colour Affects defines 'cool' and 'warm' colours differently: instead of the traditional definitions of long wavelengths = warm, and short wavelengths = cool, we support Aristotle's (and Goethe's) emphasis on blue and yellow as the true primary colours, and base our definitions on blue-based (cool) or yellow-based (warm) hues. Thus it is quite possible for a red with a touch of blue in it to be cooler than, say, a blue with a touch of yellow in it. Each colour group contains versions of all hues.

Furthermore, we have found that the property that determines whether any colour is stimulating or soothing is not, as previously thought, a matter of the wavelength, but a matter of the chromatic intensity of the colour. So, for example, a strong, highly saturated blue or green will stimulate, whilst a soft pink (a tint of red) will soothe.

Li-Chen Ou's view that people do not say 'That colour makes me feel…' has not been Colour Affects' experience. In fact, at seminars for designers and architects our tutors often flood a large screen with one colour and ask the audience to analyse how the colour makes them feel. They are also asked if they can identify where in the body they feel their reaction. The audience is always highly articulate in describing how the colour makes them feel; most people can also pinpoint where in their bodies they feel the reaction.

Neither does the author agree with Kobayashi that, 'Basically, the words do not have negative image association.' Every colour and every adjective has the potential for negative association, depending on how they are used. It is our contention that one cannot control how someone else will interpret a word.

As humanity has striven throughout history to order the myriad colours that exist, and organise them into manageable form for practical use, scientists have also produced excellent colour notation systems: NCS and Munsell are examples that immediately come to mind. These systems also bear no relation to Colour Affects – but Colour Affects works perfectly well within them.

4. CONCLUSIONS

Once the patterns had been identified, it became possible to extrapolate them to classify any colour into one of the four harmony groups. (We are often asked how we know there are not more than four groups. We do not know – but we have never found a colour that did not belong in one of the four.) There appears to be very little limiting the number of colours that Colour Affects can classify into harmonious groups – since the classification database will ultimately include all the CIELAB colour cubes. So, for example, the whole of the NCS or Pantone colours could be inputted and would present no problems at all for the Colour Affects System.

The Colour Affects original prototype contained approximately 16 adjectives in each of the four groups and there are a further 48 in each group, ready to go into the electronic system currently in development – a total of 256 colours. Angela Wright can provide many more adjective/colour associations, if required during development.

Over 28 years of application, empirical testing and scientific research, we have found that positive response to any colour can be consistently achieved using the Colour Affects System's different approach to colour harmony. Whether people respond positively or negatively to an individual colour is dependent on how the colour is used – i.e. whether the whole palette is harmonious or not. Humanity does not respond to one colour in isolation, but to all the colours confronting us. Both colour and musical harmony are underpinned by mathematics. Disharmony negates.

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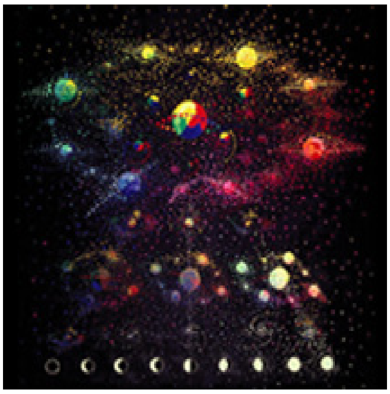
The Planetary Colour System

Michel ALBERT-VANEL

ABSTRACT

When I was teaching the various systems of colour classification, such as the Munsell, the NCS… at the National Higher School of Decorative Arts (ENSAD) of Paris, my students inevitably asked me about the use thereof, since these colours changed radically due to contrasts between juxtaposed colours. And it seemed necessary to move from the field of absolute certainty to that of relativity, which corresponded more to the spirit of the time. Moreover, their work: painting, design, architecture, textile… was always based on combinations of colours, and not on isolated colours. I wondered how to establish a system functioning on the combinations of colours. But all my colleagues said it was impossible, because, according to them, the number of these combinations was infinite… However, on my way back from a conference in Berlin, in 1981, I foresaw a solution, in the shape of a galaxy of colours, which was, to tell the truth, rather shapeless. And several decades were needed to concretise this intuition. The research ended up with success, and received a mathematical confirmation. But shall we pretend that the problem of the combinations of colours is completely solved? That is the question addressed in this article.



1 – The Planetary Colour System

1. What are the bases of such a system?

The bases of visual perception seemed well-established starting from the theory of the trichromatic primary colours of Young. However the theory of Ewald Hering, preaching the existence of "elementary colours", also known as "psychological primaries", came to sow discord within the scientific community. These primary colours are: black and white, yellow and blue, green and red. Curiously, they are the prototypes of Jung, but also the "authentic colours" of much of beliefs in the world. However the existence of these primary colours, functioning by antagonist couples, was established by various experiments, such as the work of Edward F. MacNichol and this of Leo M. Hurvich and Dorothea Jameson from Pennsylvania. They could show that signals received by the three receivers, in the retina, were transformed into antagonistic signals to be transmitted to the brain. The primary colours of Hering are thus closer to the awakening, and this is why they are so significant! Thus any association of colours, such as paintings, images, and architectures… results from a combination between these six primary colours. Finally, it is surprisingly simple!

2. How does the combinatorics function?

These six primary colours will enter in action into the “window” of the eye, and will develop combinations by juxtapositions and mixtures. We are dealing more with visual perception, than with physics! The association of these six primary colours obeys to the laws of visual perception described by the Gestalt-theory, according to which the unit is different from the simple sum of the parts. The result is that associations such as: red/green, yellow/blue, black/white, or the polychromy… will be perceived like complex colours, or colour groups, and not like the addition of isolated colours. They are perceptions of a whole share. And we can list some principal combinations, called “colour groups”.

3. What are the principal combinations?

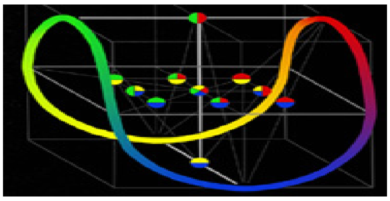
The development opens like a tree structure, going from the simple toward the complex. At the beginning, we will consider three principal categories:

- The Colours, generating fifteen tonal combinations;
- The Values, summarizing themselves in three principal achromatic states;
- The Mixed one, presenting three polychrome combinations, associated the Values.

The result is twenty-two fundamental colour groups, which are the most different possible. Many exercises practised with the students of the schools of art could show the cogency of this design of these twenty-two groups.

4. How to represent the hues?

They can be represented by a disc filled of the fifteen tonal combinations. Those are ordered according to four pure colours, put in cardinal opposition: yellow/blue and green/red. Then quadrichromatic associations come from the centre, then the trichromatic ones, the bichromatic ones, and finally, the mixed colours of the chromatic circle of the external belt. This chromatic circle is not flat, but it possesses a curious apple chips shape!



2 – Representation of the hues combinations

5. And the achromatic ones, or the neutrals?

Starting from the two poles, which are the black and the white, we find, in the intermediary, the black and white contrast, that will cause, by fusion, the different types of grey. This is drawing a figure in half-circle, where the rays with an external hearth allow finding the potential fusion of these various contrasts using the revolving discs. It should be considered that the juxtapositions on the pointillist mode of optical fusions operate in a way that is identical to fusions caused by revolving discs. Those can thus be used as an estimated model.

6. How to characterize the contrasts of values and colours?

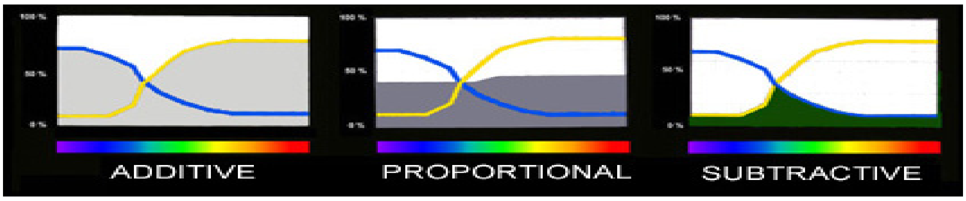
It is certain that the pure colours or the pure neutrals are extreme cases. And, in the majority of the cases, colours and values will be associated. The fifteen preceding cases of hue contrasts will be confronted with the black, the white, or the black and white, creating the category of the Mixed one. Those will diversify in subgroups, forming sixty-four cases of contrasts. These contrasts are everywhere where it is necessary to bring a good legibility, as in the old heraldry, or in the current motorway signals.

7. What is it about the nuances?

But if we push the reasoning further, we realize that instead of remaining in contrast, these coloured components can also mix, and more or less amalgamate. Thus these fusions will cause a new category: that of the Nuances. Their characteristic is to present tones, which are very close each other. We find it mainly in nature, with the subtleties of the colours of the ground, of the vegetation, and of the animal furs…

8. How do these mixtures occur?

Until now, the scientific literature retained only the additive and subtractive syntheses, which had the disadvantage of digging the gap between painters and physicists, up to making their dialogue impossible. However it appears that optical fusions operate on the proportional mode, which is intermediary between the additive and the subtractive one. This can be shown by the revolving discs, where the fusion is the result of a weighting between the parts put in presence. The analysis made by measuring tools shows that the obtained synthesis is not only a visual illusion, but also that the resulting curve is located very exactly between the curves of the additive and the subtractive one. Thus, we may have a tendency to additivity, or subtractivity, when we deal with light or with matter. We can thus replace the old paradigm of the additive and subtractive, by continuity, whose optical fusions of the proportional type constitute the standard and the average.



3 – Additive – proportional – subtractive

9. Is the progression infinite?

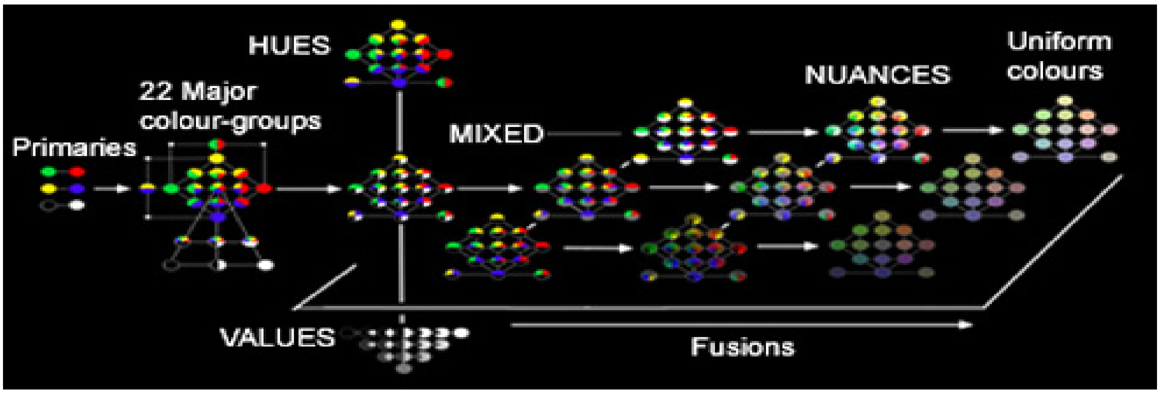
It is still possible to associate contrasts and nuances in complex groups. And we can always go further in subtlety. But very quickly, we will note that all is lost, and that we fall into the confusion, the inconsistency, and the impression of fortuity, of anything… The result is that combinations of really different colours are then confused like similar, and cannot be memorized, because their sense is no longer detected. It is thus very meaningful to consider that the progression we may believe as infinite, is closed to randomness, or chaos, because of this reducing aspect of visual perception.

10. And what about plain colours in all that?

Through fusions, we come to the point where internal contrasts are lost. It seems there is no more difference between hues, between clearnesses, and between saturations, and we are dealing necessarily with plain colours. And these plain and isolated colours can be regarded as being extreme cases in the combinations of colours. The system is then closed on the traditional systems of colours. It is thus possible to integrate them into a more global total design, where contradictions are resolved.

11. What does this overall representation will look like?

The whole of the system has multiple dimensions. But the planetary mode allowed escaping this dilemma. We may figure there the galaxies, of principal stars, the planets, which are associated to them, their satellites, going toward the asteroids of the most varied and thinnest combinations…



4 – Global representation

12. What is the utility of such a system?

The experiment shows that this system is very useful, and very effective, to classify the combinations of colours. In particular, the twenty-two colour groups can optimise the coloured solutions in various fields, like that of architectures, in order to better differentiate spaces and circulations. And in the field of the images, a related study succeeded with the classification of twenty-two paintings of the Impressionist period. We could characterize each one of these paintings as well as possible, see their oppositions and their correspondences. And it was possible to establish their palettes, and to create colour charts, which are usable in house paintings. The result was that the old questions about the harmony of the colours became simple inherent cases of this combinatorics. In short, the concept appears very effective, and suitable for many applications. Perhaps, it would be there still many other details to develop, but the broad outline appears as well established, and opens toward a vast field of research.

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Colour and the Creative Process in Contemporary Practices: Connecting Pictorial and Architectonic Languages through Chromatic Relations

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ABSTRACT

This paper belongs to a developing practice-based research on the use of colour as groundwork in the creative process of contemporary painting, analysing specifically its influence and significance in the artistic practice that somehow connects pictorial and architectonic languages, mainly in the field of expanded painting.

The study is a consequence of the author's experience as a painter, whose work always privileged colour as an element that transforms spaces, their representations and the way we perceive and experiment them. Besides an appropriation of architectonic language to painting, the author is interested in the distension of painting to real space, which causes new preoccupations with the relation between colour and space and between the spectator and the perceived work, a relation that can be more physical and interactive.

The research aims to conduct a reinterpretation and contextual redeployment of the act of composing and creating through colour in artistic contemporary practices, emphasizing the cases of artistic works that represent an abolishment of the frontiers between painting and architecture. It is a fundamental objective to explore, experiment and analyse the transformative potential of colour in those projects, approaching colour subject trough the artistic object and valuing the experimental component of the investigation.

1. INTRODUCTION

The discourse on colour is often divergent and inconclusive, which is transversal to distinct knowledge areas. Mainly when constructed in an artistic context, the colour subject is fundamentally approached and though in the act of doing things and through practice. In studio art investigations the concepts of investigation and creation tend to merge and be contaminated, so based on this assumption, this research intends to approach colour subject through a continuous artistic experimentation in the field of painting, connecting practice and reflexion in a coherent unit. It is, in fact, a project centralized in the artistic practice developed by the author, where colour is determinant in the creative process and a fundamental composition element. Therefore, this paper wants to focus the main issues of a practice-based investigation on the privileged and confident use of colour in artistic practices that create a communication relation between pictorial and architectonic languages. This will lead to an unavoidable reflexion about the role of intuition in the creative process that focuses on colour and chromatic relations and interdependence: how much of reason and intuition are part of the artist's decisions? Josef Albers defended that the development of sensitivity for colour arises through experience (Albers 1976: 1). The author proposes that, through experience and a process of trial and error, we can develop the ability to see colour, its action, relations and connectivity. So, it is important to question if an artist that works in an assumed and privileged way with colour is able to develop, through experience, an intuition that leads him to perform balanced choices in his creative process. Also, what is the role of colour theory in this process? How can colour interaction guide a whole composition? Can the intentions inherent to a creative process based on colour interaction be effectively controlled? These questions lead the investigation to a reflexion about colour entropy and how it can influence the creative process in painting. The concept of entropy is widely used in an artistic context and in this investigation it is the ambiguous and vulnerable characteristics of colour that better associates to the concept of entropy in art, as it leads to a reflexion about order, disorder, chaos, organization, dynamics, flow and balance inherent to chromatic relations. If colour identity arises exclusively by relation and we can´t isolate it from a context containing a number of variables, how can we identify and establish an order and balance in an artwork where colours are determinant? How can we control the results, reactions and perceptions of an established order, if we can´t control the variables? "Order is a necessary condition of everything that human mind wants to understand." (Arnheim 1997: 361). That order and balance between colours and forms are always dependent from a series of relations that can be better understood through a perceptive intuition developed within a continuous artistic practice.

2. ARTISTIC PRACTICE: A CREATIVE PROCESS BASED ON COLOR

The developed artistic practice wants to explore the distinct possibilities of dialogue between painting and architecture, through colour, such as: architectonic representations in painting; creation of pictorial objects with an architectonic dimension, like constructions that we can physically explore and contour; painting made directly in architectonic space or exhibition room, where colour can be a kind of skin of the construction that assumes autonomy from its structure and functionality.

In the developed painting work, there is an assumed use of colour as a composition element, and it is only in a process of addition, subtraction, overlap, nulling and emphasis, a process of total conditionality, that the result appears. Then, there is an appropriation of architectonic language to pictorial space, although turning it into something dysfunctional and fictional. The use of chromatic relations wants to create an image of depth, of several reading plans and representations of places and landscapes that appeal to our desire to inhabit them, valuing the formal and aesthetical dimension of the architectonic language (Figure 1).

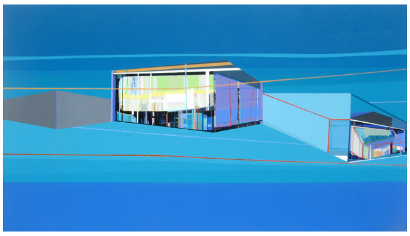

Figure 1: Ana Pais Oliveira. New strange place to live #16.
Acrylic on canvas. 130×230cm. 2011.

Wanting to create a more direct relation between painting and the architectonic space, it was developed a new project that would reflect that relation between colour and space. It is a series entitled *Houses, several corners of the world*, composed by seventy drawings with collage on different coloured cardboards. Each piece has its own autonomy, but the project contemplates its view in a frieze that designs a colourful line (of about 24 meters) in the architectonic space or exhibition room (Figures 2 and 3). The interaction of the chromatic results achieved through the different funds appears only when the drawings are exhibited together. It is intended to create a game of contrasts and harmonies, approximations and deviations, a dynamic and pulsed reading of the whole piece that models space and our perception of it through colour.

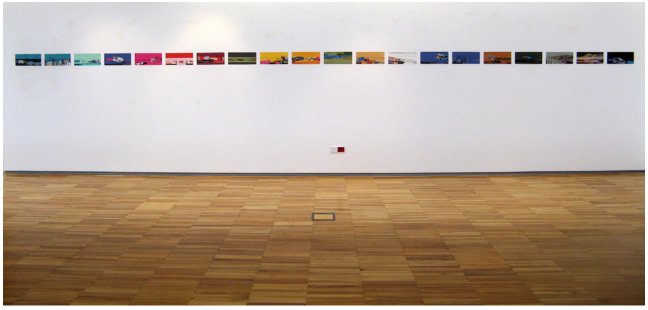

Figure 2: Ana Pais Oliveira. Excerpt from the Series Houses, several corners of the world. 20 drawings 15×30cm. Exhibition View, Espinho, Portugal. 2012.

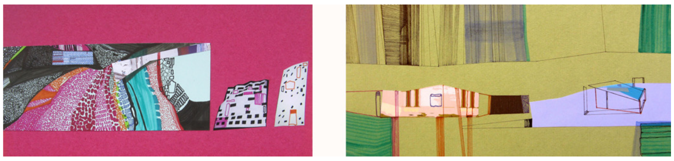

Figure 3: Ana Pais Oliveira. From the Series Houses, several corners of the world. #62 and #15 from 70. Drawing and collage on coloured cardboard. 15×30cm. 2012.

At this point of the investigation became crucial to begin an approach to a three-dimensional expression of the connection between painting and architecture. The project *Neighborhood* (Figures 4 and 5) comprises a series of elements that come together in an exhibition context, resulting of the articulation of screened panels with the dimension 13x18cm. First, it was assumed the support within its bi-dimensionality to carry out paintings composed by architectonic constructions and chromatic relations. Then, several identical supports were used to compose two three-dimensional pieces through chromatic relations, wanting to create an idea of habitability and dichotomy interior/exterior. These pieces are intended to be like three-dimensional paintings: they are exhibited in the wall, but they materialize a need to bring out some constructions present in the paintings. With this exercise, using their values, hues and luminosity can enrich chromatic relations. In *Neighborhood #2* (Figure 5) colour is, in fact, used as a concept and an autonomous element that creates an architectonic construction through different saturations of the same or similar colours. New possibilities of approaching the way that architectonic and pictorial languages can be contaminated, trough a three-dimensional thinking, are now under development. It is intended to explore new materials and scales.

Most of the writings on colour “are performed into and through practice” (Batchelor 2008: 5). This research intends to think and write about colour while doing objects.

A final and primordial purpose of the investigation is to create an exhibition project where we can perceive a chromatic dialogue and interaction between painting and three-dimensional constructions or pictorial objects that approach an architectonic quality and dimension. The communication relation between the pieces presented should reflect a previous study on the effect of chromatic relations in the perception of those objects, on the creative process that originated them and on the mutuality between the presented languages.

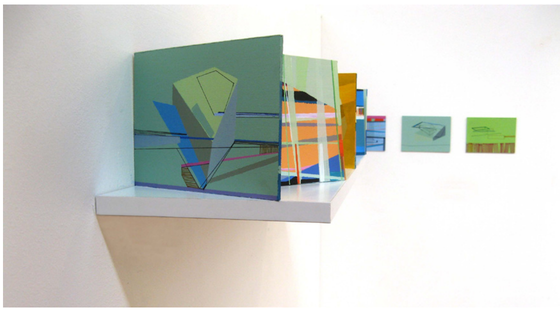

Figure 4: Ana Pais Oliveira. Series Neighborhood. (Exhibition view). Espaço Habitado, Fórum de Arte e Cultura de Espinho. 2012.

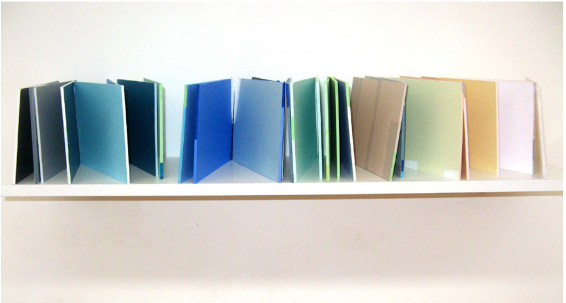

Figure 5: Ana Pais Oliveira. Neighborhood #2. Acrylic on screened panels, wooden shelf. 80×20×15cm. 2012.

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Colour in Medicine and Architecture: An Interdisciplinary Pre-pilot Research Project

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ABSTRACT

A pilot study was planned at the Medical Faculty at Lund University with the intention to map out colour discrimination (CD) in persons with Parkinson's disease (PD). A pre-pilot was made preparing research methodology including a colour test developed to meet demands from subjects with motor deficiencies as PD.[4] The overall goal for the project was to develop colour guidelines that can help patients to achieve increased life quality.

Changes in contrast sensitivity and impaired CD are considered to be established signs of PD, yet no consensus has been achieved on problematic colour areas. Problems may cause disturbances in the visuospatial orientation. Farnsworth-Munsell 100 Hue was used in most of the previous studies, despite severe difficulties for the subjects to handle the colour test.

The newly developed colour test, using three nuances, was found easy to handle for PD. Instructions were easy to understand and the test examination was not exhausting. It does not seem meaningful to use three nuances as scored errors did not differ significantly between the used nuances. Different kinds of errors needed scoring. The long colour sequence enables sudden discontinuation in colour sequence. Preliminary test results divide in two groups.

1. BACKGROUND

Colour guidelines can be used for environmental design in hospitals and nursing homes and be helpful in fighting the effects of the diseases, to maintain the patient's ability to live independently and thereby improving the quality of life. Conscious application of colours in interior design can contribute to a more distinct and hereby safe environment to move around in. A problem is that we lack knowledge of how colour vision is affected by neurodegenerative diseases, a big problem as the aging society will meet a growing need for good health care for these groups. Wijk et al (2002) has created helpful guidelines concerning colour vision in Alzheimer disease and dementia. Colours are used to mark out certain spaces and doorways so that they become easier to find and serve as "colour cues" for the memory.

Studies on colour and health concerning the environmental design occur also on persons with Parkinson's disease (PD). Colours are used as a supplement for additional stimulation; lines on the floor in contrasting shades or colours are found to encourage persons with PD walking ability and stride length. Previous research has shown that neurogenerative diseases develop a disturbance of colour perception. Changes in contrast sensitivity and impaired colour discrimination (CD) are considered to be established signs of PD, Nico et al (2002). Over time, many persons with PD develop Parkinson's disease dementia (PDD), associated with profound visuoperceptual impairments. Armstrong (2011) concludes that there may be disturbances of visuospatial orientation. Despite extensive research on colour vision in PD no consensus has been achieved on which colour areas that are particularly problematic. Reduced levels of dopamine cause PD condition. Müller et al (2003a) point out long-term treatment with a dopamine drug pramipexole as a source of deteriorated colour vision while

Nico argue that dopamine can improve the deficits. The most frequently used Farnsworth-Munsell 100 Hue test (FM100) has been criticised as malfunctioning for persons with motor disorders. Müller (2003b) mentioned severe difficulties for the subjects to handle the small round colour samples and mount them in the narrow test cases. Müller argue that FM100 is inappropriate for use with PD patients. Mostly retina is suggested as the damaged cite responsible for the impairments whereas some studies point out possible cortical involvement.

2. STUDY DESIGN

2.1 Problems and objectives

Problem was that FM100 was judged unsuitable for subjects with motor difficulties such as limited dexterity; involuntary tremors and stiffness. Main target was to develop and test out a special colour test, designed so that motor problems should not affect test results. Another aim was how different nuances might affect the achievement and to present actual scenes of result arrangements. Research questions:

- Are the colour samples easy to grip and handle?
- Are the instructions easy to comprehend?
- Will the subjects become too tired?
- Is it meaningful with three nuances?

Figure 1a. FM 100 Hue test. 85 colour caps in one nuance with one fixed cap at each end, total 97. The round colour caps 11 mm diam, shall be mounted in the four test cases.

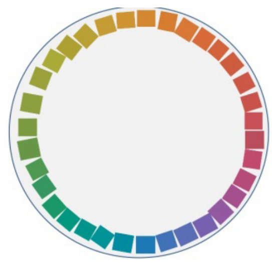

Figure 1b. The colour test used. 35 NCS colour samples on a round plate with a rim. Here test 1, the chromatic nuance S 2050.

2.2 Methodology

5 subjects with idiopathic PD among inpatients volunteered. Exclusion criteria's were low visual acuity with glasses, symptomatic cataract, untreated glaucoma or inborn colour blindness. Mini Mental State Examination of dementia should not be less than 24 and assessed as not psychotic by the Brief Psychiatric Rating Scale (BPRS). CD was tested with 72 colour samples from the Natural Colour System (NCS) in three nuances. Hues were chosen in an even range between elementary hues from ordinary NCS collection. First test included 36 hues in the chromatic nuance S 2050; -Y, -Y10R, -Y20R, -Y30R, -Y40R, -Y50R, -Y60R, -Y70R, -Y80R, -Y90R, -R, -R10B, -R20B, -R30B, -R40B, -R50B, -R60B, -R70B, -R80B, -R90B, -B, -B20G, -B40G, -B60G, -B80G, -G, -G10Y, -G20Y, -G30Y, -G40Y, -G50Y, -G60Y, -G70Y, -G80Y, -G90Y. Test 2 included 18 colour samples in the whitish nuance S 0510 and test 3, 18 in the blackish nuance S 6030, both in hues -Y, -Y20R, -Y40R, -Y60R, -Y80R, -R, -R20B, -R40B, -R60B, -R80B, -B, -B30G, -B70G, -G, -G20Y, -G40Y, -G60Y, -G80Y. Colour samples are 20 x 20 mm., staunch wooden cleats unlikely to move off when handled, mounted on a 30° angle and with a neutral gray background colour; test 1 NCS S 1000-N, test 2 and 3 in darker S 3500-N. The subjects were tested in one room at the treating hospital in a regular light situation supplemented with a desk lamp, D55, 5400 K, RA 98.

Time was unlimited and the subjects used between 10-20 effective minutes for all three tests, altogether with registration, instructions and arranging between the tests, 1 hour.

2.3 Procedure

Each nuance test was presented and used separately, beginning with the chromatic before the whitish and closing with the blackish. Colour samples were spread out in disorder on a round plate with a rim. The subjects were instructed as follows:

> *Arrange the color samples in a continuous color circle along the rim. Start with yellow and work your way to the orange and red, proceed towards purple and blue, thereafter towards blue-green and green and from there to yellow again.*

Figure 2. Test 2 with colour samples in the whitish nuance NCS 0510 to the left and test 3 with the blackish nuance NCS 6030 to the right.

3. RESULTS

Table 1. Examination protocol.

Subject order	1	2	3	4	5
Age	38	71	50	64	77
Sex	f	m	m	f	m
Disease duration	min 6 y	18 y	3 y	12 y	4 y
Medication			“Off” 3 d	1 h	2 h
Self-assessment	mild “on”	mild	mild	severe	moderate
Agility	bad “off”	good hypermob.	bad “off”	good hypermob	bad “off”
Time	10 min	21 min	13 min	12 min	20
Tired	no	no	no	no	no
Diff to handle	no	no	no	no	no
Diff to understand	no	no	no	no	no

4. CONCLUSIONS

- The colour samples were found easy to grip and handle. No problems to manage or hold the samples occurred.
- The instructions were easy to comprehend. Some subject asked to reassure the instructions.
- Four subjects did not become tired at all. One subject become tired but not severly.
- It does not seem meaningful to use three nuances in a pilot as scored errors did not differ significantly between the used nuances.

Analysing data we found different kinds of errors that needed scoring. A test with a long colour sequence enables placement of the colour samples in different orders around the colour circle. As the group consist of 5 subjects only data has no representative value but represent the individuals only.

5. DISCUSSION

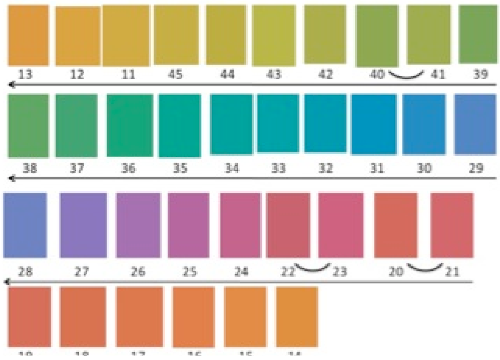

Fig 2. Group A, few errors. Analysis arrangement shows 3 simple errors.

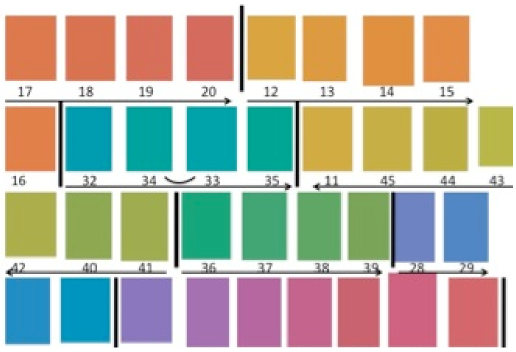

Fig 3. Group B, many errors. 7 interruptions (arrows), 4 mixed sequences (vertical bar), 2 simple errors (bowl shape). Main error in this group was sudden discontinuation and switched directions in test sequence.

Data divide into two groups. Group A: subject 3 and 4 had few errors. 3 was "off" medication and 4 has a trained colour vision by profession. Difference in colour discrimination ability between subjects on and off medication has been noticed in previous research. Group B: subject 1, 2 and 5 performed worse. Subjects made sudden discontinuation and switched order in test sequence. After a correct sequence came a discontinuation with a mismatched colour followed by another sequence in correct order. Sometimes this sequence went in the same direction, sometimes in the opposite. The colour circle was by this way organized both clockwise and counter-clockwise. In some cases the initiated order whereby the colour wheel was arranged, amended several times. By using a test with a full colour circle the test data resulted in unexpected errors possibly showing the cognitive involvement in arranging.

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An Overview of Using Colour Clinically in Optometric Practice

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ABSTRACT

There has been a long history of using colour in clinical practice although the assessment and prescribing techniques to date have been largely unscientific with the consequence of variable and unpredictable results. Using instrumentation that allows precise control of colour in both lighting and lens prescribing has enabled us to develop a model in which interventions can have predictable results. There are a wide range of conditions that can be addressed at this time and it is likley that more will be found as techniques develop. We will be using videos to illustrate the range of conditions that are affected by colour.

1. INTRODUCTION

Optical professionals are supposed to be able to prescribe tints and filters for clinical need. However, they have had significant difficulties in this as to date methods of colour assessment and management have been inadequate. Trial and error using a range of lenses which cover a small range within colour space has been the principal method of addressing problems, although a subtractive colour wheel instrument (the Intuitive Colorimeter) has been used recently with some success. It does however have a very limited range. We use an additive colour instrument (the Read Eye) for assessment and prescribing information which has a sufficent range for clinical use. Using the Read Eye we can achieve effects which are predictable and unlike any method used in the past we can provoke symptoms by process reversal.

2. METHOD

Patients are given a standard eye examination initially in which pathology, refractive error, visual fields, intra ocular pressures, binocular vision, convergence and accommodation are assessed and managed. Visual acuity is measured as is stereopsis. Other non stimulus related optometric tests are undertaken as appropriate.

A very comprehensive history and symptoms is taken (with particular emphasis on signs and symptoms which may indicate a visual processing difficulty)

2.1 Stimulus assessment

Assuming that signs or symptoms are present which indicate a potential stimulus related problem we will proceed to assess the way in which colour is processed at an individual level. It is critical that this is accurate and there is sufficient range within colour space to allow us to determine the optimum stimulus for the patient. We use an additive colour instrument with a range within colour space of XY (CIE 1931) 0.1/0.05 – 0.14/0.7 – 0.6/0.25 with a tolerance of ± 0.001 and graduations of 0.001 This gamut is sufficiently large for clinical use.

By a variety of techniques we can determine the gamut in which the patient reports optimum vision when either looking at a near or distant target. This may be achieved using RGB, Hue/ saturation/ luminosity, forced choice or isoluminance rotation of hue. Colours may be assessed in light adapted or non adapted eyes. In addition the gamut in which the patient reports poor vision is also determined.

These gamuts are used as a baseline for visual performance and a variety of tests may be undertaken under various lighting conditions. These include tests on timing (based on the Pulfrich effect), acuity, eye movement, visual fields, visual persistence, fixation and accommodation / convergence. Depending on symptoms presentation tests may be undertaken to determine the effects of stimulus / colour on other sensory systems, cognition and praxis.

Provocation of symptoms and cessation of symptoms is almost immediate, therfore it is possible to determine which symptoms are caused by colour and stimulus and which are unrelated.

In some cases the environment can be changed and lighting advice is all that is necessary, but for most patients tinted or filtered lenses are required to modify the visual input. Prescribing tinted lenses to clinical standards is very complex. The lighting and task have to be determined and where possible recreated for the assessment. We can factor in up to three lighting environments for a given task and convolve to enable the gamut available with the combination of the ambient light and the filter to be assessed. Clinical decisions will be determined by tolerances of the individual patient.

2.2 Signs and symptoms

There are a large number of signs and symptoms which are associated with colour problems. Physical effects such as eye movement and brain arousal levels can be measured and compared although some cognitive responses are inevitably anecdotal. This does not negate their relevance as they are consistent within some presentations. We will use video to illustrate the range of effects that are seen as an overview of the type of problem we encounter in practice.

Physical effects

The two most important physical effects are changes in visual processing speed and four dimensional mapping of sequences. These have significant effects on a large number of sensory processing responses including spatial awareness, vestibular function, control mechanisms and body awareness. A range of symptoms in neurological conditions such as Parkinsons Disease and Multiple Sclerosis often respond well to colour intervention and we will show how colour can cross the senses and effect conditions such as tinnitus.

A range of optometric and ophthalmolgical effects will be shown, from stopping strabismus using colour to restoring visual fields. Virtually everything measurable optometrically is affected by colour.

Cognitive effects

As well as the physical effects that can be measured there can be a range of cognitive responses which include metamorphopsisia, zoomorphopsia, synesthesia. We will show the effects on prosopagnosia in special needs patients with conditions such as Autism.

In most cases there is a ‘cocktail’ of symptoms, which vary from relatively innocuous problems to those having a serious effect on the quality of life.

Within each category there are a wide range of potential symptoms which appear to be caused or may be caused by colour or light stimulus. In addition there are a number of symptoms which may be provoked by colour. These may be interpreted as a primary problem or alternatively they may produce symptoms which may appear to have little relevance to vision e.g. anxiety as a result of metamorphopsia. Deatailed symptom analysis is beyond the scope of the presentation.

3. RESULTS AND DISCUSSION

Colour is an extremely powerful tool in the hands of a knowledgable clinician. There are well over a hundred signs and symptoms that can be addressed by colour prescribed clinically either by use of spectacles or lighting modification. The effects are immediate and often better than conventional medical, optometric or psychological interventions.

Colour is prescribed in a novel way in that unlike drugs it is individually determined and managed i.e. management of tint is not is not determined empirically. This requires a high level of knowledge. In clinical management, the symptoms can be provoked and stopped immediately by reverse “engineeering” of colour.

4. CONCLUSIONS

There is a need for much further research in this area as the signs, symptoms and effects of colour in the environment are common, not well recognised and inadequately managed. Many diseases and conditions may have a “colour component” which may be treatable and a further sub group may have to endure significant cognitive problems due to inability to process colour appropriately.

The videos shown will introduce to the wider scientific community a sample from the range of problems that may be found, and that can be treated using colour. The effects of colour could prove to be a new and important clinical discipline in the future.

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colorimetry

Blacks' Colorimetric Boundaries based on the Perceived Blackness

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ABSTRACT

In this study, the occupied volume of 216 black fabrics is defined in a 3D colorimetric space based on the perceived blackness of a group of observers. Samples which have been detected by the majority of observers as blacks within a series of deep gray-black samples generate the desired volume. Results show that samples with high lightness values and low chromas are perceived as blacks if their hue angles lie in the third hue area of CIELAB color system from 180-270 degrees. This would be true for greenish to bluish blacks with low lightness and high chroma values. Besides, there is not any greenish-bluish black sample that none of observers evaluate it as black. Moreover, samples with high lightness and chroma values won't be assessed as blacks if their hue angles do not lie in the third hue area.

1. INTRODUCTION

Blacks are important color for different industries such as textiles, prints, paints, ink and cosmetics manufactures while in contrary to whites, the spectral and colorimetric attributes of blacks have not been studied, powerfully (Westland *et al.* 2006, Jafari *et al.* 2012). Recently, some researchers tried to investigate the colorimetric aspects of blacks based on the perceived blackness of observers and tried for some indices to systematically assess the blacks (Westland *et al.* 2006, Clonts *et al.* 2010, Clonts *et al.* in press).

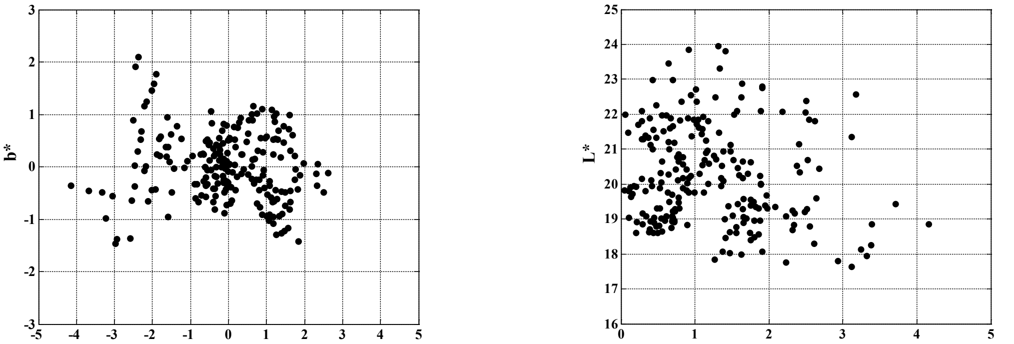
Obviously, similar to whites, blacks occupy small volume of color spaces. While it is clear that colors with low lightness and chroma values are considered as blacks, nobody tried to investigate the black's colorimetric boundaries in color spaces. Since the hue property of black samples plays an important role in blackness perception, the colorimetric attributes of samples, i.e., lightness, chroma and hue, should be considered in demonstration of black's boundaries, simultaneously. This study tries to investigate the colorimetric borders of a series of deep gray-black samples according to the judgments of a group of observers.

2. METHOD

2.1 Sample Preparation

216 black fabrics were prepared via printing the of woven cotton fabrics by using different combinations of black and colored pigments (Jafari et al. 2012). The reflectance spectra of blacks were measured by using the Texflash spectrophotometer from Datacolor with 20nm intervals from 400-700 nm. The measurement geometry was 0/d while the specular reflectance spectra as well as the UV radiation were omitted. The colorimetric attributes of black samples were then computed under D65 standard illuminant and CIE1964 standard observer. A suitable distribution of black samples was proved by scattering of samples over the four hue areas of CIELAB color space while the blacks' lightness values varied between 17.64 to

23.95 with the chroma values between 0.04 to 4.16. Figure 1 shows the colorimetric distributions of samples.



(a) *(b)*

*Figure 1(a): The a*b*and (b): the C*L* scatter plots of 216 black fabrics.*

2.2 Psychophysical Experiment

To assess the blackness of samples, 216 black fabrics were firstly grouped in 9 random groups while there were 24 black samples in each collection without any prior planning. Then, 10 amateur observers evaluated the samples of each group, individually. The visual assessments were carried out in a standard light booth equipped with D65 light simulator and the distance of observers from the samples was fixed to provide the CIE1964 standard observer. The observers were asked to find whether she/he accepts samples as black or not. In this way, the corresponding acceptance percentage of each sample as black was achieved between 0-100% while the higher percentage value means the higher blackness perception. Finally, samples were sorted in 5 groups according to their corresponding perceived blackness percentages (abbreviated by PBP), i.e., 0%, 0%< PBP <50%, 50%, 50%< PBP <100% and 100% while the 0% of perceived blackness means that none of observers evaluated the sample as black.

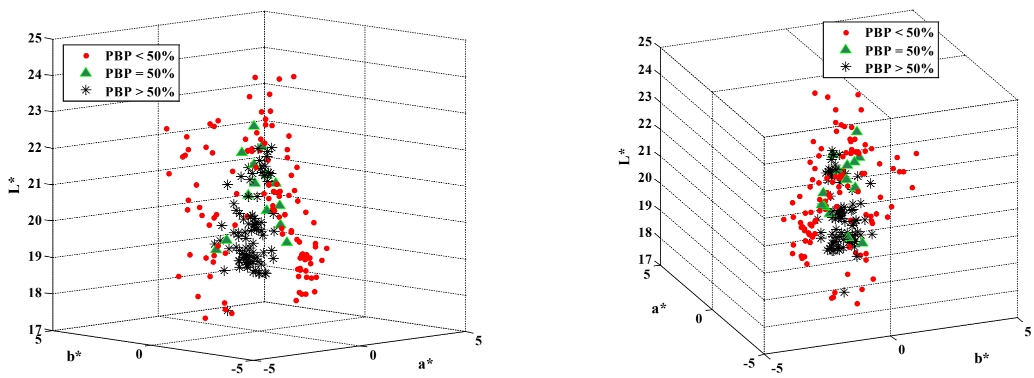


Figure 2: The colorimetric boundaries of 216 black fabrics.

3. RESULTS AND DISCUSSION

Figure 2 shows the volume which three groups of blacks with the perceived blackness percentages of 50%, PBP<50% and PBP>50% occupy in a 3D space according to their corresponding CIELAB colorimetric attributes. According to Figure 2, increasing of perceived blackness leads to the decreasing of assigned colorimetric volume. In order to demonstrate the colorimetric boundaries in more details, the a*b*, C*L* and the hL* scatter plots of black fabrics with different percentages of perceived blackness have been plotted and shown in Figure 3. The first column of Figure 3 indicates to the percentage of observers who have evaluated the black fabrics as blacks. According to the first row of Figure 3 there is not any greenish-bluish black sample that none of observers evaluate it as black. It means that at least 10% of observers evaluate greenish-bluish black samples as blacks.

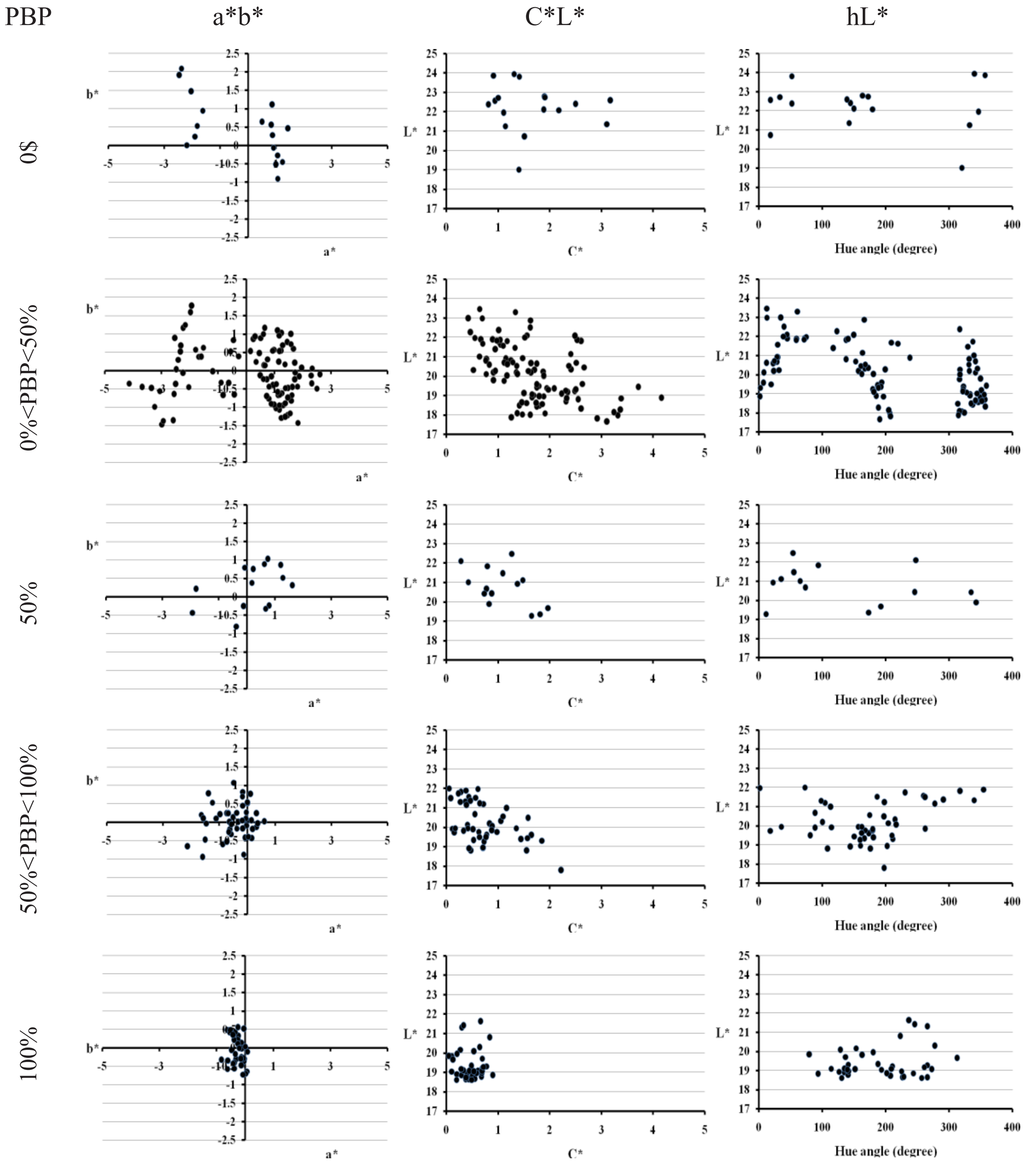


*Figure 3: The a*b*, C*L* and hL* scatter plots of black fabrics with different PBP values.*

Figure 3 also shows that samples with high/low lightness values and low/high chromas are perceived as blacks if their hue angles lie in the third hue area from 180-270 degrees. Besides, according to the 4th and 5th rows of Figure 3, samples become darker and more saturated while the majority of observers assess them as blacks. Moreover, it is found that 100% of observers perceive the greenish to bluish blacks with low lightness and chroma values as blacks. It means that while the blacks reasonably occupy the downward volume of CIELAB color system, the deviate into the third hue area make them more acceptable.

4. CONCLUSIONS

To demonstrate the colorimetric boundaries of blacks based on the perceived blackness, a set of 216 black fabrics with different shades and tints were prepared and assessed by 10 amateur observers. The occupied volume of blacks was defined based on the percentage of observer who assess samples as blacks as well as the CIELAB colorimetric attributes of samples. Results showed that samples with high lightness values and low chromas as well as blacks with low lightness and high chroma values were perceived as blacks if their hue angles lay in the third hue area i.e. 180-270 degrees. Besides, there was no greenish-bluish black sample that none of observers evaluated it as black. In fact, at least 10% of observers evaluated greenish-bluish black samples as blacks. Moreover, samples with high lightness and chroma values were not assessed as blacks if their hue angles did not lie in the third hue area.

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colorimetry

The Extent of Metamer Mismatching

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ABSTRACT

Metamer mismatching refers to the fact that two objects reflecting light causing identical colour signals (i.e., cone response or XYZ) under one illumination may reflect light causing non-identical colour signals under a second illumination. As a consequence of metamer mismatching, two objects appearing the same under one illuminant can be expected to appear different under the second illuminant. To investigate the potential extent of metamer mismatching, we calculated the metamer mismatching effect for 20 Munsell papers and 8 pairs of illuminants (Logvinenko & Tokunaga, 2011) using the recent method (Logvinenko, Funt, & Godau, 2012) of computing the exact metamer mismatch volume boundary. The results show that metamer mismatching is very significant for some lights. In fact, metamer mismatching was found to be so significant that it can lead to the prediction of some paradoxical phenomena, such as the possibility of 20 objects having the same colour under a neutral ("white") light dispersing into a whole hue circle of colours under a red light, and vice versa.

1. INTRODUCTION

As a result of metamer mismatching two objects appearing as having the same colour under one illuminant can appear as having different colours under a second illuminant. In fact, a single colour signal under a first illuminant projects into a volume of potential colour signals under a second illuminant known as its metamer mismatch volume. It is frequently believed that metamer mismatching is not all that serious, however, we show here the metamer mismatch volumes can be very large. Fig.1 shows an example of a metamer mismatch volume produced by the flat spectral reflectance function (0.5 across the visible spectrum) for the case of a change from a red illuminant to a neutral ("white") illuminant.

2. METAMER MISMATCH VOLUMES UNDER 6 ILLUMINANT CONDITIONS

A metamer mismatch volume is a convex body, and therefore can be specified by its boundary. The boundary can be computed precisely using the code of Logvinenko et al. 2012 (Logvinenko et al., 2012), which determines the maximum amount of potential metamer mismatching that can occur for any given colour signal. In order to look into the implications of metamer mismatching, we computed the metamer mismatch boundary surfaces for the colour papers used by Logvinenko & Tokunaga (2011). Specifically, they used 20 chromatic Munsell papers [(i) 10RP5/14, (ii) 5R4/14, (iii) 10R5/16, (iv) 5YR7/14, (v) 10YR7/14, (vi) 5Y8/14, (vii) 10Y8.5/12, (viii) 5GY7/12, (ix) 10GY6/12, (x) 5G5/10, (xi) 10G5/10, (xii) 5BG6/10, (xiii) 10BG5/10, (xiv) 5B5/10, (xv) 10B5/12, (xvi) 5PB5/12, (xvii) 10PB4/12, (xviii) 5P4/12, (xix) 10P4/12, (xx) 5RP5/12] along with a grey (N5/) and a black (N1/) paper. They also used six different lights to illuminate the papers: neutral (N), yellow (Y), blue (B), green (G), and two reds (R1 and R2) of which we will only consider R1 and label it R. Their spectral power distributions are plotted in Logvinenko et al. (Logvinenko & Tokunaga, 2011).

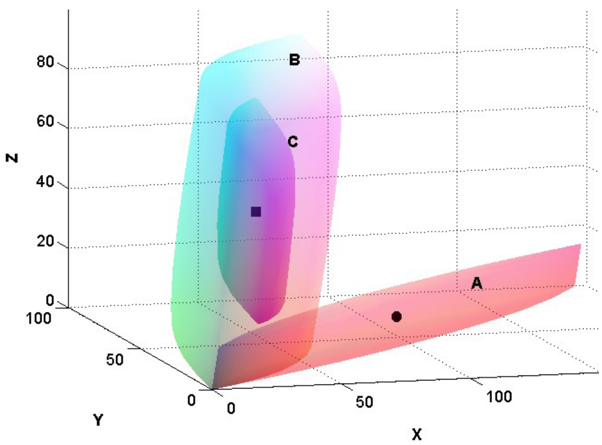

Figure 1: Label A indicates the object colour solid under red light (R). Label B indicates the object colour solid under neutral light (N). The black dot indicates the XYZ of flat grey under red. The black square shows its XYZ under neutral. C indicates the metamer mismatch volume of the flat grey for a change in illumination from red to neutral.

Each illumination condition is described by a pair of illuminants, for example N and Y, and written as NY. We evaluated the metamer mismatch boundary surfaces for the 20 chromatic Munsell papers under the 8 illuminant pairings NR, NY, NG, NB, RN, YN, GN, BN based on the CIE 1931 colour matching functions (Wyszecki & Stiles, 1982). The intersection of mismatch volumes can be hard to see in a 3D plot, so instead we will plot 2D projections of the volumes in the CIE 1931 chromaticity diagram. The set of the xy chromaticity coordinates of the points in a metamer mismatch volume forms the *chromaticity mismatch area* in the CIE chromaticity plane showing how the initial chromaticity disperses due to metamer mismatching. Fig. 2 shows the chromaticity mismatch areas for the NY and NB illumination conditions. Clearly, the chromaticity mismatch areas are significant, even for the NY illumination condition. Note that not only are the areas big, the chromaticity mismatch area for a single paper covers the chromaticities of many other papers. For example, for B, the metamer mismatch area of paper *ii* covers the chromaticities of 18 of the 20 Munsell papers. For the G and R illuminants, some of metamer mismatch areas cover all 20 Munsell papers.

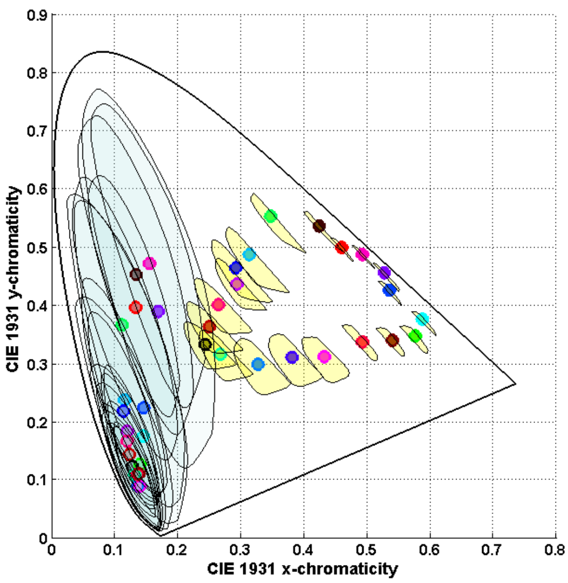

Figure 2: Chromaticity mismatch areas for the shifts from N to the Y and B illuminants. The circular markers are the chromaticities of the 20 Munsell papers under the corresponding illuminant. The mismatch areas for NY are the smaller yellow areas on the right, and for the NB are the larger bluish areas on the left.

3. METAMERIC HUE CIRCLE

The seriousness of metamer mismatching leads to some paradoxical phenomena. For example, for each point in the metamer mismatch volume in the red-light-changed-to-neutral-light condition there exists a reflecting object such that the CIE XYZ tristimulus coordinate of the light reflected by it under the red illumination is equal to that reflected by the flat grey, while the CIE XYZ tristimulus coordinate of the light reflected by it under the neutral illumination differs from that reflected by the flat grey. Consider a sample of such objects representing each point in the metamer mismatch volume. The following question arises: How large is the difference in colour signals within this sample under the neutral light? To answer this question we ascertained which Munsell papers fell into the corresponding metamer mismatch volume. It turns out that, being illuminated by the neutral light, 28% of the 1600 Munsell papers reflect light having CIE XYZ tristimulus values that fall into the metamer mismatch volume in question. While papers from this subset of the Munsell collection are not themselves metameric to the flat gray under the red illumination, they represent the colour of some real objects whose XYZs fall within the metamer mismatch volume. In other words, they give an indication as to the range of colours the flat grey reflectance potentially can become under the neutral illumination. As can be seen from Fig. 3, this range is very large. This figure includes 20 Munsell papers coming from every other page of the Munsell book of Colour. Note their significant Munsell chroma. It is quite a paradoxical phenomenon that metamer mismatching can occur to such a large degree that it can lead to the possibility of 20 objects having the same colour as the flat grey reflectance under a red light that then disperse into a whole hue circle of colours under a neutral light, and vice versa.

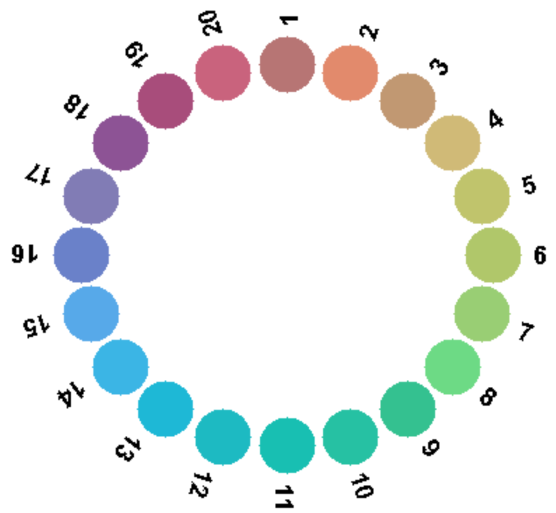

Figure 3: Pictorial representation of the 20 Munsell papers lying inside the metamer mismatch volume for the RN illumination condition (5R6/8, 10R7/10, 5Y7/6, 10YR8/6, 5Y8/6, 10Y8/6, 5GY8/6, 10GY8/8, 5G7/8, 10G7/8, 5BG7/8, 10BG7/8, 5B7/8, 10B7/8, 5PB7/8, 10PB6/10, 5P6/8, 10P5/12, 5RP5/12, and 10RP6/12).

4. CONCLUSION

The extent of metamer mismatching is shown to be greater than might be initially expected. In some cases, the metamer mismatch volume fills more than half the object-colour solid. The effect is large enough that the flat grey reflectance under a red light disperses into a hue circle under a neutral light that can be represented by an appropriate selection of Munsell papers.

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The Need for Negative Tristimulus Values

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ABSTRACT

This paper will first describe the cases where negative tristimulus values (TSV) are involved. With negative TSVs, most of the colour transformations are failing. Secondly, proposals will be made to colour transforms such as between XYZ and $L^*a^* b^*$, between XYZ and $L^*u^*v^*$, and CIECAM02 to cope with negative tristimulus values.

1. INTRODUCTION

Historically, two experimental results made great contributions to the CIE 1931 colorimetry system (Schanda 2007, Chapter 2). One experiment was carried out by Guild in 1926 and one by Wright in 1929. Although they used different set of primaries, when the data was transformed to the same primaries, the two sets of experimental results were surprisingly similar. The average of these two set data resulted in the colour matching functions (CMF) r-bar(λ), g-bar(λ), and b-bar(λ). Unfortunately, this set of CMFs had negative quantities which was regarded by some scientists at that time as quite unacceptable in a colour-measuring system for use in commerce and industry. However, by carefully choosing X, Y, Z reference primaries, r-bar(λ), g-bar(λ), and b-bar(λ) were transformed to non-negative x-bar(λ), y-bar(λ), and z-bar(λ). These x-bar(λ), y-bar(λ), and z-bar(λ) functions were then standardised as CIE 1931 CMFs and form the basis for the CIE colour specification system. With this set of CMFs, the tristimulus values (TSV) are non-negative. Since then all colour transforms involving TSVs consider them non-negative by default.

2. COLOURS OF MAXIMAL SATURATION

However, recently, scientific research and applications result in 'supersaturated' or 'virtual' colours which cannot be specified by positive TSVs. Fry (Fry 1980, 1981, 1983 and 1995) published a series of papers based on the modified zone theory of colour vision as shown in Figure 1. Fry reported that the spectral locus on the CIE chromaticity diagram represents monochromatic stimuli which have been exposed to a dark adapted fovea. Some of these colours can be made to appear more saturated by chromatic adaptation. Fry found that colours both inside the spectral locus and the supersaturated colours outside are bounded by a four sided boundary: the quadrilateral RKJB shown in Figure 2 which constitutes the locus of colours of maximal saturation. The four sided boundary line encloses a region with part having negative chromaticity coordinates and hence negative TSVs. The horseshoe shape curve in Figure 2 is the CIE spectral locus. Fry has shown that the monochromatic stimuli in the spectral locus which fall on the RK side of the quadrilateral can be shifted along this line by red or green adaptation, but cannot be made more yellow by blue adaptation. Hence, colours on this side of the quadrilateral are considered as maximal saturation. In the same sense, Fry showed that the mixtures of 700 and 380 nm can be shifted along the RB side of the quadrilateral by red or blue adaptation, but cannot be made more purple by the green adaptation. Hence, colours on this side are considered as maximally saturated. Furthermore, except in the case of 460nm, which falls on the side BJ of the quadrilateral, the colours on the spectral locus from 380nm to 540nm can be shifted by red/yellow adaptation towards the (blue) side BJ or the (green) side JK of the quadrilateral. In other words, these colours can be made to appear more saturated than colours on the spectral locus.

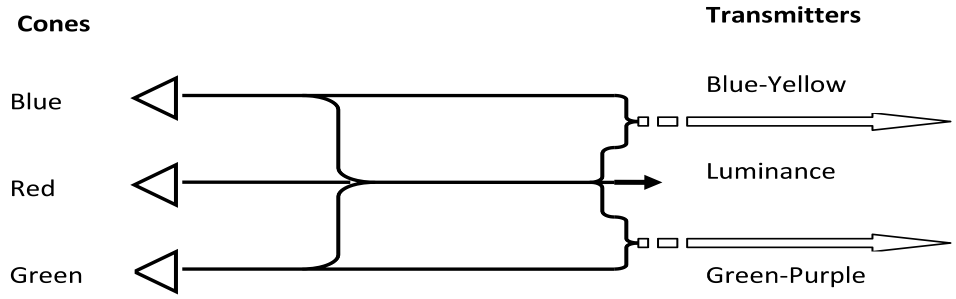

Figure 1: Zone theory of colour vision.

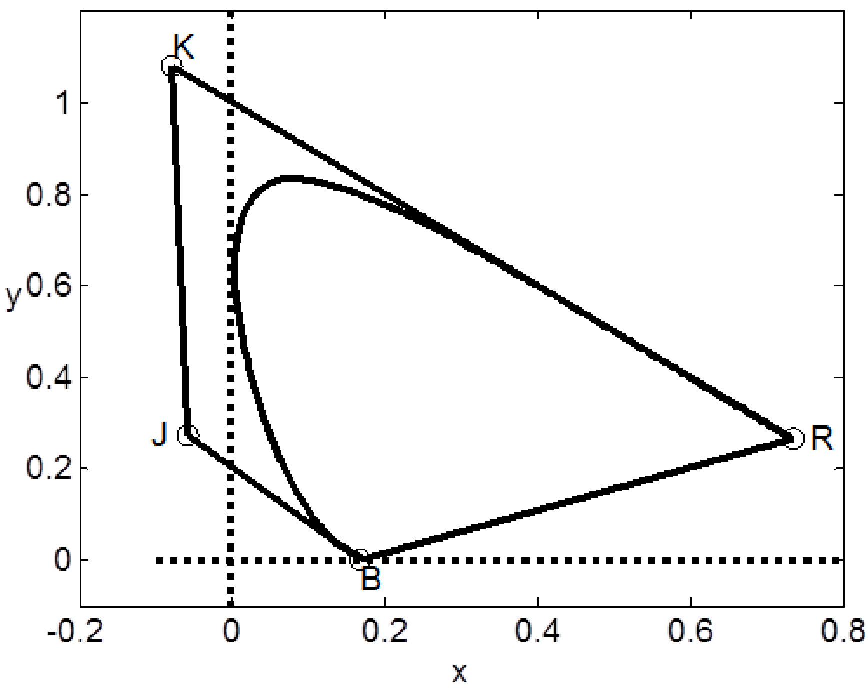

Figure 2: Maximal saturated colour boundary (quadrilateral boundary RBJK) of Fry and CIE chromaticity diagram (horseshoe shape curve). Horizontal and vertical dotted lines are the x and y axes respectively.

3. ICC PROFILE CONNECTION SPACE

In cross-media colour reproduction, a profile connection space (PCS) is needed. The CIELAB space with regular grids in L^* from 0 to 100, a^* and b^* from -128 to 127 (Tastl et al 2005) is often chosen as ICC (International color consortium) PCS. It was found that there are many points with negative TSVs when transform from $L^*a^*b^*$ to XYZ. Similarly, CIECAM02 is often chosen as a gamut mapping space since it is considered having better uniformity; CIECAM02 also has problems with negative TSVs.

4. ACCOMODATING NEGATIVE TRISIMULUS VALUES IN COLOUR TRANSORMATIONS

In order to reproduce the supersaturated colours or for cross-media colour reproduction, we have to accommodate the negative TSVs. The most often used transformations in colorimetry are the CIE L*a*b*, CIE L*u*v* (CIE 2004 Pub 15) and the CIECAM02 colour appearance model (CIE 2004 Pub 159). The CIE L*a*b* transformation is given by:

$$\begin{aligned} L^* &= 116 \cdot f(Y/Y_n) - 116 \\ a^* &= 500 \cdot [f(X/X_n) - f(Y/Y_n)] \\ b^* &= 200 \cdot [f(Y/Y_n) - f(Z/Z_n)] \end{aligned} \tag{1}$$

Here, X_n, Y_n, and Z_n are the tristimulus values of the reference white and function f(t) is defined by

$$f(t) = \begin{cases} \sqrt[3]{t} & \text{if} \quad t > (24/116)^3 \\ (841/108)t + 16/116 & \text{if} \quad t \le (24/116)^3 \end{cases} \tag{2}$$

Fortunately, the transformation from XYZ to L*a*b* defined by equations (1-2) works for negative tristimulus values. However, the magnitudes can be very large for some negative tristimulus values. We therefore suggest replacing equation (2) with equation (3):

$$f(t) = \begin{cases} \sqrt[3]{t} & \text{if} \quad t > (24/116)^3 \\ (841/108)t + 16/116 & \text{if} \quad -(24/116)^3 \le t \le (24/116)^3 \\ -\sqrt[3]{-t} + 8/29 & \text{if} \quad t < -(24/116)^3 \end{cases} \tag{3}$$

The transform from L*a*b* to XYZ can be easily converted based on equations (1-2) or (1) and (3). For the CIE L*u*v* transformation, similar extension can be considered.

For CIECAM02, the adjustment is more complicated. The CIE has set up a technical committee TC8-11 in Beijing 2007 to look at the problem and to repair the inconsistencies for the CIECAM02. Some progress (Li et al 2009, 2012a, 2012b, 2012c, Brill 2006, Brill and Süsstrunk 2008) has been made, but due to space constrains, the results cannot be discussed here (see references). To accommodate negative tristimulus values for the CIECAM02 will require further work.

ACKNOWLEDGEMENT

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colorimetry

The Effect of Calibration on the Inter-instrument Agreement in Whiteness Measurements: CIE or Ganz-Griesser?

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ABSTRACT

In order to contribute to the work of the CIE Technical Committee TC1-77 we investigated the effect of the instrument setup (SPEX or SPIN) and UV calibration method (CIE or Ganz-Griesser) on the inter-instrument agreement in whiteness measurements. For the experiments we used 46 samples (Spectralon, plastic, ceramic tile, textile and paper) which can be considered commercially white or near white, i.e. they fall within or just slightly outside the limits established for the CIE formula. All the samples have so far been measured on four industrial spectrophotometers; we here report the results of inter-instrument agreement for these in whiteness measurements for four calibration and measurement modes (SPEX – SPIN / CIE – Ganz-Griesser).

1. INTRODUCTION

The CIE Whiteness Index (CIE 2004) can only be used for samples that "are measured on the same instrument at nearly the same time" – a restriction which makes its application practically useless in an industrial environment, where within-plant quality control and the communication between supplier and customer require that measurements be made on different instruments and not necessarily at nearly the same time. The Ganz-Griesser formula and calibration method (Griesser 1994), widely used in the textile industry, is supposed to overcome these restrictions, but it has never been accepted as an international standard.

To complicate matters, there are two UV calibrated sample sets available as calibration standards for the textile user: one from the Hohenstein Institute with SPEX calibration (Ganz-Griesser or CIE) and the other from AATCC with SPIN calibration (CIE only); both claiming to be the right geometry for textile specimens.

2. METHOD

We collected a set of 46 white or nearly-white samples and measured them on four industrial colour measuring spectrophotometers calibrated according to the CIE resp. the Ganz-Griesser method, in both SPEX and SPIN mode. The inter-instrument agreement in terms of CIE and Ganz-Griesser whiteness and tint was evaluated, using D65 illumination and the 10 degree observer.

2.1 Sample Sets

The following sample sets were collected or (in for most of the textile samples) prepared:

- Spectralon (Labsphere) standards (6), five of which with NRC calibration
- Ceramic tiles (glossy and matte) (2) with NPL calibration
- FTS glossy plastic standards (8)

- Paper (10)
- Textile (20), one with AATCC and four with Hohenstein calibration.

2.2 Instruments (industrial spectrophotometers)

- Datacolor 600: conventional, desktop
- Konica-Minolta CM 3600d: desktop; numerical UV control (NUVC) and numerical gloss control (NGC)
- Konica-Minolta CM 2600d (two instruments; portable; NUVC and NGC)

2.3 Calibration and measurement

The photometric scale adjustment (‘white calibration’) of the instruments was performed using the same NPL calibrated glossy white tile for all instruments and setups except for the CIE calibration of the CM 3600d instrument, where the software didn’t permit this, in this case we used the white tile (with its own nominal values) supplied with the instrument.

Ganz-Griesser UV calibration was performed according to the manufacturers’ instructions using a set of white textile reference specimens calibrated by the Hohenstein Institute (2013). CIE UV calibration was performed according to the manufacturers’ instructions using a white textile reference specimen calibrated by AATCC (2013).

After each calibration process a set of 12 Ceram Research CCS-II (non-fluorescent) coloured tiles with NPL calibration was measured to verify the colorimetric accuracy of the instruments with the given setup. We determined ‘accuracy’ as the mean of the 12 colour differences (in CIELAB) between the measured values and the nominal values as given by NPL for the 12 tiles.

The 46 white samples were each measured at three points and the average values of the three readings were reported.

3. RESULTS AND DISCUSSION

3.1 Colour measuring accuracy

The colour measuring accuracy is around 0.5 CIELAB units for the DC 600 (conventional bench top) instrument for all measurement setups, but, surprisingly, it strongly depends on the UV calibration procedure and (expectedly) on the measurement geometry for the three CM instruments with numerical UV control (NUVC) and numerical gloss control. These results may not be easily explained as the UV calibration should in no way influence the measurement results of non-fluorescent specimens (like the CCS-II tiles).

3.2 Inter-instrument agreement of whiteness and tint

Ganz-Griesser and CIE whiteness values were measured on the four instruments. For the sake of better clarity in Figure 1, the individual measurement point of only three of them are shown against the average of the four (the two CM-2600 instruments gave nearly identical results).

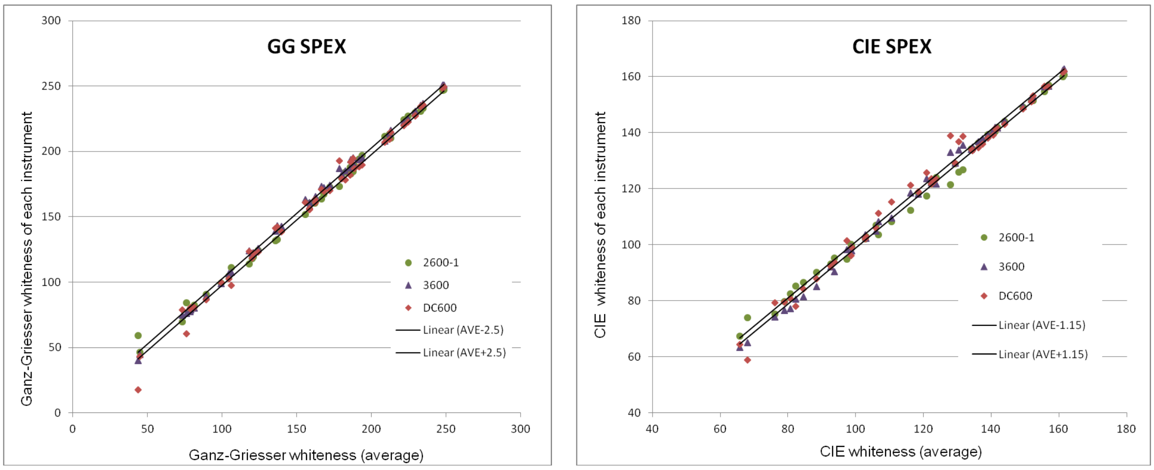

Figure 1: Spread of whiteness values measured on four industrial spectrophotometers.

The parallel lines on the figures represent ± half the perceptible whiteness limits (Griesser 1996): ± 2.5 units for the Ganz-Griesser and ± 1.15 units for the CIE formula. The Ganz-Griesser method shows somewhat less spread, the significantly outlying points are those of either strongly tinted samples or those of plastic tiles exhibiting strong triplet effect on the CM-2600 instruments and nearly no triplet effect on the DC 600. If we consider only those samples whose whiteness and tint values are within the CIE limits and show no triplet effect the picture is much better: all the whiteness values are within or very near the perceptible whiteness limits.

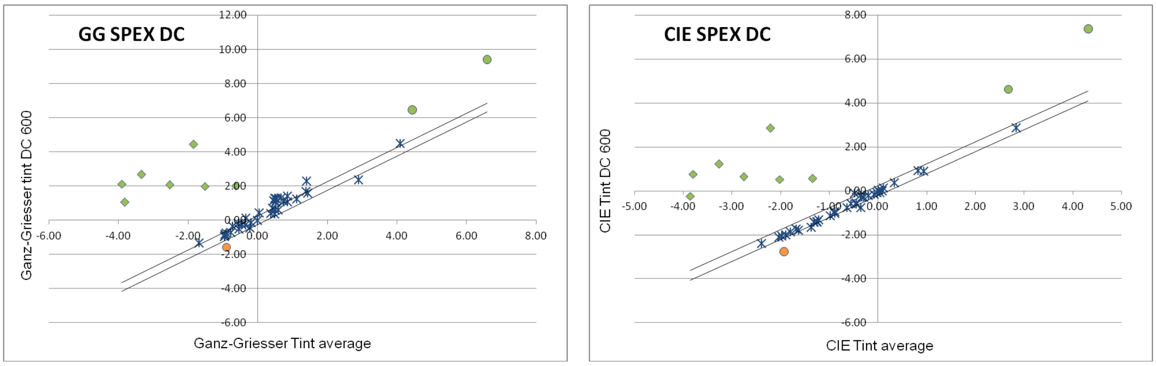

Figure 2: Spread of tint values measured on an industrial spectrophotometer.

Figure 2 shows Ganz-Griesser and CIE tint values of one instrument and the perceptible tint limits shown from the average of four instruments (Griesser, 1996): ± 0.25 units for the Ganz-Griesser and ± 0.225 units for the CIE formula.

In this figure we can clearly see the outlying points for the set of FTS plastic samples (marked with diamonds) showing significant triplet effect on the two portable instruments and those for the strongly tinted Spectralon samples (marked with circles).

If we re-plot the diagrams with only the textile and paper samples we do not have the strongly outlying points, but still find perceptually significant differences between different instruments, which were to be expected for the CIE formula but not for Ganz-Griesser.

Table 1 shows the R^2 values for the tint in different experimental setups. For the full sets CIE appears to give better correlation than Ganz-Griesser, but the samples with strong triplet effect and very high tint values distort the results. For the more homogeneous paper and textile sets Ganz-Griesser shows better correlation among the four instruments than CIE calibration, and – as was expected – SPIN geometry shows less variation than SPEX.

Table 1. R^2 values for tint in different experimental setups.

	Full set		Paper and Textile sets	
	SPEX	SPIN	SPEX	SPIN
GG	0.6367	0.6847	0.9292	0.9388
CIE	0.6515	0.7629	0.8594	0.911

4. CONCLUSIONS

The interim results for four instruments do not show significant improvement when using the Ganz-Griesser calibration method and the whiteness and tint formulae as compared to the CIE. Further investigations are necessary to discover why we have Ganz-Griesser tint values so much different for different instruments even for the limited data sets of paper and textiles (disregarding strongly outlying Spectralon and plastic samples) and why we could not find as good correlation among instruments as those shown in Griesser's publications (1994, 1996).

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Colour Rendering Metrics - Do they Reflect Real Life?

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ABSTRACT

Various colour rendering metrics were tested using a food selection test. If was found that the subjects were able to select the food item of choice equally well under all of the different light souces tested, however the flourescent 840 lamp was the prefered source.

1. INTRODUCTION

For many years the light source industry has being trying to find a replacement for the incandescent lamp, however, there have been significant difficulties getting compact fluorescent and LED sources accepted in the domestic environment. To ascertain what are the key properties necessary for domestic light source the authors have carried out a number of tests (Raynham et al 2010).

The first test was to check colour discrimination under various light sources. This was done by asking a number of subjects to perform the Farnsworth-Munsell 100 hue test under each light source. Table 1 gives information on the light received by the coloured tiles used in the test together with the average root total error score. The results of the tests are analysed using the Farnsworth scoring system (Farnsworth 1943). From this study we concluded that colour discrimination was not that important in domestic lighting.

Lamp	CCT	x	y	CRI [Ra 8]	CRI [Ra 14]	CQS	Average Root TER
CFL	5 642	0,329	0,352	83,8	76,2	82,9	4,11
D65	6 621	0,311	0,329	97,9	97,0	96,8	4,46
TL84	4 155	0,377	0,385	77,9	66,8	74,8	5,11
LED	4 300	0,371	0,382	76,6	69,3	70,0	5,44
GLS	2 430	0,488	0,422	96,5	95,4	76,6	6,46

Table 1: The colour properties of the light source with the Average Root Total Error score from the Farnsworth-Munsell test.

The study reported here was carried out as a MSc final report study (Garay 2011) and was designed to assess a typical domestic task where colour might be important so that the impact of the colour properties of the light source could be assessed.

2. METHOD

The task chosen was the selection of fruit and vegetables. A cohort of 16 subjects was recruited with age range 22 to 45 to select the fruit under 5 different light sources.

2.1 Fruit Selection and Presentation

The five fruits selected for the test were: apples, bananas, carrots, mushrooms and radishes. They were chosen as they are all hard fruits and so there would be little impact of the feel of the fruit on selection. There were six of each fruit, however, for every test four of each type were selected for presentation at random.

2.2 Light Sources

The experiments were carried out in a colour matching booth. The colour of light reaching the bottom of the booth was measured and the metrics of correlated colour temperature, colour rendering (CIE 1995), colour quality scale (Davis and Ohno 2010) and memory colour quality evaluation (Smet et al 2010). The lamp characteristics are given in Table 2.

Lamp	CCT	CRI [Ra 8]	CRI [Ra 14]	CQS	MCRI
Fluorescent 965	6761	95.2	93.8	94.0	90.4
Fluorescent 840	3865	85.5	76.4	82.0	86.4
Compact Fluorescent	6115	86.2	78.9	82.3	86.9
LED	4318	80.8	75.4	77.4	87.4
Tungsten GLS	2678	98.4	98.0	96.2	89.8

Table 2: The colour properties of the light sources used.

2.3 Method

Four of each of the fruits and vegetables were placed into the booth with a given light source and the subjects were asked to select one of each type that they would like to eat. Once the 5 items had been selected the subjects were given a questionnaire for a subjective assessment of the selection process. The first part of the questionnaire asked the questions listed below and requires the subject to reply on a 5 point bipolar scale.

- How easy was it to choose the food? [very easy ... very hard]
- How comfortable were you in choosing the food? [comfortable ... not comfortable]
- How good do you think the food looks under this light source? [very good ... very bad]

The final question which word do you think refers best to how the food looks under this light source? The subjects had to pick a word list given in Table 3.

Attractive	Fresh	Unattractive	Nasty
Tasty	Natural	Tempting	Stale
Bad	Delicious	Artificial	Good

Table 3: Possible answers to the final question.

The selection of the 4 pieces of food was done at random and the order of presentation of light sources was also randomized.

3. RESULTS AND ANALYSIS

3.1 Selection of the fruit

The selection rate for each food item was calculated as the number of times an item was selected divided by the number of times it was presented. Figure 1 shows the selection rates for the different food items. Regression analysis of the selection rate shows that predictive models (Box 1987) of selection for each fruit or vegetable could be obtained from the experimental data. Light source, and hence any colour rendering index, was not a factor in any of the derived models.

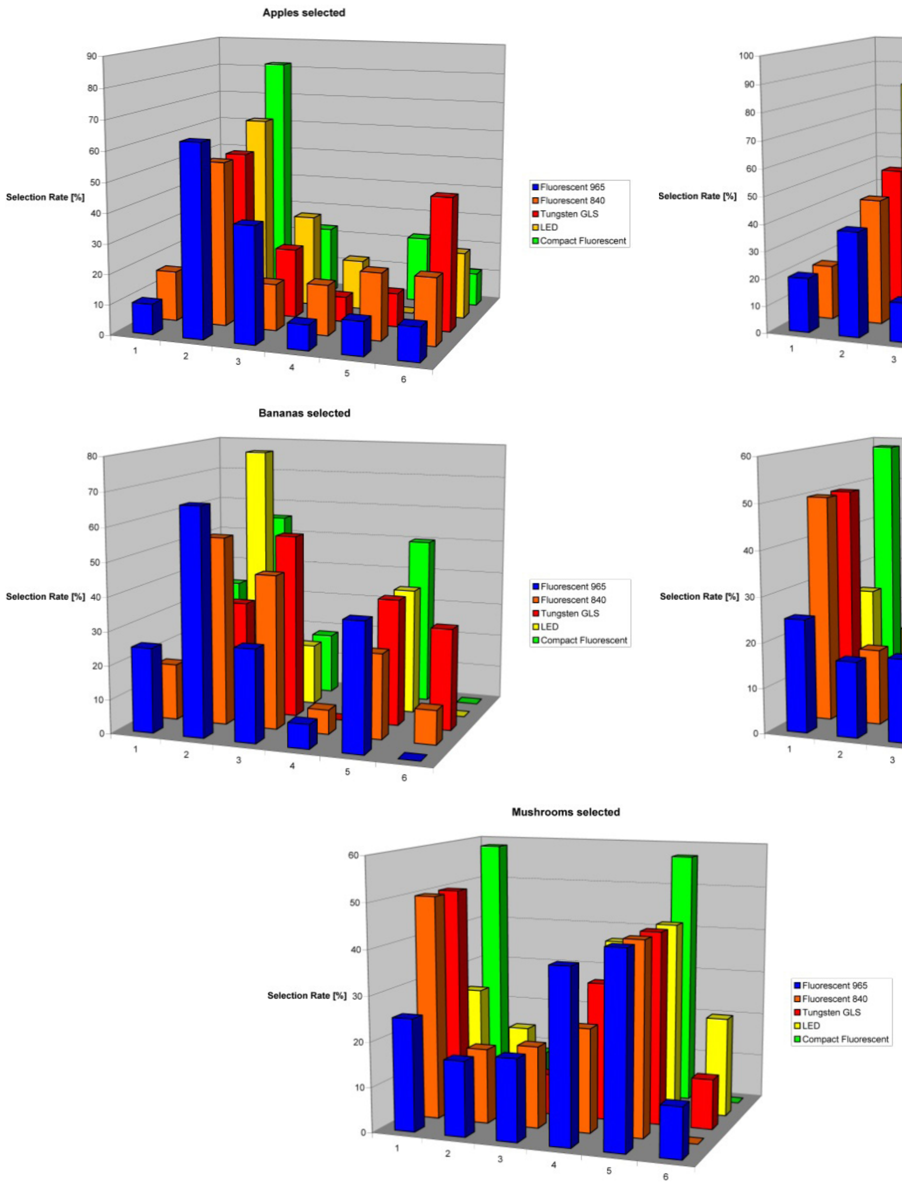

Figure 1: Selection rates of the food items.

3.2 Subjective responses

The average responses to the first 3 subjective questions are given in Table 4.

Question	Fluorescent 965	Fluorescent 840	Compact Fluo-rescent	LED	Tungsten GLS
How easy... easy - hard [1 - 5]	2.25	2.06	2.19	2.25	2.06
How comfortable... comfortable - uncomfortable [1 - 5]	2.06	1.88	2.38	2.22	1.81
How good... good - bad [1 - 5]	2.94	2.13	3.38	2.97	2.22

Table 4: Average responses to the first 3 subjective questions,

From the results it is clear to see that the subject found it relatively easy to select their favourite food item under each of the light sources. Moreover, all subjects were found to be comfortable working under all sources with fluorescent 840 and GLS being preferred. In considering how good the food looked the scores suggest that fluorescent 840 and GLS were preferred to the other sources. Figure 2 below shows the number of occurrences of the positive and negative key words used to describe the appearance of the food under the different light source. Note the words *nasty* and *delicious* were never chosen. Fluorescent 840 had then most positive words and compact fluorescent the most negative words.

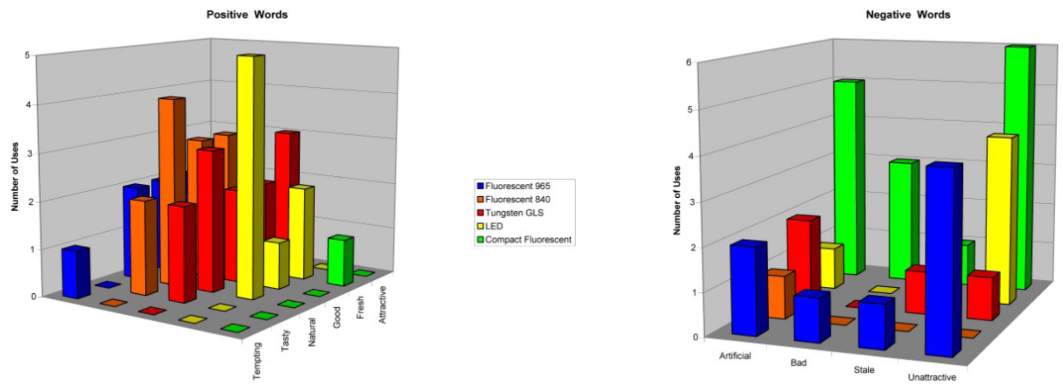

Figure 2: Occurrences of good and bad words.

4. CONCLUSION

The ability to select food items appears to be independent of the colour properties of the source used, however all of the lamps in the test had reasonable colour rendering properties ($Ra_8 > 80$). The subjects preferred to the fluorescent 840 and GLS sources, perhaps this is associated with familiarity.

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colour difference

A Comparison of Different Psychophysical Methods for Color-Difference Evaluation

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ABSTRACT

A study was conducted to investigate the relationships among visual data obtained from three different psychophysical methods (gray-scale, ratio and constant-stimuli) usually employed in color-difference evaluation. 50 printed color pairs (10 pairs surrounding 5 centers, including gray, yellow, blue, purple and magenta colors), with a good coverage in lightness, hue and chroma differences, were used in the study. The mean color difference of the 50 pairs was 3.88 CIELAB units. A total of 42 observers judged the same 50 pairs using the three psychophysical methods. The results from the three visual experiments were found to be equivalent, but the results of ratio are closer to gray-scale than to constant stimuli.

1. INTRODUCTION

In color-difference evaluation, it is usual to perform experiments using different psychophysical methods, such as gray-scale, ratio, ranking, constant-stimuli, paired comparison, category judgment, pass/fail, etc. Best scaling method to be applied in a specific visual experiment is dependent on many factors, for example, the magnitude of color differences, number of available observers, amount of samples, or data analysis methodology. Each scaling method has its own limitations, e.g., some scaling methods could only be used for assessing small color differences, some are not suitable for large amount of pairs, and some others require many observations. The visual color differences derived from different psychological methods may be different, beside the same color samples and observers are used in the experiments (Montag and Wilber 2003).

This paper provides results based on a new data set with 50 pairs of printed samples surrounding 5 colour centers (gray, blue, yellow, purple and magenta). The mean color difference of all pairs was 3.88 CIELAB units. From the same color pairs and observers, gray-scale, ratio and constant-stimuli methods were employed to investigate the relationships among their corresponding visual results.

2. EXPERIMENTAL

2.1 Sample Preparation and Selection

A total of 50 pairs of printed color samples, surrounding gray, yellow, blue, purple and magenta centers were produced using an EPSON Stylus PRO 7800 ink-jet printer. Corresponding to each color center there were 10 color samples, producing 10 color pairs with a good coverage of lightness, hue and chroma differences. The samples substrate was a glossy paper with 56 gloss units measured at an angle of 75° by a VGS-SENSOR glossmeter. The color coordinates of the color centres of the printed samples are shown in Table 1. Each sample was measured by an X-Rite SpectroEye Spectrophotometer with 0°/45° geometry, assuming illuminant D65 and CIE 1964 colorimetric observer. The color differences in the pairs were in the range around 1-7 CIELAB, trying to cover the most commom demands in printing industry.

Table 1. CIELAB coordinates of 5 color centers and CIELAB color differences.

				$\Delta E^*_{ab,10}$		
Color Center	L^*_{10}	a^*_{10}	b^*_{10}	Mean	Max	Min
Gray	62.83	-2.08	-1.85	3.72	6.65	1.89
Yellow	85.26	-7.94	47.42	4.33	7.09	0.95
Blue	36.65	4.43	-30.01	3.61	6.88	1.32
Purple	46.42	12.17	-13.48	3.91	6.51	1.50
Magenta	48.54	61.97	-7.66	3.81	6.99	1.34

2.2 Visual Assessments

The visual assessments of color differences were conducted in a dark room using a Gretag-Macbeth Judge II viewing cabinet equipped with a D65 simulator, which had a correlated color temperature of 6430 K and provided an illuminance of 950 lx at the surface of the samples, as measured by a Photo-Research PR-650 spectroradiometer. The pairs were viewed at approximately 45° with respect to the perpendicular to the samples and at a viewing distance of about 50 cm. A total of 42 observers participated in the experiment, all of them students and staff at Beijing Institute of Graphic Communication: 17 males and 25 females, aging from 20-33. They all passed the Ishihara color vision test and had normal color vision. The same 50 color pairs were used in the visual experiments with the three methods, gray-scale, constant stimuli and ratio. Before the real experiments, observers were trained to assess color difference using these three different methods. The color pairs were presented in a random order for each observer. 39 observers repeated assessments 3 times, while the 3 remaining observers assessed only once; thus, in total there were 120 assessments for each color pair with each of the three psychophysical methods. The whole experiment was completed within a six-month period, including sample preparation, sample selection and training sessions.

In the gray-scale method, the size and the substrate for the gray-scale color pairs were the same than for the color pairs assessed. The observers were instructed to conduct visual assessment using a seven steps gray scale. If the perceived color difference in a color pair was not equal to any of the ones provided by the gray scale, observers were encouraged to report intermediate values; e.g. 2.5 for a color difference greater than grade 2 but smaller than grade 3. As reported in the literature, all visual judgments in grades were transformed to true visual color difference (DV_{GS}) with a fitted equation which in this case was linear:

$$DV_{GS} = 0.9975 \times Grade + 0.0623 \tag{1}$$

In the constant-stimuli and ratio methods, the color pair with grade 4 was chosen as the reference or standard pair to carry out the visual experiments. In the constant-stimuli method, the observers compared the color difference in the standard pair with each of the 50 test pairs, judging which one had the larger color difference. Then the probabilities of the results “larger than” or “less than” were converted to z-score ΔV_{CS} values and the CIELAB color difference of the standard pair ($\Delta E^*_{ab,10}$= 3.9) was added (Huang 2012). In the ratio method, the observers were instructed to give a ratio of a test pair to the standard pair in terms of the color difference between them. The visual data were multiplied by 3.9 (the CIELAB color-difference of the standard pair) to obtain the visual differences ΔV_R.

3. RESULTS AND DISCUSSION

3.1 Observer Variability

STRESS (García *et al*. 2007) and WD% (Luo *et al*. 2004) values (Table 2) were used to investigate the intra- and inter- observer variability for the three methods, respectively. Low *STRESS* and WD% values mean low variability.

Table 2. The intra-and inter-observer variability in terms of STRESS (or WD%).

Observer Variability	Intra-			Inter-		
Visual Method	Mean	Max	Min	Mean	Max	Min
Constant-stimuli (WD%)	26.3	41.3	13.3	22.6	40.7	14.0
Gray-scale (*STRESS*)	35.1	52.7	24.9	27.7	51.5	17.5
Ratio (*STRESS*)	33.9	49.5	11.4	28.1	44.7	17.9

3.2 Comparison of Different Visual Methods

The 120 visual results obtained for each one of the 50 color pairs were averaged as the visual color differences, DV_{GS} (gray-scale), DV_{CS} (constant-stimuli), DV_R (ratio) and they have been plotted against each other in Figure 1.

It can be seen from Figure 1 that there is a good linear relationship, with a slope very close to 1, between the ratio and gray-scale methods. Compared with the other two methods, the visual results from the constant-stimuli method are relatively scattered, and the slope of the regression line in this region is far from 1. The main reason of this fact is that using the constant-stimuli method, when the color difference of a color pair is obviously larger than (or less than) the one of the standard pair, the percentage of “larger than” or “less than” judgments given by the observers will be higher and the real color difference of the color pair could not be distinguished. This explains the flat trend appearing in Figure 1 for the color differences obviously larger or smaller than the color difference of grade 4.

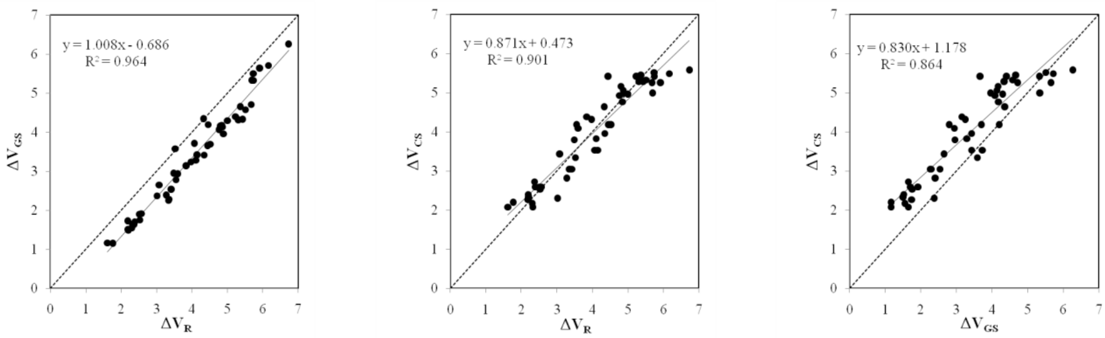

Figure 1*: The visual data from different methods plotted against each other's.*

4. CONCLUSIONS

42 observers were asked to assess 50 pairs of printed color samples with gray-scale, ratio and constant-stimuli methods. It can be concluded that the results from these three visual methods are equivalent, the results of ratio being closer to the ones of gray-scale than to the constant-stimuli. If the range of magnitudes is large and the color differences of the test samples are deviated from the color difference in the standard or reference pair, the ratio and gray-scale methods are preferable.

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Calculating Verbal Descriptions of Color Difference Components

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ABSTRACT

For many applications, it would be helpful if the various components of an observed color difference could be described verbally, based on reflection measurements. However, earlier studies show that existing descriptor methods are difficult to understand even for well trained observers. We propose a new system for describing the components of color and texture differences. It includes a modification of Hansen's method to distinguish main color categories. The new method also uses a variation of Cooper's description of hue-differences, which is better understandable for painters. In the proposed system, the components of the difference are specified as differences in four parameters: lightness, colorfulness, hue (using the three primary colors of traditional artists) and texture. The new system was shown to provide correct descriptors of observed color and texture differences in 73 to 94 percent of the cases, when compared to judgments by observers. This is comparable to assessments by an average observer, and equal or even slightly better than results from previous publications.

1. INTRODUCTION

In the car repair industry, there is a need for using a standardized system for describing color differences. For example, when the painted chip in color documentation is not perfectly matching the color of the car that needs to be repaired, a description of the remaining color difference could be helpful in identifying the exact car color in a numerical database. This description should be in terms of verbal expressions rather than in numerical values, and the vocabulary should be understandable also for those not familiar with colorimetry. Also in many other business areas users would benefit from a specification of the different components underlying the color difference observed between two samples. Colorimetric software easily produces the magnitudes of e.g. ΔL^*, Δa^* and Δb^*, but such numerical data are difficult to understand for many users (Smith, 1997). They would probably prefer software that is able to specify the components of measured color differences in terms of verbal descriptors. Therefore there is not only a need for a standardized, easily understandable system for describing the components of color differences, but also for a calculation method that produces such descriptions based on measured color differences.

Such a system may also be beneficial to people who are familiar with colorimetry. Previous studies have shown that even for experienced observers with a colorimetric background it is difficult to distinguish which color dimension is dominant in an observed color difference (Melgosa *et al.*, 2000). The rectangular CIE-Lab system is clearly not suitable for this goal. Describing color differences in terms of cylindrical coordinates ΔL^*, ΔC^* and Δh^* is much better, but often not straightforward even for well trained observers (Smith, 1997). Melgosa et al. (2000) found that when observing color pairs that differ in one color attribute, only 60.2% of the observers could identify the correct color parameter. For experienced observers this was only slightly better (72.4%), where it should be remarked that the random probability is 33.3%. These results were confirmed by Zhang and Montag (2006).

Identifying the color parameter that is dominating an observed color difference becomes even more difficult when the color difference is small. Zhang and Montag (2006) showed that even for experienced observers, the percentage of correct identifications of the dominant color attribute in a color difference drops to below 55% for sample pairs with small color difference (CIEDE2000 =8.05). In most of these studies, especially the term chroma has been found to present difficulties. Therefore in our tests we introduced the term "colorful", as we found that it is more clear to people even when not having a background in colorimetry. As mentioned below, we tested several identifications for this word colorfulness with parameters known in the CIE-Lab system, in CIECAM02 *etc*.

Another source of confusion is the method in which to characterize hue differences. As shown by Smith (1997), for colourists the most straightforward system is by using a limited number of main colour categories (such as red, yellow, green and blue), and describe each hue difference as a trend towards one of these terms (i.e.: redder, yellower, greener, bluer). In a system derived by Cooper and McLaren (1973) and McLaren and Taylor (1981), eight different main color categories are used (red, orange, yellow, lime, green, turquoise, blue and violet). In this system hue differences are expressed referring only to the four color categories just mentioned. Thus, one turquoise color may differ from another turquoise color by being either greener or bluer. One blue color may differ from another blue color not by being "more turquoise", but by being greener (or redder).

We found that a disadvantage of the system of Cooper and McLaren is that it does not relate to the traditional artists' primaries of red, yellow and blue (complemented by the three secondary colors orange, green and purple) that are familiar to most painters (Pridmore, 1991). Cooper's method is based on the four opponent colors red–green, yellow-blue. By referring in our new method to the traditional artists' primaries, we have modified Cooper's method in order to make it more intuitive for painters.

In this article, we discuss how we derived an algorithm that converts a measured color and texture difference into a verbal description of its various components, using the new system. The algorithm should: (a) produce a specification of the main color group, from a list of six color categories: red, orange, yellow, green, blue and purple; (b) specify if there is a significant difference in lightness, hue, colorfulness and/or coarseness, and if that difference is large. We also indicate which of the specified differences is most salient.

2. PRELIMNARY TESTS

2.1 Specify color group

Based on the results from preliminary tests we found that for establishing the color group, a good starting point is provided by the Hansen method (Hansen, Walter and Gegenfurtner, 2007). Based on hue values it distinguishes seven chromatic groups apart from an achromatic "Gray" group. However, since we wanted the main color categories to be consistent with the names used in the conventional painter's color wheel, we modified Hansen's method. The turquoise color group name was eliminated, and its colors were assigned to the green group. With 7 observers assessing the color group of 109 paint samples, we found that the definitions from Hansen's method worked well, except for the separation line between the green and blue color category, which needed a hue shift over 5° as compared to Hansen's results. Also, we found that the color group Neutral colors refers to cases with measured chroma value $C^*<5$, and to colors with $5<C^*<13$ and $L^*>70$.

With the definitions just given, we found that in 87.5 percent of the cases the same color group is found as in the visual tests. The highest scores are found in the red and yellow color groups (100%) and in the green (96.4%) and blue (94.7%) color group. Lowest scores are found for the neutral (77.9%) and purple (81.3%) color groups. We conclude that the main color group can be determined well based on reflection measurements.

2.2 Specify components of color and/or texture difference

For each of the components of color and/or texture differences, we performed preliminary visual tests to choose between several parameters that could be used to describe these components. Thus, for lightness differences we correlated visual data for this difference component with calculated values based on either the CIELab parameter ΔL^*, or on one of the CIECAM02 parameters ΔJ (lightness) and DQ (brightness). For the magnitude of hue differences, we used the CIELab parameter ΔH. The direction of hue differences was calculated by the CIELab expression Dh_{ab}. We tested several different parameters to quantify "differences in colorfulness", based on parameters from CIELab and CIECAM02.

In a test we let five observers assess 92 pairs of metallic samples, and describe the color difference. From all parameters tested, we found that the best correlation with the descriptions from the observers was found if we use the different components in the dE_{CMC} equation. Thus, the value of $\Delta L^*/(lS_L)$ correlated best with observed lightness differences, the value of $\Delta C^*/(cS_C)$ with observed differences in colorfulness, and the value of $\Delta H^*/(S_H)$ with observed hue differences.

Our results confirm earlier studies stating that the component that is most difficult to assess is colorfulness (*i.e.* chroma, in earlier studies). We found correct assessment of differences in colorfulness in 60 to 80 percent of the cases, comparable to percentages from 50 to 80 percent reported before (Melosa *et al.*, 2000, Zhang and Montag, 2006). In comparison, lightness differences are correctly predicted by the algorithm in 80 to 90 percent of the cases.

3. MAIN TEST: EXPERIMENTAL

We selected 222 pairs of metallic coating samples, covering color space as good as possible. The average color difference between pairs is ΔE_{CMC} (1.5:1)=3.4 for the face angle. In this set, the ten percent smallest and largest color differences occurr for ΔE_{CMC} (1.5:1)=1.3 and 6.6, respectively. All pairs were visually assessed by 5 trained observers with normal color vision, in individual sessions of the test. After finishing the test, all five observers participated in a group session. In the group session, the visual assessments for every sample pair were discussed among all observers until a group assessment was formulated. Obviously, the group assessment did not necessarily agree with the average value of all five assessments from the individual sessions.

2. RESULTS AND DISCUSSION

Our results show that based on reflection measurements we are able in 73 to 94 percent of the cases to produce the same descriptors for the components of color differences as a trained group of observers. This performance is very similar to the performance of an individual observer doing a visual examination. For the components of the color difference, this performance is comparable or even slightly better than the results published before, cited in the introduction.

For example, lightness differences were predicted by the algorithm as equal to the group session result in 73% (face angle) and 85% (flop angle); for individual observers this varied between 69% and 86% (face angle), and between 68% and 86% (flop angle). Results for other parameters are presented in Table 1. For texture differences, no results from previous investigations have been published, but our results show that observed texture differences can be predicted with a performance very similar to that for the components of color differences.

Table 1. Percentage agreement in specifying color difference components, compared to result from group session. Li : lightness, Cf : colorfulness, Hu : hue, Tx : texture.

	Face				Flop			
	Li	Cf	Hu	Tx	Li	Cf	Hu	Tx
Individual observers	69-86	66-78	68-84	76-86	68-86	67-86	62-81	89-98
New algorithm	73	80	83	76	85	82	77	94

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Perceptual Color-Difference Thresholds for Images under Different Viewing Conditions

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colour difference

ABSTRACT

A psychophysical experiment has been conducted to measure the color-difference thresholds in displayed images under different viewing conditions. The four ISO SCID 400 images N2, N3, N5 and N7 were used as original images, whose colors were systematically altered in CIELAB lightness, chroma and hue attributes to form the test images to be compared with the original ones. The average CIELAB color difference in our image pairs ranged from 0 to 4.18 CIELAB units. The test image pairs were displayed on a carefully calibrated EIZO CG19 LCD color monitor either in ascending or descending order according to the magnitudes of each CIELAB color-difference component. The test image pairs were assessed by 14 normal color-vision observers using a pass/fail method under D50 and D65 simulators, and the illuminance levels were controlled in 5 grades ranging from about 200 lx to 3000 lx for each simulator. The average CIELAB color-difference thresholds under our conditions ranged from 0.44 to 1.04 with average thresholds of 0.90, 1.00, and 0.51 for CIELAB lightness, chroma, and hue differences, respectively. In general, thresholds under D50 were slightly higher than under D65.

1. INTRODUCTION

In printing industry, the displayed images are often used as the reference of print. The viewing conditions, such as the spectral power distribution of the illuminating source, lighting intensity and viewing environment, are important environmental elements for assessing images. ISO TC130 specifies the standard illuminating and viewing condition for graphic art industry, indicating that the displayed images should be viewed under D50 simulators (ISO 2008, ISO 2009). But in real world the illuminating and viewing conditions are not conform to this strictly. For example, the correlated color temperature and spectral power distibution of light sourses are not always D50 and the lighting levels in workshop or in office are quite different for different companies. Some researchers (Stocks 1991, Gibson *et al.* 2000, Song and Luo 2000, Sano *et al.* 2003) have conducted investigations to find the magnitude of color thresholds in images. But all these researches were made under a constant viewing condition, while it is important to inspect also the effect of different viewing conditions on the soft-proofing, as intended in the current paper.

2. EXPERIMENTS

The four ISO SCID 400 images N2, N3, N5 and N7 as shown in Figure 1 were used as original images, whose colors were altered in CIELAB lightness, chroma and hue angle systematically as indicated in Equation (1) to form the test images to be compared with the original ones.

$$Out = 100 * (In / 100)^k , \qquad Hue_O = Hue_I + offset \qquad (1)$$

The first transform function in Equation (1) is an exponential function applied to CIELAB lightness and chroma in all image pixels. The second function in Equation (1) is an offset transform for CIELAB hue angle in all image pixels. There were 13 grades for lightness and chroma and 11 grades for hue angle, including a zero difference (no color difference) of image pair, by changing the exponent *k* and *offset* parameters. The average color difference in our image pairs ranged from 0 to 4.18 CIELAB units calculated by Equation (2).

N2 *N3* *N5* *N7*

Figure 1: I*mages used in the experiment.*

The color differences of image pairs were computed pixel by pixel and represented by the average difference of all pixels, as indicated for CIELAB in Equation (2). The subscripts “1” and “2” denote the modified and original images, *i* and *j* are the row and column number of pixels, *M* and *N* are the width and height of image pixels, respectively. The calculations for other color-difference formulae are similar.

$$\Delta E = \sum_{0 \le i \le M} \sum_{0 \le j \le N} [(L^*_{1ij} - L^*_{2ij})^2 + (a^*_{1ij} - a^*_{2ij})^2 + (b^*_{1ij} - b^*_{2ij})^2]^{0.5} / (M \times N) \quad (2)$$

The test image pairs were displayed on a carefully calibrated EIZO CG19 LCD color monitor either in ascending or descending order according to each one of the CIELAB color-difference components. The monitor was placed in a light booth to simulate different viewing conditions. The test image pairs were assessed by a series of pass/fail experiments under D50 and D65 simulators with 5 illumination levels ranging from about 200 lx to 3000 lx as shown in Figure 2, in which 20%, 40%, 60% 80% and 100% denote 5 illumination levels and Y-axis is illuminance in lx. Fourteen normal color-vision observers (7 males, 7 females with average age 22) took part in the experiment and they were asked to pick up the first image pair with just noticeable difference in ascending order or just no-noticeable difference in descending order. The experiment was repeated three times by each observer under 10 different viewing conditions in ascending and descending order respectively, and a total of 10080 judgments (4 images × 3 attributes × 2 light sources × 5 illuminance levels × 14 observers × 3 repetitions × 2 orders) were thus accumulated.

3. RESULTS AND DISCUSSION

In order to find out the color-difference threshold, cumulative probability of the judgments was calculated first for each original image under each viewing condition for ascending or descending order and then converted into Z-Score. The zero Z-Score corresponds to the color-difference threshold. Figure 3 shows an example of Z-Score calculation for the N2 test image under D50 simulator at 60% illumination level. In this Figure, C-A, L-A, H-A represent experimental results in ascending order for CIELAB chroma, lightness and hue attributes, respectively, C-D, L-D, H-D represent those in descending order, and the lines are the best fit of the Z-Score for the different attributes and orders. The color-difference threshold was the average color difference corresponding to zero Z-Score in ascending and descending order and the distance between them is the experimental uncertainty. The same calculations were repeated for all images and viewing conditions. It can be seen from Figure 3 that the threshold value for hue is much smaller than that of chroma and lightness.

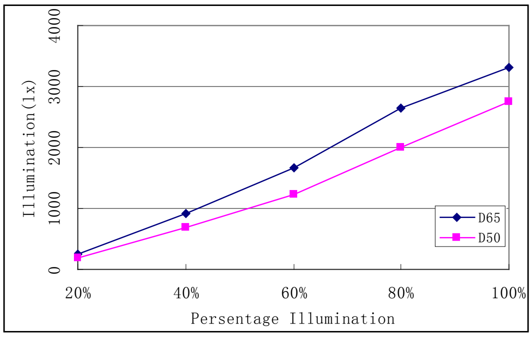

Figure 2: Illumination levels of viewing condition in the experiment.

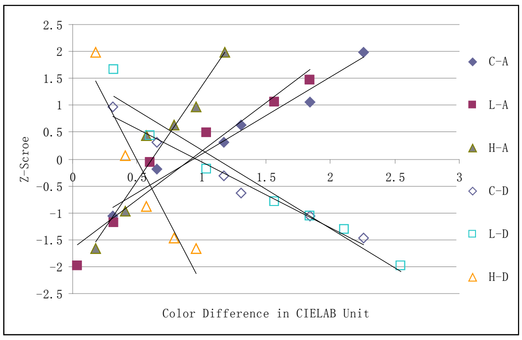

Figure 3: An example of Z-Score calculation for N2 image under D50, 60% illumination.

Table 1. CIELAB color-difference thresholds found in the experiment

		D50						D65					
		20%	40%	60%	80%	100%	STD	20%	40%	60%	80%	100%	STD
N2	C	0.96	0.92	0.95	0.91	0.93	0.02	0.90	0.84	0.83	0.82	0.92	0.04
	L	0.93	0.98	1.02	0.99	0.93	0.04	1.07	0.92	0.93	0.93	1.01	0.06
	H	0.45	0.47	0.56	0.55	0.53	0.05	0.39	0.47	0.52	0.34	0.51	0.08
N3	C	1.03	1.06	1.12	1.08	1.06	0.03	0.98	0.98	1.08	0.99	1.07	0.05
	L	0.96	0.95	0.93	0.94	0.91	0.02	0.92	0.85	0.89	0.84	0.83	0.04
	H	0.74	0.74	0.73	0.69	0.54	0.09	0.61	0.64	0.71	0.62	0.58	0.05
N5	C	1.05	1.10	1.04	1.04	1.12	0.04	1.02	0.99	0.93	1.02	1.00	0.04
	L	0.82	0.90	0.78	0.82	0.87	0.05	0.80	0.84	0.75	0.80	0.84	0.04
	H	0.44	0.47	0.46	0.45	0.43	0.01	0.42	0.40	0.39	0.36	0.38	0.02
N7	C	0.99	1.08	1.08	1.08	1.00	0.04	1.02	1.02	1.00	0.99	0.99	0.02
	L	0.91	0.93	0.90	0.88	0.87	0.02	0.88	0.87	0.91	0.87	0.85	0.02
	H	0.53	0.43	0.51	0.54	0.53	0.04	0.53	0.50	0.43	0.45	0.35	0.07
MEAN	C	1.01	1.04	1.04	1.03	1.03	0.01	0.98	0.95	0.96	0.95	0.99	0.02
	L	0.91	0.94	0.91	0.91	0.90	0.02	0.91	0.87	0.87	0.86	0.88	0.02
	H	0.54	0.53	0.56	0.56	0.51	0.02	0.49	0.50	0.51	0.44	0.45	0.03
STD	C	0.04	0.08	0.07	0.08	0.08		0.06	0.08	0.10	0.09	0.06	
	L	0.06	0.04	0.10	0.07	0.03		0.11	0.04	0.08	0.06	0.09	
	H	0.14	0.14	0.12	0.10	0.05		0.10	0.10	0.14	0.13	0.11	

The results of color-difference thresholds for each image under different viewing conditions are listed in Table 1. The first column denotes the test images, the second denotes the visual attributes, the columns corresponding to D50 and D65 are the CIELAB results under D50 and D65 simulators at 5 (20% to 100%) illumination levels. The rows marked by "Mean" and "STD" are the average and standard deviation of thresholds for four images, and the column marked by "STD" are the standard deviation for the 5 illuminance levels. The mean CIELAB thresholds in Table 1 show that the changing of illuminance level has little effect on the color-difference threshold, and also that among the three attributes the threshold of chroma is the highest while that of hue is the lowest. It is noted that the standard deviations of thresholds for the illuminance levels (8^{th} and last columns) are smaller than those for image contents (last three rows), which means that the change in color-difference thresholds with illuminance level is less important than that associated to image content.

4. CONCLUSIONS

The magnitude of color-difference threshold in images under different viewing conditions was tested by a visual experiment, the results showing that some general trends existed but there were no statistically significances among the viewing conditions analyzed. The CIELAB hue threshold was much smaller than that of chroma and lightness. It means that human eyes are more sensitive to the change of hue than that of lightness and chroma in images. The mean CIELAB color-difference thresholds under all conditions ranged from 0.44 to 1.04 with average threshold values of 0.90, 1.00, and 0.51 CIELAB units for lightness, chroma, and hue differences, respectively. In general, the thresholds under D50 were slightly higher than those under D65.

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Analysis of Three Euclidean Color-Difference Formulas for Predicting the Average RIT-DuPont Color-Difference Ellipsoids

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ABSTRACT

The RIT-DuPont data set is used to investigate the Euclidean color-difference formulas DIN99d, DIN99o and IPT. The coordinates of the metrics as well as the metrics themselves are transformed to the CIELAB color space, the latter by means of the Jacobians of the coordinate transformations. The RIT-DuPont ellipsoids in the CIELAB space are compared to the Euclidean metrics using two different methods. First, the predicted ellipsoid cross sections in the principal planes of the CIELAB space are compared to the observed data using the ratio of the union to the cross section of the ellipses, giving a single match ratio. Secondly, the full ellipsoids are compared by the method proposed by Schultze. Neither of the methods show a significant difference in the behaviour of the three different color-difference formulas.

1. INTRODUCTION AND METHOD

DIN99d and DIN99o (Cui et al, 2002)[1] and IPT (Ebner and Fairchild, 1998) are important Euclidean color-difference formulas. They were developed using different visual color-difference data sets. All these color-difference formulas have their own associated color spaces which were intended to be perceptually uniform. They have a common aim: to give the color difference given by the Euclidean metric close to the visually perceived color difference. However, this is still challenging due to the non-existence of a perfect uniform color space. Also, it cannot be assured that such formulas are able to predict other sets of visual data which are obtained under different experimental conditions.

It is necessary to do analyses of the above mentioned formulas to know how well they predict color-difference ellipsoids around particular color centers in a common color space. For doing such kind of analyses, we need mathematical models and a reliable color-tolerance data set. The RIT-DuPont data set (Berns et al 1991) is an advanced data set which has been used for testing recent color-difference formulas and uniform color spaces. The experimental average ellipsoids fitted to this data set by Melgosa et al. (1997) will provide us the reference of visual color differences. Study of various color-difference formulas by a Riemannian approach and the Jacobian method was proven efficient by Pant and Farup (2012). It provides a framework to compute metric tensors of different color-difference formulas in a common color space. The coefficients of such tensors give equi-distance ellipsoids in three dimensions and ellipses in two dimensions. The computed ellipsoids can be compared with the experimentally obtained ellipsoids to determine their performance for predicting visual color difference.

In this paper, we have computed ellipsoid cross sections associated to the DIN99d, DI-

1 DIN99o was denoted DIN99b by Cui et al. (2002), but has later been referred to as DIN99o by, e.g., Witt (2005).

N99o and IPT color-difference formulas in the three planes of the CIELAB color space, (*a**, *b**), (*a*, L**) and (*b*, L**), respectively. They are compared with the average experimental RIT-DuPont ellipsoid cross sections by using two different methods. The first method, proposed by Pant and Farup (2012) uses the ratio of the union to the intersection of the cross section ellipses to give a single match ratio, *R,* indicating how well two ellipses with a common center match each other. This is a robust method when we need to account for variations in the size, the shape and the orientation simultaneously for a pair of ellipses. The second method, proposed by Schultze (1972), is a measure for the average deviation of two ellipsoids (V_{AB}). The V_{AB} value expressed in terms of percentage gives the difference between the shapes and orientations of the two ellipsoids. It is also an indicator that tells us the average deviation of color differences.

2. RESULTS AND DISCUSSION

Figure 1 shows the computed ellipsoid cross sections of the DIN99d, DIN99o and IPT in the (*a*, b**) plane of the CIELAB color space. They are plotted on the top of the cross sections of the ellipsoids fitted at the RIT-DuPont centers in the same plane. The DIN99d ellipsoids are rotated at moderate blue, brilliant greenish blue and dark blue color centers as visually compared with the RIT-DuPont ellipsoids. In the case of DIN99o, they are rotated closely in the same direction as these color centers. However, the sizes of ellipsoids are smaller than the reference. The IPT ellipsoids in the same color centers are better both in the size and the rotation than predicted by previous two color difference formulas. For light brown, moderate reddish brown, and dark reddish orange, the DIN99d and the DIN99o seem to be better than the IPT. Similarly, in the grayish yellow green, moderate yellow and grayish purple centers, the IPT predicted ellipsoids look more similar to the reference than the ones predicted by the DIN99 formulas. In other color centers, the ellipsoids computed by the three formulas are similar.

In Figures 2 and 3, we can see computed ellipsoid cross sections of three formulas in (*a*, L**) and (*b*, L**) planes. The DIN99d and the DIN99o ellipsoids are having the same angle in the lightness direction for all 19 color centers, but the IPT ellipsoids have different angles for these color centers in the both planes. The shape and size of the DIN99o and IPT ellipsoids are closer to the reference ellipsoids in the color centers having dominant blue hue than the ones predicted by the DIN99d in the (*a*, L**) plane. However, in the same plane, the DIN99d ellipsoids perform well to match the reference at brownish and reddish hue centers. For black color, the DIN99o matches well than the IPT and DIN99d. In the (*b*, L**) plane, the DIN99d and the DIN99o ellipsoid cross sections have a similar pattern of matching with the reference for all color centers.

We have computed matching ratio *R* of ellipsoid projections of all three planes for these formulas. The resulting *R* values are in the range $.15 < R < .95$. Figure 4 shows a box plot of the *R* values of the three metrics. In the plots, the median value is marked by the central horizontal lines. The notch indicates the 95% confidence interval of the median as computed by ANOVA, and the box is bounded by the upper and lower quartiles of the data. The range of data is shown by dashed line. We can see that median values of all three formulas are approximately similar, and that the confidence intervals are overlapping, indicating a non-significant difference between the three metrics. Indeed, the pair-wise statistical sign test of the *R* values shows that at a 95% confidence level, there is no significant difference between the performance of the DIN99d, DIN99o and IPT metrics in how well they predict the RIT-DuPont ellipsoids.

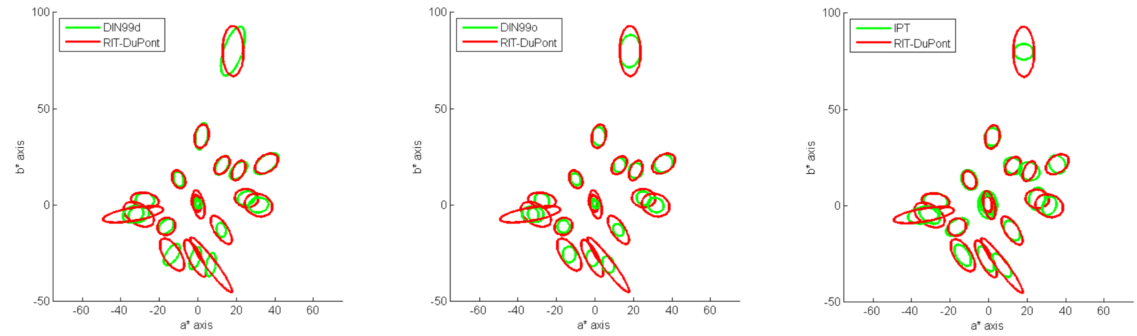

Figure 1. Cross sections of the DIN99d, DIN99o and IPT ellipsoids in the (a, b*) plane.*

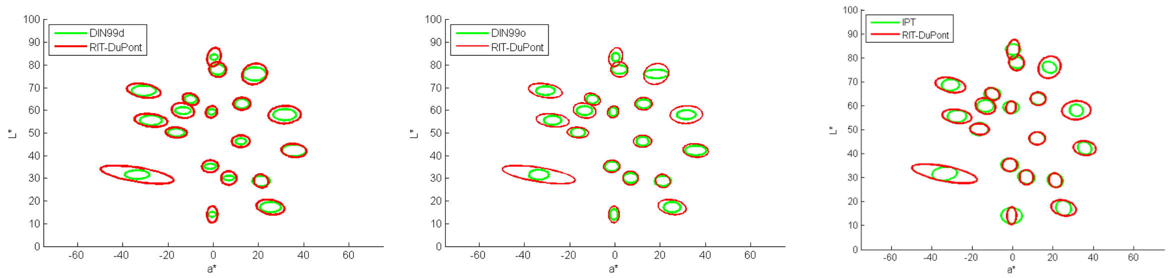

Figure 2. Cross sections of the DIN99d, DIN99o and IPT ellipsoids in the (a, L*) plane.*

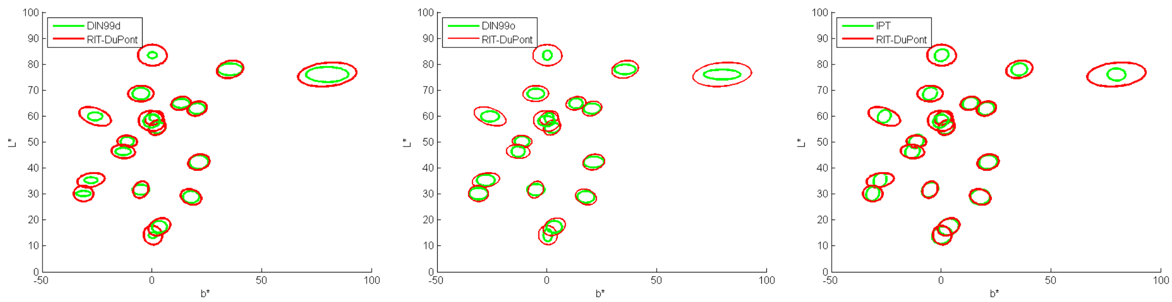

Figure 3. Cross sections of the DIN99d, DIN99o and IPT ellipsoids in the (b, L*) plane.*

Schultze's (1972) measure of deviation, V_{AB}, is calculated between computed ellipsoids and RIT-DuPont ellipsoids for three metrics using a correction factor $F = 1$. The value expressed in terms of percentage gives the difference between the shapes and orientations of the two ellipsoids. The resulting V_{AB} values of three metrics are close to each other: $V_{AB,DIN99d} = 10.12\%$, $V_{AB,DIN99o} = 9.13\%$, $V_{AB,IPT} = 7.93\%$, Also this indicates that the performances of the three metrics for predicting RIT-DuPont ellipsoids are similar.

3. CONCLUSION

The analysis shows that there is no statistical significant difference between the three Euclidean metrics DIN99d, DIN99o and IPT with respect to how well they reproduce the RIT-DuPont ellipsoids as fitted by Melgosa et al. (1997).

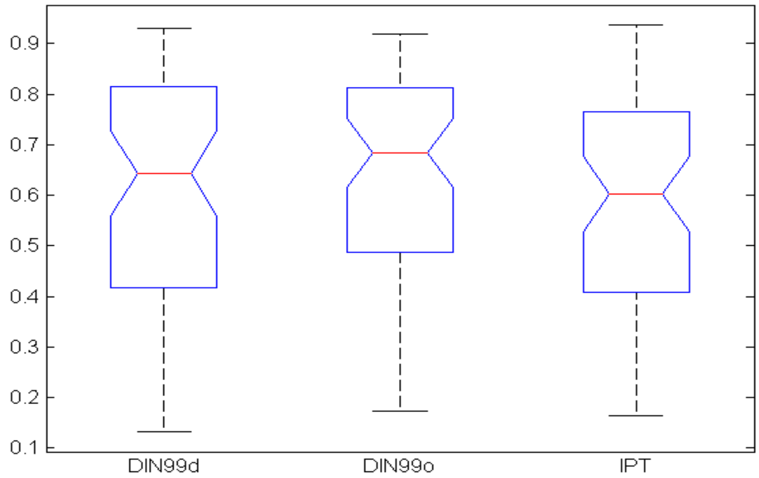

Figure 4. Box plots of matching values R of DIN99d, DIN99o and IPT.

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Relationship between Subjective Contrast and Color Difference based on CAM02-UCS

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ABSTRACT

The aim of this paper is to examine whether the color differences matches the equivalent color differences in CAM02-UCS by Luo et al. under the same combination of lighting colors and illuminance levels. The equivalent color difference is an index of the subjective contrast between colored patches and their backgrounds. It is defined as a difference of achromatic color pair whose subjective contrast is the same as a difference of chromatic and achromatic color pair in each color space. Two pairs which have the same equivalent color difference were obtained as a result of our experiment comparing achromatic or chromatic patches and their achromatic backgrounds. The color difference for two color pairs should match in the uniform color space. Then it was examined for J-C and Q-M color spaces in CIECAM02.

Under lower illuminance levels, the correspondence between the color difference and the equivalent color difference in CAM02-UCS is better than that in J-C and Q-M color spaces. However, regarding lighting colors, there isn't much difference between the range that can be used with CAM02-UCS, and that which is used with J-C and Q-M color spaces.

1. INTRODUCTION

The visual differences between a patch and its background are caused by factors such as surface texture and color, as well as the lighting environment.

A color specification and color measurement system is being established to describe surface colors with numerical values. In addition, it is possible to predict a subjective color appearance using the CIECAM02[1] color appearance model. However, most of these studies have considered only single color. The difference of color appearance between surfaces play an important role in the case of a color arrangement for example.

Our research has focused on the visual difference between the surface colors. We defined subjective contrast as subjective and comprehensive difference between a colored patch and its background.

We conducted subjective experiments[2], and collected a data set of the chromatic and the achromatic color pair whose subjective contrast are the same under several lighting conditions. In the experiments, subjects selected the combination of an achromatic patch and its achromatic background that had the same visual differences between a chromatic patch and its achromatic background. It was carried out under combination of six types of lighting colors and five illuminance levels.

The equivalent color difference was defined as an achromatic color difference whose subjective contrast is the same as a difference of chromatic and achromatic color pair in each color space. Then it was calculated from the data set. The color difference of chromatic color pair and its equivalent color difference should match in the uniform color space. The uniformities of the color differences of J-C and Q-M color spaces based on CIECAM02 were examined under each lighting condition. Although the color difference based on CIECAM02 is not defined, under white, red, green, or yellow light and illuminance levels of 30 lux or more, subjective contrast matches the difference of color index based on CIECAM02. These results have been reported by authors[2].

In this paper, the uniformity of the CAM02-UCS[3] which is developed by Luo et al. as a uniform color space, is examined by the same method mentioned above for CIECAM02.

2. METHOD

In the experiment the subject was asked to select a reference target with the same visual difference as the test target under each lighting condition. The test target consisted of a test patch and its background. The reference target consisted of a reference patch and its background. Both backgrounds were made with the same achromatic colors at a Munsell Value of 7.0.

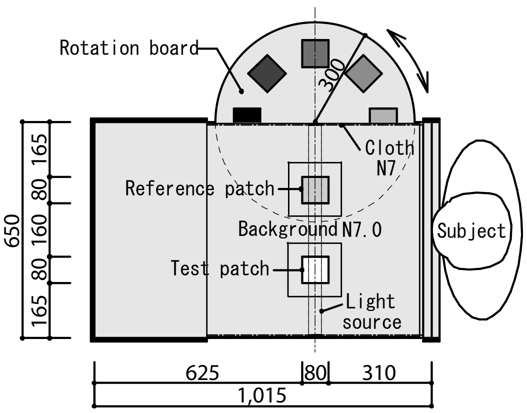

Figure 1: Apparatus.

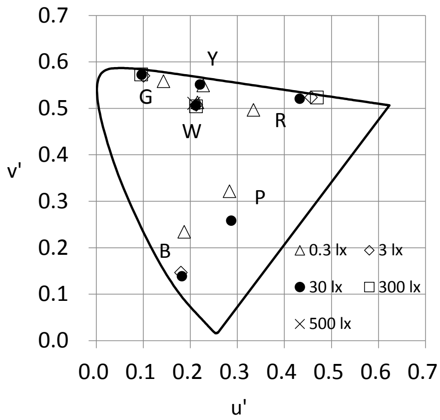

Figure 2: u'v' chromaticity coordinates of light.

As shown in Figure 1, the wall and ceiling visual layers in the apparatus were achromatic colors (N7). The test target was placed on the left and the reference target on the right in the apparatus. All targets had matte finishes, the patches were 80×80 mm squares, located at a visual distance of about 50 cm. The reference patches were arranged on a rotating board that allowed the subject to select the reference patches one by one. The lighting conditions used in the experiment were set to combinations using six types of colored lights and five illuminance levels as shown in Table 1. The colored lights were white fluorescent lamps covered with red, yellow, green, blue, or purple filters. The u'v' chromaticity coordinates under each lighting condition are shown in Figure 2.

A total of 63 colors were used for the test patches, as shown in Table 2. There were 55 chromatic colors, plus two achromatic and 6 safety colors. These chromatic colors were selected systematically based on Munsell Hue, Value, and Chroma. The safety colors are high Chroma colors defined by JIS (Japan Industry Standard). The kinds of test targets used under each lighting condition differed respectively, as shown in Table 1 and 2. Ten achromatic colors, in 0.5 steps from N2.5 to N7.0, served as reference patches. The five subjects had color-normal vision and averaged about 21 years old. Each subject had to conduct three evaluations for each condition.

3. RESULTS AND DISCUSSION

Relative errors (*RE*) as given in Eq. (1) were used as an index to show whether the color difference matches the equivalent color difference.

$$RE = \frac{SE}{\overline{\Delta E_t}}, \text{ with } \quad SE = \sqrt{\frac{\sum(\Delta E_t - \Delta E_e)^2}{n(n-1)}} \qquad t(1)$$

SE is the standard error and $\overline{\Delta E_t}$ is the average color difference between a test target and its background. *n* is the number of test targets, ΔE_t is the color difference between a test target and its background, and ΔE_e is the equivalent color difference.

Table 1. Lighting conditions.

Illuminance level [lx]	White	Red	Green	Blue	Yellow	Purple
	Lighting color					
0.3	○	○	○	○	○	○
3	○	○	○	○		
30	●	●	●	●	●	●
300	◎	○	○			
500	●					

The number of test targets: ○=13, ●=18, ◎=63

Table 2. Munsell Hue, Value and Chroma of the test patches.

	Hue	Value	Chroma			
Chromatic colors (55)	5R	3	2,	4,	5.24	
		5	2,	4,	6,	8
		7	2*,	4,	6,	8
	5YR	7	2,		6,	
	5Y	3	1.74			
		5	2,	4,	6	
		7	2*,	4,	6,	8
	5GY	7	2,		6,	
	5G	3	2,	3.24		
		5	2,	4,	6,	8
		7	2*,	4,	6,	7.56
	5BG	7	2,		6,	
	5B	3	2,	3.5		
		5	2,	4,	6	
		7	2*,	4,	6	
	5PB	7	2,		6,	
	5P	3	2,	4		
		5	2,	4,	6	
		7	2*,	4,	6	
	5RP	7	2,		6,	

	Hue	Value
Acromatic (2)	N	3.0
		5.0
Safety colors (6)	10G4/6.5 : Safety	
	2.5PB3.5/8 : Caution	
	2.5RP4/7 : Radioactive	
	7.5R4/11: Stop	
	2.5Y8/13.5 : Attention	
	2.5YR6/13 : Danger	

Table 1:

○: (13 colors)

●: +* (18 colors)

◎: All (63colors)

Figure 3 shows the relationship between the color difference and the equivalent color difference under each lighting colors at an illuminance level of 30 lx. The broken lines show if the color differences match; the closer they are to the line the more they match. The white shapes show the chromatic colors and the crosses show the achromatic colors. The black shapes indicate the safety colors. When the lighting color is white, red, yellow, or green, *RE* is largely unchanged between the color differences in J-C color space and that in CAM02-UCS. In these lighting colors, all results match closely. Results for the color differences in Q-M color space were also very similar, but aren't shown here.

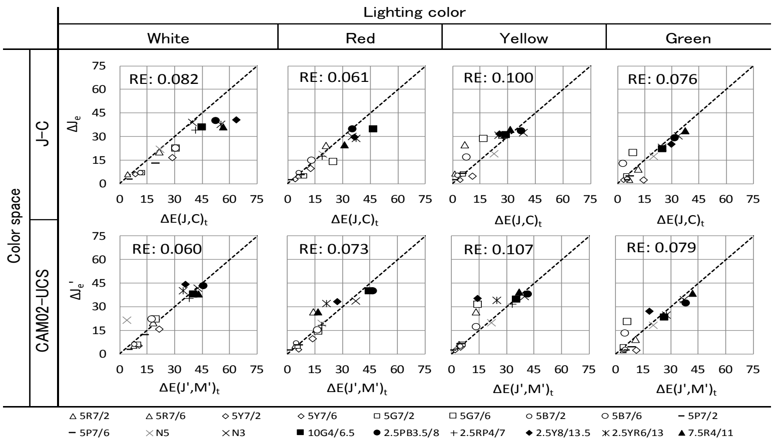

Figure 3: Relationship between the color difference and the equivalent color difference under each lighting color at an illuminance level 30 lx.

Figure 4 shows the relationship between the color difference and the equivalent color difference under each illuminance level using white lighting color. When the illuminance level is above 30 lx, the color differences in Q-M color space matches than that in J-C color space because *RE* is lower. Compared with the color differences in Q-M color space, that in CAM02-UCS matches better at illuminance levels 0.3 lx and 3 lx. In particular, the safety colors are closer to the line.

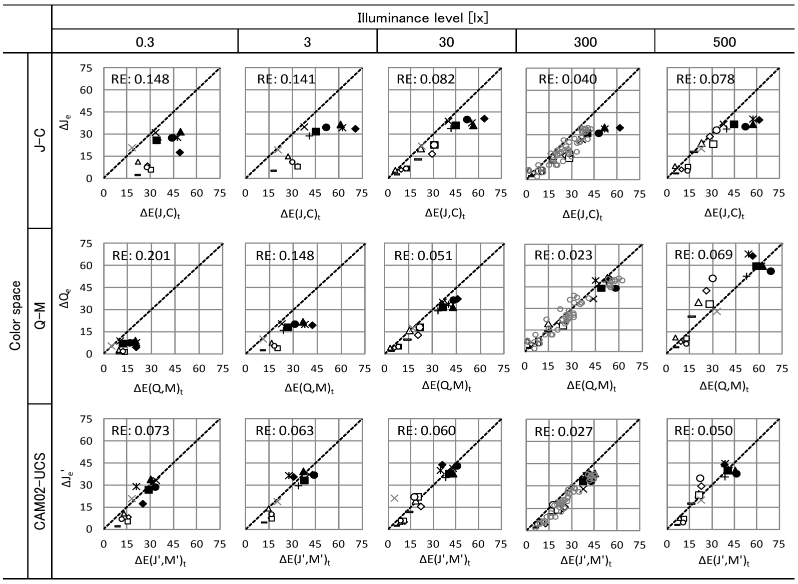

Figure 4: Relationship between the color difference and the equivalent color difference under each illuminance level using white lighting color.

Table 3. RE for J-C and Q-M color spaces, and CAM02-UCS.

J-C color space

Lighting color	Illuminance level [lx] 0.3	3	30	300	500
White	0.148	0.141	0.082	0.040	0.078
Red	0.126	0.089	0.061	0.079	
Yellow	0.139		0.100		
Green	0.100	0.087	0.076	0.045	
Blue	0.280	0.356	0.246		
Purple	0.244		0.337		

QM color space

Lighting color	Illuminance level [lx] 0.3	3	30	300	500
White	0.201	0.148	0.051	0.023	0.069
Red	0.166	0.112	0.047	0.155	
Yellow	0.193		0.139		
Green	0.154	0.089	0.073	0.060	
Blue	0.266	0.356	0.252		
Purple	0.264		0.309		

CAM02-UCS

Lighting color	Illuminance level [lx] 0.3	3	30	300	500
White	0.073	0.063	0.060	0.027	0.050
Red	0.139	0.148	0.073	0.110	
Yellow	0.066		0.107		
Green	0.074	0.045	0.079	0.059	
Blue	0.245	0.265	0.159		
Purple	0.099		0.273		

Table 3 shows *RE* for J-C and Q-M color spaces, and CAM02- UCS relative to illuminance levels and lighting colors. The lower *RE* the closer the color difference and the equivalent color difference are. The shaded areas describe data that couldn't be calculated because of minus values of Gw' in CIECAM02. When the lighing color is white, red, yellow, or green, and the illuminance level is 0.3lx or 3lx, *RE* for CAM02-UCS is lower than that for J-C and Q-M color spaces. The usable range of lighting conditions is larger in CAM02-UCS, than that in J-C and Q-M color spaces.

4. CONCLUSIONS

We examined whether the color differences matches the equivalent color differences in CAM02-UCS under the same combination of lighting colors and illuminance levels. Under lower illuminance levels, the correspondence between the color difference and the equivalent color difference in CAM02-UCS is better than that in J-C and Q-M color spaces. Regarding lighting colors, there isn't much difference between the range that can be used with CAM02-UCS, and that which is used with J-C and Q-M color spaces.

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symposium: environmental colour

The Dichotomy of Colour in Mechanistic and Organic Modernist Architecture

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Gjøvik University College

ABSTRACT

Early modernism in architecture was separated in two branches regarding theory and building morphology, a materialistic and mechanistic side as opposed to another humanistic and organic side. The application of colour makes this dichotomy clearly evident. The mechanistic approach is manifested in either pure white or saturated, uniform colors with strong contrasts conforming to an abstract or formal architectural composition. The organic approach, on the other hand, is manifested in multi-faceted colour palettes and transparent layers, chosen according to specific sites and personal demands and aiming for environmental richness and human inspiration. The analysis perfomed is based on an hierarchical decomposition specified as physical-practical, emotional, mental and spiritual consciousness, unifying classical architectural theory and modern research on human health and well-being. The paper is based on a literature review of a selection of architects and works representing the two branches of modernism.

1. INTRODUCTION

Within the pluralistic picture of early modernism, with all its theories, political programs, disputing groups of architects, revolutionary designs and technical innovations, this article suggests there are two distinctively separate tendencies. The idea of a two-split modernism is meagerly commented in international literature, but is mentioned by the Danish architect Nils-Ole Lund as an Apollo-Dionysus conflict (Lund 1991), describing the Nordic trend as approaching the Dionysian (organic) side. This paper investigates whether the presumed dichotomy is specifically manifest in the application of colour, and how the two trends relate to different layers of human consciousness. The investigation has relevance to strategies of handling recent challenges in sustainability of the built environment.

Colour, as a manifestation of light, influences all levels of human existence. Colour can thus be related to levels of human consciousness, or dimensions of life (Figure 1). The classification can be viewed as a hierarchical decomposition linking classical architectural theory since Vitruvius to modern research on human health and well-being in relation to the built environment (Björnfot et al., 2013). Vitruvius prescribed that architecture should be solid, beautiful and useful, referring to the classical reality concept of human action, feeling and thinking, in architecture labelled statics, aesthetics and ethics.

Level of Consciousness	Human experience	Architectural theory level
Spiritual	Believing	Religion, spirituality
Mental	Thinking	Philosophy, conceptual sciences
Emotional	Feeling	Social & aesthetic sciences
Physical - practical	Doing	Natural sciences

Figure 1: Four main levels of consciousness linked to experience and architectural theory.

An addition in 20th century research is a separate spiritual level. E.g. Hatfield & Hatfield (1992), emphasized cognitive processes as a significant catalyst for overall well-being, including intellectual, physical, social, emotional, occupational and spiritual levels. Donatelle et al. (1999) underlined that an expanded health concept encompass all aspects of a person, namely mind, body and spirit. Consequently, the basic model of human health and well-being, as well as architectural theory, consists of physical, emotional, mental and spiritual levels (Figure 1).

2. METHOD

This paper links the hierarchical model to modern colour theory through a literature review of a selection of architects and works representing the mechanistic and organic branches of modernist architecture. The target group of study consist of dominant and well published actors on the scene, focusing on one hand on purist functionalists such as Le Corbusier, Adolf Loos and the dutch De Stijl movement, and on the other hand on a group of architects linked to german expressionism or the term organic architecture. The review is further enriched by photographs and visual documentations of buildings.

3. RESULTS AND DISCUSSION

Undisputably among the most influential and leading personalities, Le Courbusier (a pseudonym for Charles-Édouard Jeanneret de Gris) propagated in his early career an intellectual, purist modernism through extensive building and writing. He was among the founders of CIAM (Congrès Internationaux d'Architecture Moderne) in 1928. His shiny white Villa Savoy outside Paris (1929-31) is often published as an icon of the white purity of early modernism, but the floor was covered in green, and the roof draped in pink and blue. This use of colour is typical of modernism; a few, strong accents in uniform, saturated colours, often enhancing the stringent, whitish impression. It reflects Le Corbusiers statement: *"Architecture is the masterly, correct and magnificent play of volumes brought together in light"* (Corbusier 1989). No mention of colour, only light.

This tendency of stylistic priority and intellectual approach to human conditions is perhaps seen most explicitly in De Stijl, a limited Dutch group emerging in 1917, as a reflection of world war 1. Central figures were Gerrit Rietveld (architect), Piet Mondrian (painter) and Theo van Doesburg (theorist). As proper idealists, De Stjil had a manifest, attempting to pinpoint the emergence of a new, universal consciousness outbalancing the previous dominance of individualism, blamed for the war. Topping the agenda was a reform of art and culture through a new and abstract architectonic language ("neo-plasticism"), de-individualizing the built environment. Pure white was an ideal vessel, adding minor accents of primary (universal) colours. Note here that the application of colour originates from ethical considerations striving for universal ideals, although it later became strongly associated to an aesthetic style. The influence of world war 1 is frequently underestimated in analyzing early modernism, which truly was a revolt against the old order of the world, with its preconceived historicist aesthetic and colourized language.

Rietvelds signature building, Schroderhuis (Figure 2), looks like a three-dimensional version of a Mondrian painting, built up of straight lines and angles, mainly white, rectangular and square areas, added a few saturated primary colours. A visual echo of Doesburg's articles emerges, abolishing everything natural, proclaiming universal rationalism and de-individualizing of private living quarters, along with the apotheosis of the straight line in architecture. *"This battle (Neo-Plasticism) against individualism constituted simultaneously* *a blow against art, that is, the tyranny of aesthetics in art."* (Doesburg 1990). Perhaps even more extreme are the writings of Adolf Loos, pinpointing the modernist rejection of ornament in his essay "*Ornament und Verbrechen*" (Ornament and crime). In the utilitarian spirit he proclaimed that *"Only a very small part of architecture belong to the arts, the tomb and the monument. Everything else, everything that serves a purpose, should be excluded from the realms of art"* (Frampton 1992). This is in particular related to colour, which was partly considered as a kind of ornament, and partly serving to falsify "material truth", a misunderstood concept of John Ruskin, originating back in 1849. Indeed, Le Corbusier applied colour, methodically but limited, the main aim being indoor use. Facades were largely devoted to "material truth", white stucco, naked steel, transparent glass and grey concrete.

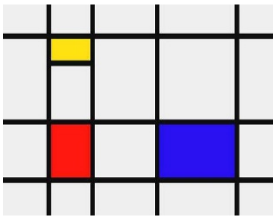


Figure 2: Mondrian: painting and Rietveld: Schroderhuis.

The tradition from Ruskin was primarily an inspiration to the organic, softer side of modernism. Here we find colour equilibrists like Bruno Taut and Hugo Häring, associated with german expressionism in central Europe, and related to Gaudi in Spain and Frank Lloyd wright in the US, the latter being accredited the term "organic architecture." Quite differently to the mechanistic approach of the white modernists, they stressed artful expression and specific adaptation to site demands and individual client needs, also in regard of colour. In the words of Taut: *"Everything in the world has colour of some sort. All man has to do is to give this phenomenon form…Since everything has colour, everything that people do must have colour"* (Brenne 2008).

Häring, in opposition to Le Corbusier, launched the idea of Organwerk versus Gestaltwerk. Taut and Häring co-worked on the project nicknamed "Uncle Tom's Cabin" outside Berlin in the 1020's, modest living quarters answering a housing crisis. The morphology was typically modernist, but the colours were soft and pluralistic, with comfortable, sometimes pastel shades far from the flashy contrasts of De Stijl. The palette is reminiscent of Frank Lloyd Wrights rich selection for Taliesin (Figure 3). Häring stressed the psychological and emotional effects of colour, suggesting the theme should be moved from questions of social hygiene and technical psychiatry over to larger problems such as psychic growth in urban life and spiritual nourishment.


Figure 3: F. L. Wright: Taliesin colours and Taut&Häring: Uncle Tom's Cabin.

Perhaps most extreme in this direction is the spiritual philosopher Rudolf Steiner. His work encompasses an extensive colour theory. Steiner designed about seventeen buildings, including the monumental "Goetheanum". On the theoretical side, colour is here deeply linked to emotional and spiritual aspects of human nature, corresponding to architectural features. On the practical side, he inspired the tradition of "anthroposophic architecture", perhaps the most long-lived and widespread branch of modernism, vital worldwide to this very day. It is characterized by organic morphology draped in layers of transparent, etheric soft colours aimed at evoking both emotional responses and spiritual aspirations. *"We absorb colours into our being in a spiritual sense…, we cannot help wanting to have aesthetic feelings about it and applying standards of beauty. This implies that we must learn to grow into colours, to live in them as though in our own element"* (Steiner 1992).

4. CONCLUSIONS

Our investigation shows that two different branches of early modernism are clearly defined in the application of colour. Chromatic patterns mirror a distinct dichotomy between mechanistic and organic modernists, seeking different approaches to the challenges of their age. Although the two have similar or largely overlapping intentions originating from ethical concerns, they separate on method. This fact links them to the hierarchical model of human conciousness. The mechanistic fraction focuses primarily on a mental and physical level, underlining universal utilitarianism and rejecting individual emotions, seeking downward in the hierarchy to face the hard realities of life. The organic fraction, on the contrary, focuses primarily on individual, emotional experience and seek upward to spiritual or higher forms of existence. The first approach manifest in either pure white or saturated, uniformly colored areas, strong contrasts, conforming to abstract or formal architectural composition. The second approach manifests in multi-faceted colour palettes and transparent layers, choosing colours according to specific sites, personal demands and organic building structures, seeking environmental richness and human inspiration.

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Colour Vision and Communication Design: Older People – Problems of Legibility and the Readability of Analogical Supports

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ABSTRACT

This paper presents the results of a research project which implemented a systematic approach to an overlap between Colour Vision, Visual Communication Design, Printed Colour, Legibility, Readability and Inclusive Design, for older people, with the aim to develop of a set of research-based communication design guidelines and recommendations for the use of Colour in printed material (analogical displays). The initial literature review included a critical synthesis crossing different areas and the second part of the project focused in the implementation of an experiment to measure the different colour experiences of the participants in four sample groups (two in UK and two in Portugal), using printed material, to find out the colours one should use in analogical communication material, being aware of the colour contrast importance (foreground versus background) and the difficulties experienced by older people to read and understand lettering, signs. After crossing the results from the two phases, and as main contribution of this research project, we developed a set of guidelines based on the reviewed literature and the sample groups' findings, trying to demonstrate the importance of these guidelines when conceiving communicational design projects, achieving vision comfort and understandability, especially for older people, in an inclusive design perspective, underlining the importance of having colour and colour vision knowledge to develop such projects.

1. INTRODUCTION

The EU and most other developed countries have identified population ageing as one of the key economic and social challenges to be faced. Most of us are aware that in an ideal world, inclusive products and services, would be standard and not the exception. To work in the Visual Communication Design area one needs to have knowledge of different techniques and how to manipulate them. Despite the knowledge in this professional circle, there is a gap in knowledge of Colour and Inclusive Design, and how to use them to develop communicational products. This paper summarizes the content and output of a research study concerned with colour, inclusive design and visual communication in analogical support for older people. Most of the studies that have been implemented until now addressing the research topic focus on the use of colour and text in digital displays, not in analogical supports. The research object of this study was the overlap between Inclusive Design, Visual Communication Design, and Printed Colour. The main objective was to introduce colour as a variable of great importance in Visual Communication, in an Inclusive Design perspective, having older people as target. Until now, little research has been carried out on how colours in form and background relationship affect older people. If text does not have sufficient contrast compared to its background, people will have problems.

2. METHOD

The study started with an exploratory qualitative literature review of the relevant material. From the theoretical contextualization, we were able to draw a hypothesis: "to produce a more inclusive design project when designing visual communication analogical products, designers must be aware of the issues related with colour and text legibility, due to the reading problems experienced by many users, like older people".

The Project overlaped different areas of knowledge, among which: Colour contrasts and color measurement; Light sources (natural and artificial); The evaluation of the proprieties of the light sources and the influence of the surfaces; Ergonomics; Inclusive design; Visual Communication; The evaluation of the colour aspects inside visual communication area; Legibility and the obstacles to reading; Older people and visual limitations. The work involved experts in the area of Colour, Inclusive Design, Visual Communication and Older People, as well as the users and the associations of people with impairments. For the second stage of this research project, we decided to develop a direct field work with the users, i.e., an experiment (active research) using sample groups of older people with the same gender composition and general characteristics. In order to allow a detailed exploration and the handling of complex and diverse information, a qualitative method was chosen. The process involved development of tools to work with the groups, especially printed color material always relating front and background colours. The search was carried out in several rounds, using the same material in similar lighting conditions and the same distances. We had the light up, on average, 900 lux (illuminance), as recommended by O'Neill (2003). The examples were very simple and designed to be readily understood. They were written in plain English for the UK sample groups and in Portuguese for the Portuguese groups. For this reason no technical terms were required. The words and sentences acted as forms, using different colour schemes, in form/background relationship.

Every sample group was formed by 8 people, with ages comprised between 65 and 85, all in sight normal conditions for people in this range of age, only with aged vision, but with no specific sight diseases. Several messages, in different color contrasts were printed on A4 format cards for a total of 24. All messages were created using 48 point Myriad. The lettering size was chosen having in mind that the group members would be placed at a two meters distance from the cards. For the colour production, we used the Pantone Matching System Colours. Information for each group included the gender, age, requirement for eye wear. The results for colour blindness were recorded as "normal" for all group members. To be selected for each of the sample groups, the members couldn't have any eye disease, only older vision. After informed consent had been obtained, and the subjects' visual acuity and ability to perceive colour had been tested, each one was seated in front of a researcher holding the A4 cards, with a 2 meters distance between them, and asked to read the text written in each card, where object (text) and background had different colour combinations. There were also cards with different types of lettering and spacing, but using always the same letter dimensions. We also wanted to test the level of legibility and the eventual experienced difficulty, as well as the level of eye comfort and color contrast. We also used eye-tracking, in a way to help us to understand the eyes movements and the efforts made by each participant to read the cards.

3. RESULTS AND DISCUSSION

One of the effects that growing older has on vision is that, on average, less light falls on the retina, and there is less tolerance to glare. Loss in the fovea affects visual acuity and color perception and general loss of vision across the whole visual field. Studies (Evans et al, 2002) suggest that more than 12% of people over 75 have some sight loss. Visual acuity is reduced by 10% for 60-69 year olds, 30% for 70-79 year olds and 35% in the over-80s. In the UK, 65,000 people are diagnosed with low vision each year (Morris, 1999).Vision is one of the primary senses and serious or complete loss of sight also has a major impact on a person's ability to communicate effectively and function independently (Jones, 2007).

With age, changes to the eye increase sensitivity to glare, difficulty of adapting to changing light levels, and make contrast and color harder to discern. A good color use for visual communication, as well as helping to improve visual performance, it may also increase general well-being and health.The effect of sight ageing is partially attributed to the yellowing of the retina, lens and vitreous humor yellow with age reducing the contrast sensitivity of the eye (Kelly, 1993). The effect of age on measurement legibility is further compounded by a reduced ability of the iris to dilate, under all light conditions.

The influence of contrast in reading and legibility is important not only because text of a wide range of contrasts is encountered in the environment but also because many ocular conditions lower the effective contrast of the reading stimulus. In general, reading is found to be fastest when the luminance difference between text and background is maximal. Lippert (1986) reported that legibility of briefly presented digits depended on the colour difference between the digits and the background. Tinker and Paterson (1928) found the legibility of coloured inks on differently coloured papers to depend primarily on the luminance difference between the text and the background, but the range of conditions that they could examine was limited by the nature of their stimulus medium.

When creating a composition, either something freeform, or a more text based layout, a determination for the final impact of the whole presentation needs to be identified.

Every visual presentation involves figure-ground relationships. This relationship between a subject and its surrounding field will evidence a level of contrast; the more an object contrasts with its surrounds, the more visible it becomes. When we create visuals that are intended to be read, offering the viewer enough contrast between the background and the text is important. The human eye requires contrasts for visibility and legibility. Colours of contrasting values stand out from each other. With colour deficits, the ability to discriminate colours on the basis of lightness is reduced. Designers can help to compensate for these deficits by making colours differ more dramatically in all three attributes.

After the implementation of the experiment with the sample groups of older people, we could achieve findings, which were confronted with the drawn hypothesis. We were able to verify that not only we had proved the hypothesis but also we had amplified the initial knowledge with a contribution for the study area.

4. CONCLUSIONS

With the sample groups, some conclusions were found for an inclusive approach in visual communication design, using colour in analogical material, for older people. The different rounds of tests allowed us to identify older people's main problems with colour use for visual communication. Overlaping the literature review and the experiment we were able to draw some recommendations: good legibility helps all users, but for people with low vision the issue is crucial for reading text; the text and background color combination should have high contrast; a clear open typeface (font) should be used for text; the characters must be of good proportions with clear character shapes; text should not be placed over a background image or over a patterned background; white or yellow type on black or a dark color is more legible; small type and very bold type tend to blur for some people, reducing legibility; avoid shades of blue, green and violet for conveying information since they are problematic for older users; use no more than five colours when coding information; be sure the elements have a contrasting colour value unless you want the elements to just blur together; excessive use of colours can be distracting; when using colours, one must have in mind that older people have a harder time distinguishing between colours in the cooler range - blues and greens particularly; some individuals are colourblind and find it difficult to distinguish between red and green; color is not appropriate as the sole differentiating feature between different elements - they should vary in other design features as well; varying the value of colors (the lightness or darkness) by at least two levels will enable most people to differentiate between the colours.

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Effects of Accent Colour on Apparent Distance to a Front Wall and Apparent Volume of an Interior Space

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ABSTRACT

This study was conducted to evaluate the effects of an accent colour on a wall, based on the apparent distance to the wall and the apparent volume of the interior space. Psychological experiments were conducted using room models scaled at one-tenth the size of the actual room. Based on the presence of the accent colour on the wall, the apparent distance to the wall and apparent volume of the interior space may vary. They depend on the size of the the accent colour area, as well as its hue and chroma. If the wall contains a greater amount of accent colour, the wall will appear to advance and the interior space will appear cramped. Alternatively, if the wall contains a lesser amount of accent colour, the wall will appear to recede and the interior space will appear larger.

1. INTRODUCTION

Colour produces many psychological effects, such as contrast, assimilation, advancing, receding, and area effects, among others. However, only a limited number of studies have focused on the effects of colour on actual interior spaces. The authors studied the advancing and receding effects of colours on the apparent distance to a front wall located in an interior space that was painted in a single colour. However, a house contains many accessories, such as curtains, blinds, paintings, and so on. These accessories can be considered accent colours in an interior space. The psychological effects of these accent colours have not yet been investigated. This study evaluated the effects of an accent colour on a wall. Consideration was given to the apparent distance to the wall and the apparent volume of the interior space.

2. EXPERIMENTAL METHOD

Psychological experiments were conducted using room models scaled at one-tenth the size of the actual room, which measured 2.5 meters in ceiling height and 4.5 meters in width and depth. The walls and the floor were painted with N9.5. A luminous ceiling made of milk white acrylic plate that transmitted light was included to maintain uniform interior illuminance. Fluorescent lamps of a high colour-rendering type were installed above the acrylic plate. The average interior illuminance level was approximately 500 lx. A pair of scale models (i.e., a standard model and a comparison model), was set side by side. Figure 1 shows the experimental configuration. With respect to the comparison model, an extremely thin square panel coated in a single colour was hung in the center of the front wall. Three experimental conditions existed that were based on panel size: (1) the large panel occupied 50 percent of the wall (hereafter referred to as EC50); (2) the middle panel occupied 30 percent of the wall (hereafter referred to as EC30); and (3) the small panel occupied 10 percent of the wall (hereafter referred to as EC10) (see Figure 2). A total of 34 panel colours were selected based on three equal attributes: hue, value, and chroma. Table 1 shows the assigned panel colours. A total of 102 experimental patterns were created. They included combinations of 34 colours and were constructed in three panel sizes.

The subjects consisted of eighteen females and two males who ranged in age between 20 and 23. The subjects had no colour-vision deficiencies. The experimental panels were randomly presented to each subject. Twenty subjects were asked to evaluate the apparent distance to the front wall of the comparison model based on their comparisons of both models. Comparisons were rated by the use of a seven-point rating scale. The magnitude estimation method was adopted to evaluate the apparent volume of the comparison model. The subjects were also asked to compare the ratio of the apparent volume of the comparison model with that of the standard model, whose value was set to 100.

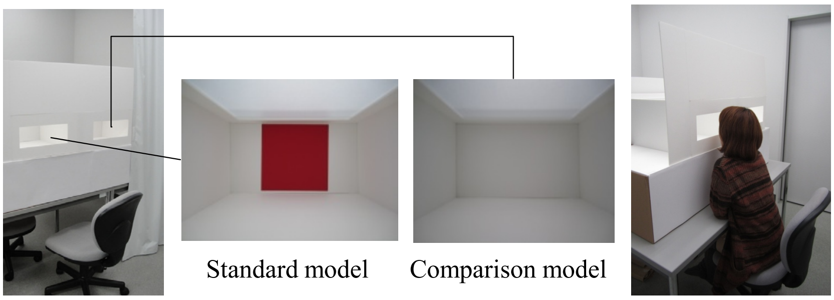
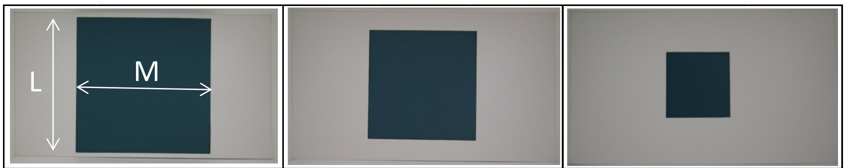


Figure 1: The experimental configuration.



EC50	EC30	EC10
L 235mm×M 235mm	L 185mm×M 185mm	L 105mm×M 105mm

Figure 2: The panel sizes.

Table 1. The assigned panel colours.

No.	Hue	Value		Chroma		No.	Hue	Value		Chroma		No.	Hue	Value		Chroma	
1	5B	Low	4	Middle	4	13	5P	Low	4	Middle	6	25	5Y	Low	4	Middle	4
2				High	8	14				High	8					High	-
3		Middle	6	Middle	4	15		Middle	6	Middle	4	27		Middle	6	Middle	6
4				High	8	16				High	7	28				High	10
5		High	8	Middle	2	17		High	8	Middle	2	29		High	8	Middle	8
6				High	4	18				High	4	30				High	14
7	5G	Low	4	Middle	6	19	5R	Low	4	Middle	8	31	N	Low	4		
8				High	10	20				High	14	32		Middle	6		
9		Middle	6	Middle	5	21		Middle	6	Middle	6	33		High	7.5		
10				High	10	22				High	12	34		High	9.5		
11		High	8	Middle	4	23		High	8	Middle	3						
12				High	6	24				High	6						

3. RESULTS AND DISCUSSION

3.1 Apparent distance to the front wall

Figure 3 shows the average apparent distance to the wall for each colour in each panel size. For EC50, the front wall seemed to advance in warm colours. The front wall also seemed to advance in cool colours. However, the degree of advancement was smaller in comparison with warm colours. For EC10, the front wall seemed to recede in almost all colours. However, the degree of recession was larger in cool colours. The values of EC30 showed intermediate values of approximately EC50 and EC10. To clarify the relationship between the apparent distance to the wall and the experimental factors, an analysis of variance was conducted using the General Linear Model procedure. The experimental factors chosen were the hue, value, chroma, and area of the panel. The effects of all factors except value were statistically significant (Level of significance 0.05). Figure 4 shows the profile plots of each significant experimental factor. With respect to the hue of the panel, the front wall in 5R appeared to advance significantly. However, the front wall seemed to recede in 5B, 5G, and 5P. With respect to the chroma of the panel, the front wall appeared to advance in higher chroma. With respect to the area of the panel, the front wall appeared to advance in EC50, to recede in EC10, and to remain neutral in EC30.

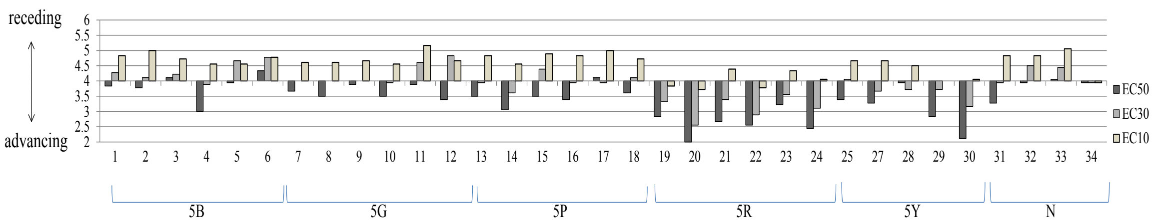


Figure 3: Apparent distance to the wall for each colour in each panel size.

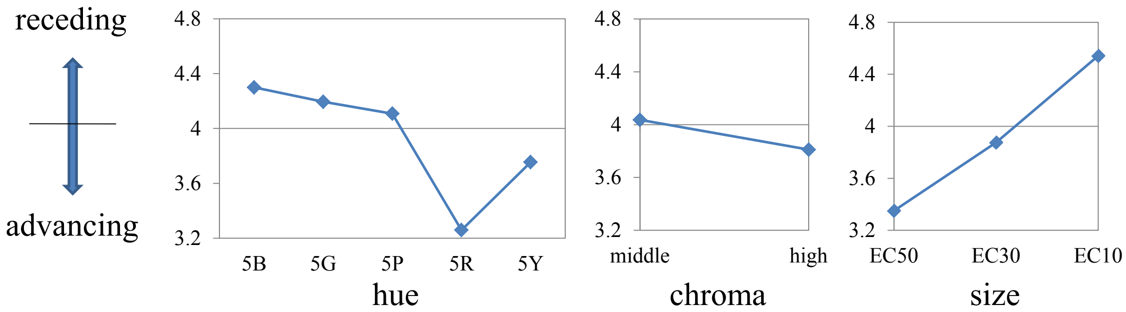


Figure 4: The profile plots of each significant experimental factor.

3.2 Apparent volume of the interior space

Figure 5 shows the average apparent volume of the interior space for each colour in each panel size. For EC50, the interior space appeared cramped in warm colours. The interior space also appeared cramped in cool colours. However, a smaller degree of shrinkage occurred than in warm colours. For EC10, the interior space appeared spacious in almost all colours. However, a larger degree of expansion occurred in cool colours. The values of EC30 also demonstrated intermediate values of approximately EC50 and EC10. In addition, an analysis of variance was conducted. The effects of all factors except value were statistically significant (Level of significance 0.05). Figure 6 shows the profile plots of each significant experimental factor. With respect to the hue of the panel, the volume of the model interior appeared most cramped in 5R. It appeared larger in 5B, 5G, and 5P. With respect to the chroma of the panel, the volume of the model interior appeared cramped in higher chroma. With respect to the area of the panel, the volume of the interior space appeared cramped in EC50. The volume appeared spacious in EC10. It remained unchanged in EC30.

3.3 Relationship between the apparent distance and the apparent volume

The correlation coefficient between the apparent distance and the apparent volume was quite high: 0.946.

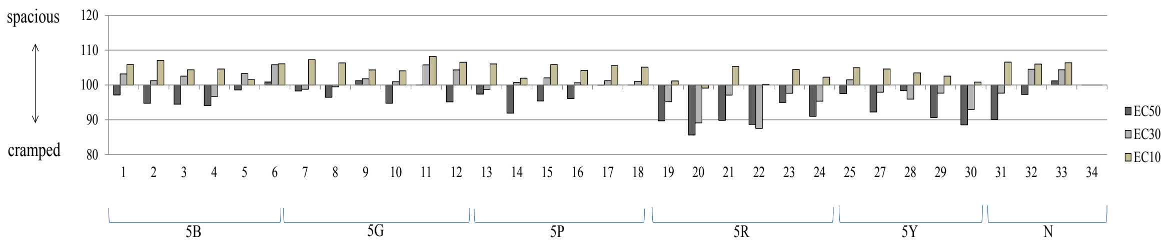


Figure 5: Apparent volume of the interior space for each colour in each panel size.

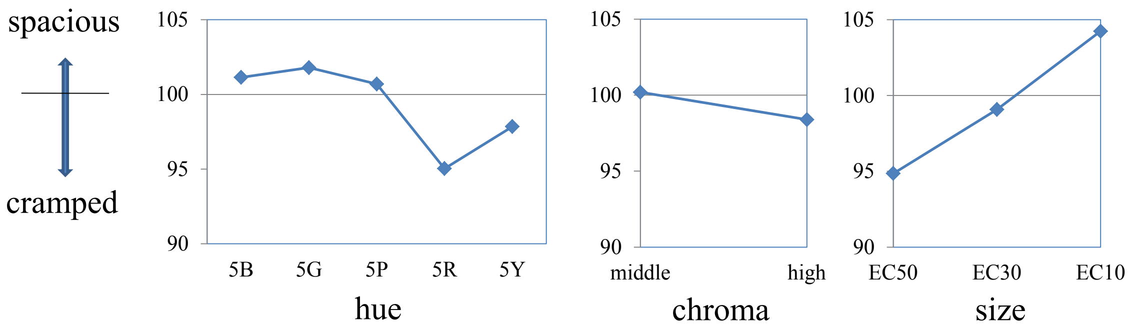


Figure 6: The profile plots of each significant experimental factor.

4. CONCLUSIONS

The apparent distance to the wall and the apparent volume of the interior space can vary based on the presence of accent colour on the wall. The apparent distance and apparent volume depend on the size of the accent colour area, as well as its hue and chroma. In the case of the wall that contained a larger area of accent colour, the wall appeared to advance and the interior space appeared cramped. Alternatively, in the case of the wall that contained a smaller amount of accent colour, the wall appeared to recede and the interior space appeared larger.

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How to Evaluate the Chromatic Integration of Architectures with Visual Impact on the Landscape by using Objective and Subjective Indicators: State of the Art

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ABSTRACT

We analyze the main indicators, both *objective* and *subjective*, that specialists have proposed to assess the visual integration degree of an architecture which has a high level of impact on urban or natural landscape. So far, most of the legislation on this issue mainly concerned industrial and energy installations in natural environments. However, more recent Spanish legislation (LOTPP 2004, RPCV 2006, etc.), like many others in the European Union do, demands considering some other architectural settings, such as the urban edges, the roads into city, or the cultural heritage environments. This requires developing a 'landscape integration study' with civil participation, in which color has to be evaluated as a conditioning aesthetic fact, but regulations do not give specific guidance on how to evaluate such a feature. Research on visual integration developed for industry; usually assess in an objective manner the impact of color by calculating an index based on the difference between the average color of the element to be integrated and the one of the background. However, the work of artists and architects demonstrate that there exist many other visual integration strategies which are worthy and are not based on color matching.

1. INTRODUCTION

This paper is part of an ongoing research project entitled: "Strategies to improve the visual integration of architectures with impact on landscape, based in chromatic criteria", founded by the Polytechnic University of Valencia (UPV, PAID-06-2012). The main objective of the project is to find chromatic strategies, different to the colour matching between figure and background, to improve the visual integration of buildings with high-impact in urban or natural landscape, and affirm other artistic possibilities to reduce the visual impact of architectures in landscape different to the idea of 'disappearance'.

In this paper, we analyze the state of the art in relation with those indicators, both *objective* and *subjective*, that different researchers have used to better reach the visual integration.

2. AESTHETICH INDICATORS

It exists an extensive literature regarding visual integration of infrastructure and industrial facilities in natural environment: (1) agro-industrial buildings (Garcia, Hernandez et al. 2003), (2) farms, (3) wind power plants (Ladenburg 2009), (4) Photovoltaic (Chiambrano 2009), (5) high voltage lines (Sumper et alt 2010), etc. However, it is smaller the number of studies regarding visual integration of architecture in landscape (O'Connor 2008), and scarce in urban settlements (Unver & Ozturk 2002) and ancient city centres.

We try to differentiate two types of visual indicators: objective and subjective. Objective indicators refer to those quantitative facts that may be distilled from the image of the settlement and are somehow measurable in a quantitative manner, following a positivistic research methodology. Although objective indicators could be based on the perception of observers, they aim to be useful for a kind of ready-to-use formulae. Subjective indicators refer to those qualitative interpretations based on people different ways of understanding the architectural integration and their meanings.

At the end, our research would like to demonstrate that *objective indicators* in relation to colour contrast/ harmony are always a first step to approach the problem of the architectural integration, but are many times overwhelmed by other *subjective indicators* that could contradict the starting point of view. The work of artists and architects demonstrate that there exist many visual integration strategies which are worthy and are not based on colour matching, or a perfect mimesis (Figures 1, 2). Contemporary architecture, in fact, moves between mimesis and singularity (Serra 2010).

2.1. Objective Indicators

Most of the research about visual integration uses different possible colour interventions for the same building and first evaluates colour contrast by *objective indicators*: differences in RGB notations (O'Connor 2008); Munsell's Hue, Value and Chroma quantities (Unver & Ozturk 2002), etc.

Considering photographs, Torres-Sibille (2009) proposed an objective indicator of the *aesthetic impact* of various industrial facilities in the landscape. This is an indicator that integrates five variables: *visibility, color, fractality*, *concurrency* and *weather conditions*, and that was contrasted with subjective indicators using the semantic differential method. The indicators were validated with three different groups of individuals: designers (*Sui validatio*), researchers (*Scientatis validatio*) and end users (*Societatis Validatio*) (Cloquell et alt 2006). However, the aesthetic impact indicator because of the colour has some limitations, since it consists solely of calculating the average colour difference between figure and ground following the CIELab* 1974 colour difference formula [AE * = "√ (" (Δ L *)^2 + (Δa *)^2 + (Δ.b *)^2)], a method that could be useful for industrial facilities in landscape, but which seems insufficient for architectures in urban environments.

Figure 1: DREWAG Stadswerke. Ev Garnier, Dresden, 2005.
Figure 2: Südzucker AG Mannheim, Ev Garnier. Ochsenfurt, Germany.

2.2. Subjective indicators

The use of the semantic differential method has been widely used in industrial design, but also in architectural spaces (Kuller 1991). Kuller used antonyms bipolar Likert scales to assess perceptions of observers in environments using architectural concepts: Pleasantness, Complexity, Coherence, Openness, Affection and Originality, which various authors add others as Naturalness and Liveliness (Real et alt 2000), Stimulation (Desmet 2003) and Protection (Torres-Sibille et al. 2009). O'Connor (2011) compares judgements about apparent size, visual dominance and congruity of buildings.

The *kansei* methodology is somehow new for architecture, as it establishes a framework for working with symbolic attributes and perceptions of the users expressed in their own language, and aims to quantify the relationship between the design characteristics and the emotional response (Nagamachi 1995).

3. A POSSIBLE CLASIFICATION OF COLOUR INTEGRATION ARTISTIC STRATEGIES

As a necessary part of Kansei methodology, we will have to classify different *stimuli*, these are photographs with different possible colour interventions onto architectures, to evaluate their integration degree. Starting with *objective indicators*, we will classify the *stimuli* in three groups (mimetic, harmonious and contrasting) and will compare them with the *subjective indicators* (assessments by observers) to evaluate their coherence.

Artistic strategies based in chromatic *mimesis* consist of approximating the color of the building to the background, trying to get their color difference the smallest possible. The distorting element is colored to be invisible, if possible (Figure 3). Artistic strategies based in chromatic *harmony* display colours not to make the architecture dissapear, but to make it congruent with the surroundings. Colours in this case are used to transform the perception of the size, geometry, weighth, rithm, or whatever visual property of the form. Artistic strategies based in chromatic *contrast* use colours that substantially differ from those of the surroundings, assuming the discrepancy as a possible way of aesthetic integration.

Figure 3: Roeland Otten, Electrical substation, Rotterdam, 2009.
Available at: http://www.roelandotten.com/

The classification proposed is similar to the one by García, Hernández and Ayuga (2006), describing three posible visual relations between building and environment: visual continuity, diversity and contrast; following in some way Gestalt's oponent visual concepts: levelling vs sharpening. Spillmann (1985) outlines the possible relationship of buildings to their surroundings with a more accurate classification: camouflage, subordination, equal ordination, superordination and isolation. All these authors conclude that it is both necessary a visual colour continuity but also a certain contrast to produce tension and change: "unity in variety or continuity in complexity" (Spillmann 1985: 6)

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Colour Harmony in an Architecture Environment

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ABSTRACT

The aim of our work is a strategic method for development of colour conception (architectural and urban complex, environment design projects). Every architectural complex or group of buildings is an integral part of the existing landscape, natural and urban environment, which means it participates actively in the creation of the colour ambiance. We develop the colour environmental concept as a synthesis of the quantitative, qualitative and structural interaction of the spatial components, including chromatic and artificial light characteristics. Each architectural, constructive, technological or "gestalt" element of exterior design has its own form and size, texture and material feature, spatial disposition and function, all of which define specific requirements of colour treatment. Thus we aim to understand the colour conception of the building and its surrounding area as a dynamic system. We offered to develop a strategy of colour in multiple cities, combining all colours and materials, architectural elements and landscape, urban art and design. All these components which create a dynamic space and characterized by three aspects (structure, chromatic contents, and dynamism) should be balanced and harmonized. We developed specific Software "Harmony of Colours" which proves to be useful tool for a systematic design approach.

1. INTRODUCTION

Our study of perception, representation and production of colour harmonies raises a historic panorama of the colour in the urban environment during the XXth century. The knowledge highlights the difference between spatial colour harmony and architectural concept developed by certain symbolic movements such as the Art nouveau, the Russian avant-garde, the modernism, the optic art, the kinetic art, the unusual achievement of Hundertwasser. It represents a theoretical base for the specialists involved in the urban colour design process.

Since the Eighties, the architects-colourists have tried to give to ensemble of the buildings a major significance. They proposed a concept of the geography of colour and suggested the general colour scheme for typical facades and details in town (Jean-Philippe Lenclos, Bernard Lassus, Giovanni Brino), they created a symbolic aesthetic system applying colour (Jacques Fillacier, Fabio Rieti), and applied the method of site analysis with development of colour charts (Michel & France Cler, Bruno Goyeneche).Their work made it possible to gather a great number of former researches in the field of practice of colour, to control them and to supplement them to constitute a coherent and operational whole by the development of a certain number of software carried out on psychometric bases. Some architectural ensembles of the "new cities-les villes nouvelles" were harmoniously emphasized by the selected polychromy. The use of a harmony of neuter colours like gray, white and, "metalized" gray dominates the Eighties. The constructions of this time have had the expression of the voluminous forms that dominates the city environment. Another tendency of the Nineties was to employ saturated colors contrasting at the structure with neutral and grayed backgrounds.

2. COLOUR HARMONY AND URBAN DESIGN

The close cooperation of the personalities of very diverse competences: architects and designers, engineers and physiologists, psychologists, painters and landscape designers added to the quality of this collaboration allowing the creation of an optimal visual comfort. Today, at this beginning of 21st century, the architectural polychromatic design has an enormous importance for the city. We can notice an interest for the ecological environmental quality which gives a particular value to the contributions of the professional designers working for human comfortable being in a daily urban environment. The colour conception using NCS System® is widely applied: by Grete Smedal for Longyearbyen in Norway or by Jem Waygood for Blackburn and Darwen and Tom Porter for New Hall in Great Britain, by Paul Green-Ermytage in Australia or Werner Spillman in Suisse and Germany, by Leonhard Oberascher in Austria or Lars Sivik, Karin Fridell-Anter & Åke Swedmir in Sweden. These numerous examples prove its contribution to control and harmonize the environment.

Today the aim of colour design space planning is creating the polychromatic environment which corresponds well to natural geographical specificity, with the space characteristics of the city planning, with the social and cultural roots, but also with the semantic significance of the color historical striates. A question that can be answered by two extremes – what is the future of urban polychromy: the "vernacular" colour, chaotic and spontaneous or the totalitarian order of the strictly organized "pixels idealization"?

Our work is an applying of the strategic method for development of colour conception of architectural and urban complex.

An environment design project has to insure the logical way of perception of the structure, its chromatic contents and dynamism of viewing .Every architectural complex or group of buildings is an important integral part of existing landscape, natural and urban environment which means it participates actively in the creation of the colour ambiance. We have to develop the colour environmental concept as an integral result of the quantitative, qualitative and structural interaction of the spatial components, including chromatic and artificial light characteristics. Therewith we have to define an understanding of colour conception of the area or building in it as a dynamic system; it proves to be useful tool for a systematic design approach. Our colour design process might be considered as a process of constant modelling of the colour characteristics and elements of our environment. The most important stages are summed up in three main steps: Analysis of existing situation (investigation, description and registration of colours); Modelling of colour/space sequences of perception respecting different factors and bonds in order to define the colour features of each element; Elaboration of colour scheme and plans, final choice of material, methods and techniques.

A profound analysis of the existing situation is a stage of primary importance. It is carried out in accordance with a number of factors, which influence the global and integral colour strategy. For this purpose we apply the methods of investigation "in situ", expert observation, samples standardized material, tests and inquiries. Documentary photography and sketch registration are applied in order to define: social and aesthetic colour preference of users and experts of different generations; traditional chromatic and achromatic palette, colour harmonies of existing architectural monuments or decorative arts; existing state of colour components of regional landscape and architectural background.

The substantial part of the design process of colour modelling should respect the influencing factors: surroundings, functional and spatial organization; architectural, technological and "gestalt" elements; specifics of visual perception and dynamical changes. It is carried out in several levels: of town planning as a whole; of boundaries of volume and spatial formations; of main "façade" exterior development; of spatial and planning structure; of filling up of spatial and planning structure; of "interior" space of area. The most important is the last stage: evaluation and final choice, discussion and expert's adjustment of colour colour design solutions in real visual context. After the conception stage the mission of the operational survey, adjustment and stage of permanent working consulting is necessary in order to keep the wright axes of sustainable development of initial project.

3. COLOUR HARMONY AND SUSTAINABLE ARCHITECTURE

The colour in the townscape along with scale, form, light and texture plays a significant role in the acceptability and success of its development. Using colour with rigour and subtlety in the domains of the chromatic restoration of the urban heritage as well as in the contemporary architecture can help to alter perceptions of scale and mass and assure the integrity of surrounding buildings, streetscape and public places. The knowledge about existing "environmental colour strategies", about different colour group and visual harmonisation, needed to make urban space more comfortable and visually balanced, is an important theoretical base for practical experience. Colour harmonies and its classifications are considered as indispensable for colour study of the urban space and sustainable architecture: buildings, equipment, and the transport infrastructures.

An environmental approach of urban colour design should not be seen separately but simultaneously with other design principles: townscape character, public realm, movement and legibility, sustainable development, diversity and adaptability. The ensemble of these principles should be used as a material consideration in the determination of planning application; it could be based on the confluence of the different stages: Survey; Analysis; Synthesis; Colour design concept. Survey involves definition of site area and collection of existing colours within that area to establish the dominant tonality and colour range of the elements which make up the site. Analysis involves the synthesis of collected colours into a representative palette, reflecting the dominant features of the site, the main view points and orientation, social and cultural aspects which could have a bearing upon the perceptions and expectations of those likely to use the site. Determining colour options involves the creation of a colour chart specifying ranges of colours based upon the synthesis of key colours. The ranges offer options for integration/camouflage, harmonization, contrast and accent. Implementation involves negotiating agreement with the developer/architect over specified materials and on site verification of these products in relation to the colour study.

Nature and landscape polychromy as well as artificial light and colour parameters of the components of environment design equipment forms help to enrich a palette of colour harmonies, semantic and visual variety of urban spaces. These harmonies can assure: colour confluence of building with landscape; contrast of architecture with natural background; creation of artificial colour landscape, which will compensate the lack of natural colours.

Today, architects and town planners need the knowledge about existing "environmental colour strategies", about different colour group and visual harmonization in order to make urban space more comfortable and visually balanced. They consider it as indispensable to the understanding of urban space and to the quality of life of the inhabitants, involving not only buildings and equipment, but even the infrastructures of transport. For our recent projects of colour design space planning (Multifunctional centre, La Rochelle, Centre Gecina, Douai, city of Caen, city of Quetigny, Grand Dijon, France etc.) we wished to create a polychrome environment that corresponds well to natural light geographical specificities, with the space characteristics of the city planning, with the social and cultural roots, and also with the semantic significance of the colour historical strata. We distinguished four colour fundamental groups of colour associations: Colour, Value, Nuance, Mixed, and 24 complementary intermediate colour groups. In our study we found it interesting to use NCS System® for the visual and scientific expression.

A specific "Harmony of Colours" software came to be useful tool for a systematic design approach. Our colour design process was considered as a process of consistent modelling of the colour, material and light characteristics of architectural elements, of built and natural environment. We conceived with a system of «Harmony of Colours» a selection of chromatic palettes. We could experiment very quickly a large number of different solutions. "Harmony of Colors" was a very useful tool for colour design process, it allowed to draw various sketches with colors and textures changing automatically according to the chosen harmony. When our project had to fit into a context, "Harmony of Colours" helped us to find solutions to save the colour identity of the city, to find and resume the historical traditions of colour as an essential part of the architectural history connected with the city; to treat information about potential for colour reconstruction, general restoration and rehabilitation work; to see the results of the investigations of architectural colour palettes.

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Smart Shading: Colours for the Environmental Quality of the Architectural Surfaces

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ABSTRACT

The colours of the architectural surfaces can make an important contribution to improve the environmental quality of manmade spaces. The perception of places, but also the psycho-physical state of the users are influenced by the presence of certain colours. The colours of the architectural surfaces can also make an important contribution to the environmental sustainability of the built environment. Lighter colours seem to be more suitable to be used in the surfaces that are most exposed to solar radiation (during the summer), as they have a low absorption coefficient of the light radiation and a high reflection coefficient. Darker colours seem to be more suitable for the less irradiated walls because their absorption coefficient is higher. Furthermore, the reflection degree of a material depends on its surface quality. The research entitled "Smart shading" conducted within Iuav University of Venice, "Colour and Light in Architecture" Research Unit, Veneto Region, Materis Paints Italia S.p.A. (a company that produces colours and finishes for the building industry) and CERT-Treviso Tecnologia (product certification company), wanted to show that it is possible to improve the thermal performance of an external wall by the application of a particular thin layer of finish.

1. INTRODUCTION

The research titled "Smart Shading" was created with the goal of identifying new technological solutions for the protection of the external walls of the buildings from the summer sunshine, possibly through the application of innovative materials and smart technologies. The research has been developed in collaboration between Iuav University of Venice and Materis Paints Italia SpA, with its brand named Settef, a global leader in paintings for the construction industry. The finishing systems for external thermal insulation solutions are the strength of Settef production. The objective of Smart Shading research was to develop, in collaboration with the partners, a 3mm colored finishing system suitable to be applied on insulating materials (but also on other surfaces), providing adequate protection from the sunshine on the walls of the buildings. The challenge was to show that a simple layer of finish can improve the performance of the building envelope and then of the whole building.

2. METHOD

To achieve the objective, the first phase of the research has been focused on two main lines: 1. The identification of solutions for the façade finishing made of smart materials (already on the market or in the testing phase) with the aim of improving the performance of thermal insulation of walls; 2. The identification of solutions for the protection from sunshine, capable of lowering the surface temperature of the external walls of the buildings through the use of chromatic technologies.

The first phase of research has shown that, to obtain the desired results it was necessary to operate in two directions: a. increase the surface reflectance of the finish system; b. locate a three-dimensional configuration of the finish, able to decrease the surface irradiated by the sun. The research, which concentrated on these two aspects, has considered various possible solutions (phase-change materials, dichroic pigments etc.), identifying in the use of pearlescent pigments the most suitable solution for increasing the surface reflectance of the finish. These pigments are made of highly reflective micaceous iron oxide inserted into an acrylic stucco which can provide the required performance. Regarding the three-dimensional configuration of the finish we made an articulated analysis of the height of the sun during the day and several months of the year (sun path). As is it known, the height of the sun in the sky above the horizon, measured in degrees, determines the angle of incidence of solar radiation on the Earth surface. Consequently it also determines the angle at which the sunlight strikes the surface of the external walls of the buildings. Since we planned to work on the increase of the finish reflectance, we considered to act on its morphology to ensure that a portion of the incident radiation could be easily reflected and a part of the wall could be shaded, decreasing its surface temperature. To achieve this effect we have identified a "toothed" section of the stucco with an average slope of teeth adapted to different latitudes (Figure 1). This section, similar to the inclined blades of louvers and brise-soleil, allows the walls to have a surface portion (one below the inclined portion) which is shaded for a rather long time.

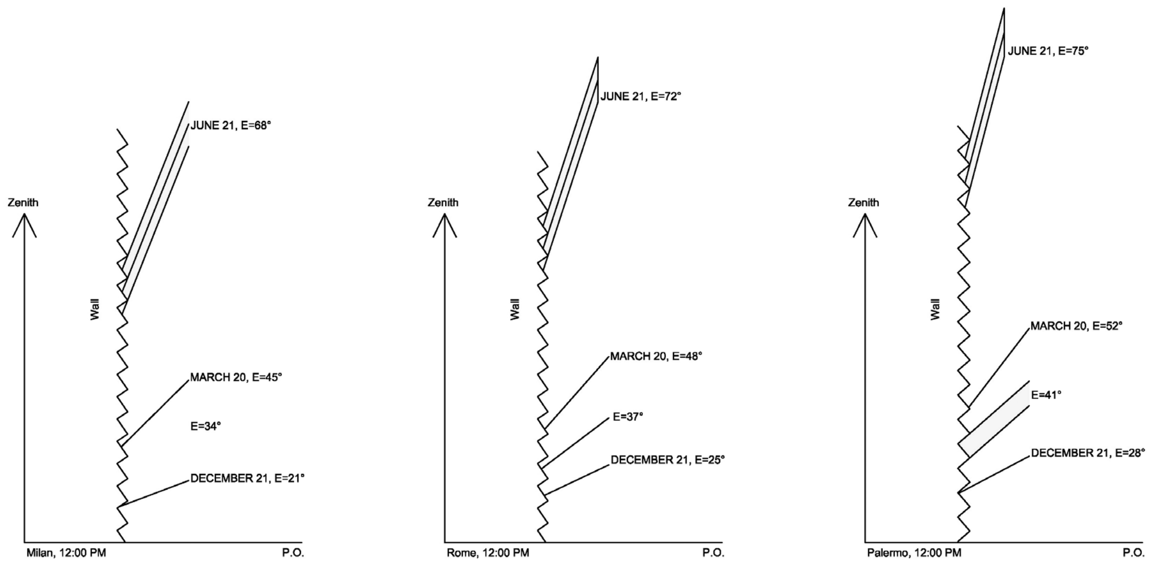

Figure 1: Three-dimensional configuration of the finish.

After the phase of theoretical research we passed the stage of experimental research. Parallel to the factory production of the finishing stucco, there was a research aimed at identifying the optimal solution for the application of the stucco by the mean of an instrument capable of imparting the desired three-dimensional configuration. The research was conducted on two lines: the study of a custom instrument and the identification of ready-made tools available on the market. The second solution was preferable because it allowed a significant cost savings. Once we have located the proper tool, application tests were performed to adjust the viscosity of the product and to control the final appearance of the finish.

Once this phase of the research was completed, Materis prepared a number of panels designed with the new finish to be tested at the CERT laboratories of Treviso Tecnologia. A comparison between panels with the new finish and panels with commonly used standard finish was necessary, to be able to determine the differences in performance. For this reason we prepared panels of white polystyrene foam (EPS-100 type), size 100x50cm, in different thickness: 3cm, 4cm, 6cm, 8cm, 10cm. The panels were equipped with three different finishes: two "standard" finishes of Materis production (Settef brand) called "Cortina Cap Medio" in white and yellow and the new finish "Smart Shading" in light gray pearl. For the "standard" panels we have chosen two colours of very frequent use: white and pastel yellow. For the new finish we opted for a light gray since white would have resulted in a too advantageous choice. In fact, white, as is it known, allows the surfaces to accumulate less heat than the other colours as it offers a high proportion of diffuse reflection. Each panel was composed by the following layers: a layer of adhesive, a glass fibre grid, a pre-finish layer and the application of the external finish.

The panels were tested in the laboratory within a custom built cell able to simulate summer environmental conditions. The cell had an internal 800 Watt halogen lamp with a colour temperature of 3200 K (similar to the sun at dusk). The lamp was placed to simulate an inclination of the solar rays of 60°. The lamp emitted also heat, quickly bringing the surface of the panels at about 60 °C, a temperature reached in summer.

3. RESULTS

The panels with the new Smart Shading finish, in all the performed tests, showed a difference of surface temperature greater than the standard panels. In fact, the new finish thanks to the special three-dimensional configuration seems to behave as a passive heat sink similar to those used in electronics. With the same wall surface, the new finish increases the surface/volume ratio that enhances heat dissipation. The heat is dissipated by the thermal conductivity of the material and by the convection currents that are generated by the temperature difference in the air around the heat sink. Some of the heat is also transferred to the surrounding environment through the phenomenon of irradiation. In fact, a body that has a temperature higher than the zero Kelvin emits energy in the form of electromagnetic radiation, thereby reducing its temperature. The high reflectance of the pigments was evaluated by the use of a reflected light meter.

4. CONCLUSIONS

The principles on which Smart Shading works are light reflection, shading in relation to the tilt angle of sunlight and heat dissipation. The finish, applied on a layer of expanded polystyrene outside the building, is provided with pigments capable of increasing the reflection property of the compound and, at the same time, it has a special three-dimensional configuration that allows to enhance light reflection and shading in the summer period, when the sun is highest in the sky, keeping the surface of the wall at a lower temperature.

The new finish is designed for new buildings and for the requalification of buildings of the second half of the Twentieth Century. This kind of buildings in fact, while requiring special care and attention in the interventions, have no particular design constraints that allow the adoption of a very wide range of technological solutions which include the redesign of the outer skin of the entire building.

At the end of the research brief guidelines for the application of the new finish were produced. Due to the high reflectivity of the finish, its use must be calibrated on some parts of the building so as not to create annoying glare effects. Since the angle of the "toothing" of the new surface finishing increases the light reflection upwards, avoiding overheating of the horizontal surfaces, it is possible to use it in the higher parts of the buildings where the overhangs can protect the surrounding buildings against an excess of light reflection. At the same time we do not recommend the use of the finish on the lower parts of the buildings, especially at head height, to avoid the problem of glare due to the high reflectivity. It is however evident that in the design phase the solutions to be adopted should be calibrated to each case.

In terms of appearance the "Smart Shading" finish seems to be similar to metallic materials, which are also widely used today in the interventions of over-cladding of the building envelope. From an economic point of view the Smart Shading finish could be a good alternative. The adopted colour palette provides colours that are close to the colours of metals: silver gray, red copper, green copper and golden yellow. We have tried, however, to prefer light colours. The tests on the finish will continue even during the summer, under natural environmental conditions.

The results of the research have provided yet another confirmation that the colour and the quality of the surfaces of the buildings are one of the most important features of the design of a single building as well as of the design of an entire district.

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colour printing

Exploration of Alternative Print Methodology for Colour Printing Through the Multi-Layering of Ink

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ABSTRACT

This paper explores the application of artist driven colour mixing and multi-layering of pigments using inkjet printing. A standardised colour management workflow is essential for predictable and repeatable colour for inkjet printing. With the correct implementation of a print methodology, input colour values are rendered through the print driver in order to determine the combinations of ink channels from which the colours will be constructed. Through this automation, the user surrenders control in the colour mixing process. From an artists' perspective this is counter-intuitive to artistic colour mixing methods, this research considers possibilities for colour printing by approaching the inkjet printing process from a more traditional colour mixing methodology. This research investigates the implementation of multi-layering for inkjet printing by reflecting on photomechanical art historical processes from the 19th century and the application of layering of pigments as demonstrated in old master paintings. By mixing inks in ways that are considered to be non-conventional for inkjet printers, but instead by implementing a layering process similar to traditional printing and painting processes, we aim to improve colour output when printing inkjet reproductions of original artworks.

1. INTRODUCTION

While the implementation of standardised procedures are universally beneficial to the inkjet printing market as a means to establish a common language, this standardisation creates limitations for artistic applications. When printing primary colours (for example CMY), the assumption is that the printer will print primary colours of CMY. However, not all printer manufacturers use the same CMYK+ colourant combinations, inks sets may be modified, or colour sets increased according to manufacturer specifications to enhance specific areas of the colour space.

Inkjet printers' colour inksets may be modified according to manufacturer specifications to enhance specific areas of the colour space. As these ink colourants deviate from other standard process colours of CMYK typically seen in other methods of colour reproduction, such as offset lithography, custom colour transforms are needed to generate the colour separations (Lammens, 2008). This results in data from the computer file being translated to a combination of the custom ink set used by the specific printer.

At this stage colour information, for example yellow, could be translated to use not just yellow ink, but also magenta or red depending on the colour palette of the machine (see Figure 1). While we may not have this direct translation, what we gain is the ability to use the approach of implementing the methodology of painting, as no artists' palettes are ever quite the same. Here we can begin to use a variety of colour mixing approaches, as well as the layering of pigment to create final colours. This technique can be used to generate the dark, rich colours observed in old master paintings that were oftentimes created through techniques of over layering paint pigments.

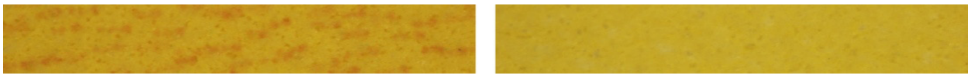


Figure 1: Colour managed yellow rendering (left) vs direct n-channel yellow (right).

By mixing the inkjet inks in similar ways to such traditional print processes, we begin to explore the potential to create colours that could not be made by customary means of inkjet printing (Parraman, 2010). Furthermore, we can explore the possibility of controlling colour through multi-pass printing techniques. When printing with multiple passes, utilising a single ink channel per pass, we can control the print order.

2. METHOD

The objective of this experiment was to qualitatively and quantitatively evaluate the final appearance of multi-pass printing. A series of colour test charts were designed to test the gamut of an inkjet printer, and to work beyond its current limitations. The test chart comprised three separate layers, and was devised so that the paper was required to be passed through the printer three times, thus creating an over-layering of primary colours. By applying each colourant through the layering process, the base layer of ink is then allowed to dry onto the paper before the second ink is applied. Accurate pin-bar registration was used to undertake these tests.

2.1 Development of Test Chart Parameters

Two test files were constructed, the first to cover one and two ink colour combinations, and a second to explore three colour combinations. The objective was to demonstrate all combinations of colour, and to demonstrate every possible print order combination. Each of the colour patches were arranged to create a perceptually arranged placement, in order to allow for qualitative analysis in observation of the charts by the viewer. Initial tests have been performed on the Canon iPF8000 inkjet printer, using the primaries cyan, magenta, yellow, plus red, green, and blue inks. Using Caldera's VisualRIP$^+$ to allow for the direct n-channel printing capabilities, the test files were printed onto Somerset Velvet Enhanced Paper, a fine art inkjet coated paper that can tolerate a high level of ink deposition.

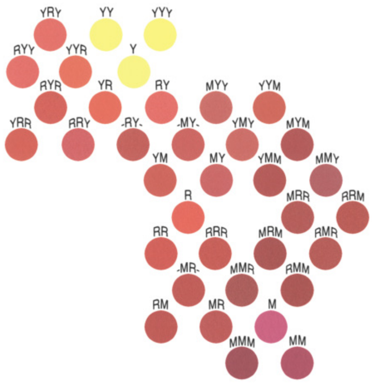
2.2 Colour Mixing by Painting with Ink

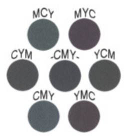
In addition to observing and verifying the colour that can be produced by ink channel combinations, these tests explore the effects of multi-pass printing. The multi-pass printing process achieves two results: firstly, when printing a swatch with a value of 100% red in the source file, the maximum density of the output is determined by the linearization implemented by the RIP software, and cannot be exceeded. In relation to colour mixing principles, this limitation can be overcome by printing a first pass of 100% red, and then a second and a third layer of 100% red ink. By using this method the density of the colour can be increased without the use of black ink, which would also simultaneously desaturate colour. Secondly, there is a perceptual difference in the appearance of colour for two coloured overprints by changing the print order. The tests involved the formulation of test charts that allowed all the variables of the six primaries to be printed as either a base colour or as an overprint. In this three pass print process the colour differences could be observed.

The first test chart, a section of which is shown here (Figure 2), depicts each of the colour primaries, printed through direct n-channel printing, along with all colour combination and colour order variations of two colour combinations for up to three print layers. This allows for a visual analysis of colour density increments of up to three layers of each primary (e.g.

R, RR, RRR), along with the differences of two colour combination printed together, in-line through a single pass (e.g. -RY-), as well as the colour generated by layering each on the two ink colourants in reverse orders (e.g. RY, YR). Furthermore, the swatches include all colour variables and orders for up to three layers where one ink colour is applied to the paper twice in conjunction with a layer of an additional ink colour (e.g. YYR, YRY, RYY, RRY, RYR, YRR). There variations were constructed for all possible combinations of CMYRGB ink colourants.

The second test chart includes each three colour combination printed both as an in-line, single pass print, as well as a three layer construction with one colour printed per pass. The multi-pass colour swatches were constructed in all possible colour-ordering combinations. With each set of three ink combinations this created six variables in colour order. One can observe the impact of the colour order on the final printed sample. While some colour shifts are subtler, others demonstrate a considerable colour deviation from the in-line print colour. In order to best allow for these observations to be made, the colours generated by multi-pass printing, with variable colour orders, are arranged in a circle around the in-line colour swatch (Figure 3). This arrangement was made for each of the twenty existing three colour combinations.



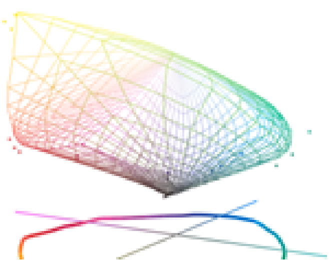


Figures 2 (left) & 3 (right): Excerpts from multi-pass print tests.

3. RESULTS AND DISCUSSION

As a result of the three-pass printing of each individual channel it was observed that the density increased significantly in every channel except the yellow, as shown by comparing the Lab values in Table 1. Additionally the differences in the colour overlays were quite significant. For example, the difference between red overprinted on green and green overprinted on red were quite significant, giving an average ΔE difference of 16.2. The base colour was much more prominent to the final hue than the overprint colour, resulting in the red over green combination presenting a perceptually more red hue in comparison to the green over magenta combination.

Table 1: ΔE Differences for Muli-Layered Primaries.



C - CCC	18.4	C - CC	11.1	C - CCC	7.6
B - BBB	10.7	B - BB	7.7	B - BBB	3.7
M - MMM	11.5	M - MM	7.9	M - MMM	3.8
R - RRR	6.6	R - RR	4.7	R - RRR	2.2
Y - YYY	3.9	Y - YY	2.2	Y - YYY	1.8
G – GGG	16.6	G – GG	10.6	G - GGG	5.6

Combined with the opportunity to exceed the typical 100% density of any single ink colour in producing the final output colour, it has been noted that colour combinations are exceeding the number of colour mixtures that are employed with standard print driver printing. By plotting the colour readings of these swatches generated in the two test charts discussed, it can be observed that a notable amount of the colours generated through this process exceed the lower limits of the colour gamut generated though a standard colour managed workflow (Figure 3). For example, a dark green colour created from multi-pass printing lies outside the colour gamut achievable by the printer's standard workflow, marking the potential for gamut expansion through this process. Further research is underway to begin exploration of incorporating black ink into the colour mixing methodology to investigate potential for colour generation as well as gamut expansion.

Figure 3: Multi-Layered Colour Samples Plotted against Standard Printer Gamut.

4. CONCLUSIONS

The paper describes initial examination into developing methods for testing the available colour gamut in a multi-channel printer as well as exploring alternative means of colour mixing. This was done by designing a series of test charts to evaluate print methods for direct colour input to output on a channel per channel basis. The data analysis for this research was conducted through a series of colour test charts that allow for both qualitative and quantitative analysis. Through this research, by implementing a layering process similar to traditional printing and painting processes, we aim to achieve improved colour output when printing inkjet reproductions of original artworks.

ACKNOWLEDGEMENTS

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Reproduction of Texture in Digitally Printed Artworks

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ABSTRACT

This paper considers alternative approaches to image making and printing that moves from the on-screen representation of images and painting applications, to the physical generation and methods for surface deposition or *2.5D printing*. The research investigates the application of new materials and print processes, as an alternative to four-colour separation and halftoning. This paper describes two routes: the development of photographic continuous tone prints by varying the depth of pigment to create a surface topology, and secondly, the application of pigments that emulates a painting method to create a physical textured surface. Both methods differ from traditional halftoning screening in as much they incorporate a vector approach to image construction. In both cases, the objective is not just to apply an image to an extruded or textured surface, but where the relationship of surface deposition and image are integral.

1. INTRODUCTION

Digitally created images and objects can be printed and fabricated in two and three dimensions and will either involve pixels or vectors to create an image. Each method carries with it different ways of making and thinking, and in some cases has implications in the way the image or artefact is manufactured (Walters, 2009). Enlarging a raster or bitmapped image on screen will show it is composed of millions of coloured pixels. The size, quality and resolution of the printed image are determined by the number of pixels and bit depth: too little and the edges of objects in the print will appear jagged, too many and a large file size could hinder the speed of processing. Zooming into a vector-based file will show that lines, Bézier curves, layers, shapes or text remain smooth with no degradation.

Building on traditional computer aided design (CAD) and computer numerically controlled (CNC) cutting and machining there are more opportunities for artists to work in a vector format. Vector based digital printing technologies, such as 3D printing, additive layer deposition, and 2D design layout (Illustrator) and 3D modelling (Rhino) software means there are more opportunities for the incorporation of surface deposition, texture and more specialist colours (metallic, white, embossing, gloss finishes). With the introduction of 2D UV curing printers, it is also possible to combine colour and texture to create a surface relief.

In the light of recent developments of *post-digital* printmaking (Catanese, 2012) processes, artists' adoption of CNC technologies has increased the range and diversity of image making, artefact construction and a re-evaluation of old analogue processes by hybridising old and new processes, and hacking (earlier but now redundant) 20th century technologies.

A major component of colour reproduction is the accurate reproduction of the appearance of texture (Ashbaugh, 2009; Campisi, 2000), which is a significant area for accurate rendering and synthetic application (for example surface rendering of 3D graphics). However, naturalistic pattern rendering has proven to be more difficult. Where the human visual system is more forgiving in the perception of halftone images, texture is problematic as our visual system can discriminate differences between natural and patterned texture.

The following sections describe two approaches that explore methods for surface deposition or *2.5D printing* (Parraman, 2012, 2013). The first section describes the development of photographic continuous tone prints by varying the depth of pigment to create a surface topology (McCallion, Hoskins), and secondly, the application of pigments that emulates a painting method to create a physical textured surface (Parraman, Cohen).

1.1 The creation of continuous tone photomechanical images using CNC machining

The creation of surface deposition is rooted in 19th century photomechanical print processes, in particular the Woodburytype, which used gelatine to create a continuous tone surface topology. As the Woodburytype print does not have a grain or halftone dot the quality of the image was considered to be superior to the silver photograph. Walter Woodbury's invention came at the end of the developments of photomechanical printing during the 1860's. The concept of the Woodburytype follows the same method as a carbon print. (Anon, 1883) The carbon print process is described, as a "*photorelief of tinted gelatine, its maximum thickness being in the deep shades and this relief is ordinarily attached to the surface of a sheet of paper or a plate glass. The highlights of the picture are those points where the layer of gelatine is either altogether wanting, or possesses a minimum thickness.*"

There also evolved a family of processes that either used the translucency of the stepped thickness (cameotypes, photo-lithophanes) or where a translucent glaze applied to a bas-relief stepped ceramic (photo-ceramic relief) that translated the depth into tones. (Atkinson, 2003) Methods to recreate these processes – to translate a 2D tonal range to produce a 3D stepped physical relief – by digital means have been explored by Atkinson (2004), Huson (2005) and McCallion (2012) using CNC routing and rapid prototyping.

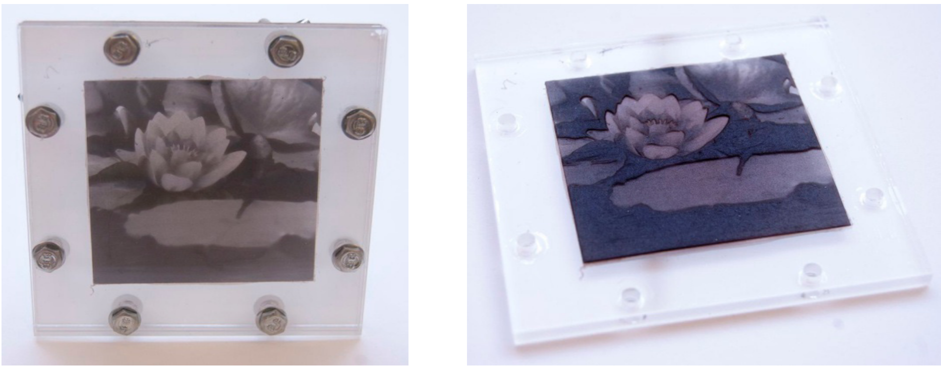

Fig. 1: Silicone duotone (2013) backlit, showing a range of tones (left) and surface relief (right)

McCallion's approach has involved the translation of a standard 8-bit greyscale image into a 256 incremental gradation, where at the two extremes, 0 is visually represented as black, and 255 is represented as white. The image is processed firstly in Adobe Photoshop, and then using 3D software (Rhino) a physical height is assigned to each grey. The result is a height field that looks similar to a traditional bas-relief. Once the heights are generated, the data is output through CNC part programming software (Mayka) to a CNC milling machine. The height that is assigned to the 256 shades of grey is determined by the CNC milling machine's cutting bit. The total height of the block from its darkest (deepest) to lightest (highest) point is 1mm. Instead of the traditional 19th century gelatine, silicone was considered by McCallion to be a 21st century alternative. The material and curing qualities of the silicone means that a colour tint can be added but retains translucency, does not shrink during curing, is non-toxic and produces no fumes when mixing. Figure 1 shows the cast image and the physical surface relief.

1.2 The development of vector based 2.5D print methods for a painting machine

The project, led by Parraman, was motivated by painting and rendering programmes and the need to providing meaningful interaction between software, the printed output and the viscous properties of the medium. Software such as Corel® Painter™, Autodesk® Sketch Book Pro for iPad, Brushes by Taptrix inc. simulate the appearance of drawn marks and brush strokes, paper and canvas textures, oil or watercolour. These examples highlight opportunities for manipulating virtual paint. Tangipaint is an interesting touch-screen paint mixing application, developed at RIT that creates the appearance of gloss, wetness and the texture of paint. (Ferwerda, 2012) By *painting* on touch-screen devices or drawing tablets the user can scroll to select colours and brushes and manipulate paint. The assumption is that images remain screen-based or are shared between mobile platforms.

Inspired by the meticulous painting methods by artists such as Van Gogh and Seurat, the objective for the experiment was to create a vector-driven painting machine that applies a brush loaded with paint to paper in a methodical and mechanical way. The difference was that although the vector marks (digital) could be created in the same way, the resulting painted brush strokes (analogue) were not. Based on the placement of the brush on the paper and the flow of paint, each painted brush stroke was similar but not exactly the same, thus creating a non-uniform but harmonious effect across the paper surface.

The paint deposition experiment was performed on a modified Roland GX24, CAMM-1Servo. Originally designed as a plotter for cutting vinyl, it has an x and y-axis and solenoid to obtain z-axis. The cutting blade was replaced with a prototype brush holder with a screw-thread for accommodating brushes of different sizes.

Fig. 2: Selection of paint brushes and nibs (left). An example of a 7mm cork stylus (right).

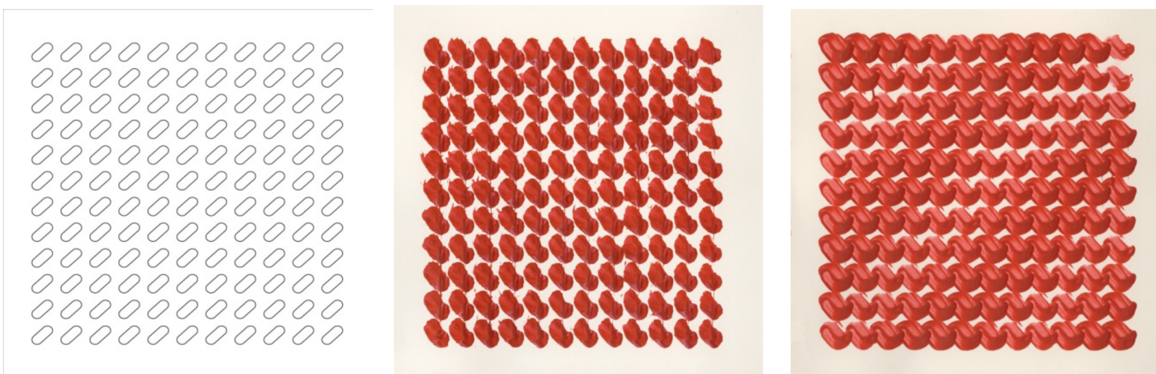

Fig. 3: Vector template from library (left), showing two different variations, using a brush (centre) and the 7mm cork stylus (right) as shown in Figure 2.

A series of different shaped brushes and nibs (Figure 2) were formed around a hollow 14-guage tip (more commonly used for dispensing glue) that has a Luer thread lock. Each brush could easily be removed and interchanged. The hollow centre meant that paint could be pumped through a rubber tube and the brush then applied the paint to the paper. The paint was dispensed from a syringe under vacuum and pumped through flexible rubber tubing to the paintbrush at the other end. In order to ensure a smooth continuous flow, the paint was pumped using a peristaltic variable flow pump.

As demonstrated in Figure 3, a library of vector lines were created in Adobe Illustrator, where each component could be modified, enlarged, rotated or removed. This example is part of a library of hand-drawn or imported vector-based patterns that could be copied, cut and pasted into a drawing. In figure 3, the test is used to compare the character and behaviour of paint, brush and mark at different flow rates. The speed and pressure of the brush remained constant, but for each test the flow rate could be modified.

2. CONCLUSIONS

As more images and objects are constructed in a vector format, there is an increasing requirement to develop universal file formats that assists in the conversion between analogue and digital, raster and vector, two and three dimensions, that works towards standards in additive manufacturing. (http://www.astm.org/Standards/F2915.htm). This approach could lead to improved opportunities for file transition between 2D and 3D formats in both directions.

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Determination of a Reduced and Non-redundant Measurement Geometry Set to Completely Characterize Colour Shift of Special Effect Coatings

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ABSTRACT

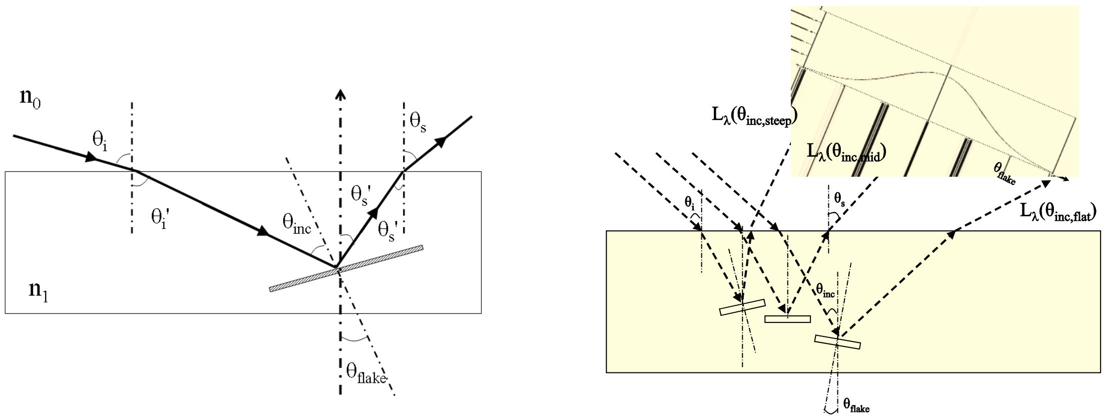
A reduced set of measurement geometries allows the spectral reflectance of special effect coatings to be predicted for any other geometry. A physical model based on flake-related parameters was used to determine non-redundant measurement geometries for the complete description of the spectral BRDF. The analysis of experimental spectral BRDF was carried out by means of Principal Component Analysis (PCA). Resulting from this analysis, a set of nine measurement geometries is proposed to characterize special effect coatings. It was shown that, for two different special effect coatings, these geometries provide a good prediction of their complete colour shift.

1. INTRODUCTION

Coatings with special-effect pigments create the illusion of optical depth and present an eye-catching effect of angle dependent colour. The increasing popularity of these coatings demands the development of new techniques and instruments to characterize the spectral reflectance and the colour as a function of the different irradiation/viewing geometrical configurations, and for different illuminants and real light sources. Full knowledge of the spectral bidirectional reflectance distribution function (BRDF) of these coatings makes it possible to infer the coating colour for any geometrical configuration (irradiation and viewing directions and solid angles) as well as for any irradiation spectral distribution. The problem to be faced is that, given the complex spectral reflectance these coatings have, it is not clear which measurement geometries should be used in order to fully characterize them. The aim of this work is to find a reduced set of measurement geometries allowing the spectral reflectance (and, therefore, the colour) for any other geometry to be predicted, regardless of the special effect coating. This, in turn, should help manufacturers to design instruments leading to a more accurate characterization of the spectral reflectance of special effect coatings, and it should provide some potential applications in optical formulation and digital rendering for computer graphics.

2. METHOD

In order to choose an efficient strategy to measure a variable quantity, something has to be known about the structure of this variability. Specifically, a general analytical model for the spectral BRDF of special effect coatings has to be the starting point to determine a reduced and non-redundant measurement geometry set to characterize it. A model based on a flake-based physical interpretation (Kirchner 2012) was chosen for this purpose (see Figure 1).



(a) (b)

Figure 1: (a) Geometrical variables to describe the reflection mechanism. (b) Scattering of the optical radiation due to the disorientation of the flakes. L_l is the spectral radiance.

The interferences produced in the flakes, which depends strongly on the incidence angle θ_{inc}, are the main responsible of the high colour shift observed in these coatings. For this reason, it is important to express the spectral BRDF model in terms of the pair [θ_{inc}, θ_{flake}] (where θ_{flake} is the disorientation of the flake respect to the coating's surface plane) instead of the pair [θ_i, θ_s] (measurement irradiation and viewing angles, respectively, respect to the coating's surface plane). It has to be noticed for a given pair (θ_i, θ_s), there is a unique pair (θ_{inc}, θ_{flake}), or, in other terms, at a specific measurement geometry, equivalently oriented flakes are assessed. Taking into account the considerations of this model, the spectral BRDF [$f_r(l)$] of a special effect coating can be written as the following simplified expression:

$$f_r(\lambda) = f_{r,0}(\lambda, \theta_i, \theta_s) + D(\theta_{\text{flake}}) f_{r,\text{flake}}(\theta_{\text{inc}}, \lambda) \tag{1}$$

where $f_{r,0}(l, \theta_i, \theta_s)$ represents the completely or partially diffuse reflection produced by the usual mechanisms (it does not depend on the orientation of the flakes), $f_{r,\text{flake}}(\theta_{inc}, l)$ represents the gonioapparent reflection produced by a representative special-effect pigment and $D(\theta_{flake})$ is the distribution of the disorientations of the flakes respect to the coating's surface plane (see Figure 1.b). The strong colour shift observed in these coatings is due mainly to the second addend $D(\theta_{flake}) f_{r,\text{flake}}(\theta_{inc}, l)$. The distribution $D(\theta_{flake})$ is expected to be Gaussian, showing a peak for the horizontal orientation ($\theta_{flake} = 0º$). In the other factor, $f_{r,\text{flake}}(\theta_{inc}, l)$, it is included the spectral reflectance of the interference pigments at different incidence angles [a more explicit inspeciton of this factor can be found in (Ferrero 2013)]. In order to determine the colour shift, these two factors have to be characterized. The strategy to accomplish this task is to choose a set of measurement geometries to sample $f_r(l)$ at uniformly distributed θ_{flake} angles to determine $D(\theta_{flake})$ (while keeping a small θ_{inc}) and at unifomly distributed θ_{inc} angles to determine $f_{r,\text{flake}}(\theta_{inc}, l)$ (while keeping a small θ_{flake}). By construction, this procedure provides a complete characterization of the colour shift, regardless of the specific special effect coating. Nine geometries were chosen according to this criterion and shown in Table 1 for a binder's refractive index of 1.5, which is correct for most effect-coatings.

Table 1. Measurement geometries to characterize the colour shift of special effect coatings.

	1	2	3	4	5	6	7	8	9
θ_i(º)	20	20	20	20	20	50	50	50	50
θ_s(º)	30	10	0	10	30	70	30	30	70
ϕ_s-ϕ_i (º)	180	180	0/180	0	0	180	180	0	0
θ_{inc}(º)	16,3	10,0	6,6	3,3	3,2	34,7	25,0	5,6	4,0
θ_{flake}(º)	3,1	3,3	6,6	9,9	16,3	4,0	5,6	25,1	34,7
θ_{asp}(º)	-10	10	20	30	50	-20	20	80	120

Once the spectral BRDF measurement is carried out for these nine geometries, the question is how to know the spectral BRDF for any other geometry. We suggest a Principal Components Analysis (PCA)-based interpolation. The procedure consists of expressing Eq. (1) as linear combination of addends in the way:

$$f_r(\lambda) = a_0(\theta_i,\phi_i;\theta_s,\phi_s) f_{r,0}(\lambda) + D(\theta_{\text{flake}}) \sum_{j=1}^{n} a_j(\theta_{\text{inc}}) f_{r,j}(\lambda) \tag{2}$$

and relating the addends to the addens of the linear combination obtained from applying the PCA to the experimental data (Ferrero 2011, Ferrero 2012):

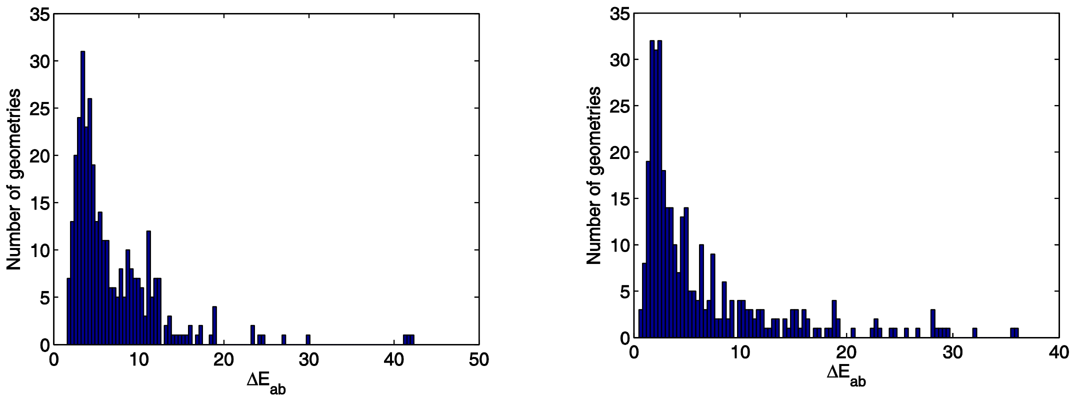
$$f_r(\lambda) \lessdot \;\; f_r(\lambda) >_{\lambda} \left(1 + \sum_{j=1}^{N} c_j(\theta_i,\phi_i;\theta_s,\phi_s) H_j(\lambda) \right) \tag{3}$$

3. RESULTS AND DISCUSSION

The performance of this procedure was assessed for two different special effect Colorstream coatings: Arctic Fire and Lapis Sunlight (Ferrero 2013). The spectral BRDF measurement were carried out with the Spanish Goniospectrophotometer (GEFE) described in (Rabal 2012), sampling at combinations of θ_i and θ_s (which take values ranging from 0º to 70º, at steps of 10º), ϕ_i (which takes only the value 0º) and ϕ_s (which takes values ranging from 0º to 180º, at steps of 30º). Using only the measured spectral BRDF at the geometries at Table 1, D(θ_{flake}), $f_{r,j}$ and a_j, were calculated by combining Eqs. 1 and 2. This calculation allows the spectral BRDF at other geometries to be calculated and be compared to the measured spectral BRDF. Histograms of the colour differences DE (D65 illuminant, 2º observer) between the measurement and the estimation for Arctic Fire and Lapis Sunlight are shown in Fig. 2. Most of the differences are below 5, while the highest differences are found for geometries were θ_{flake} is very small; that is, close to specular geometries.

4. CONCLUSIONS

A methodology to find a reduced set of measurement geometries to characterize the colour of special effect coatings is proposed. It is based on a physical model for the spectral reflectance of these coatings, which suggests that the spectral BRDF has to be expressed in in terms of the pair [θ_{inc}, θ_{flake}] (orientation of the flakes respect to the light) instead of the pair [θ_i, θ_s] (orientation of the coating respect to the light). Nine measurement geometries are proposed as a reduced set of geometries. A PCA-based procedure is proposed to interpolate at any other geometry. The viablility of this method was proven with experimental measurements of spectral BRDFs of two special effect coatings (Colorstream coatings: Arctic Fire and Lapis Sunlight).



(a) Arctic Fire (b) Lapis Sunlight

Figure 2: Histograms of colour differences between the measurement and the estimation from the nine proposed geometries. The binning is 0.4.

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Colour and Texture Appearance Modelling of 2.5D Prints

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ABSTRACT

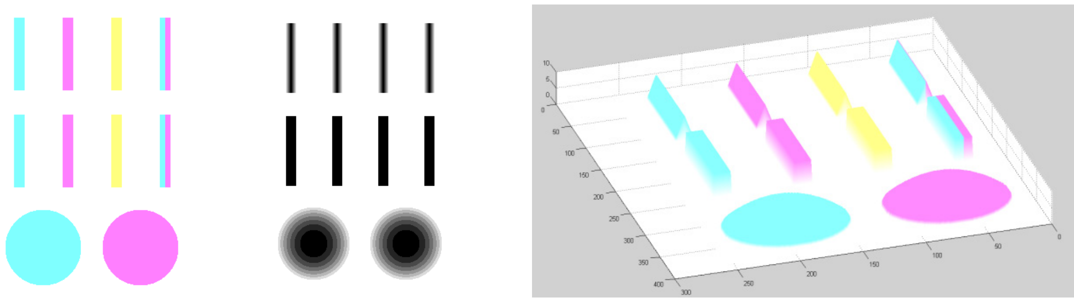
Printing images with details on relief (2.5D or relief prints) is an upcoming area in digital printing. The appearance of such 2.5D prints depends on the angle of illumination and orientation with respect to the observer. Understanding the changes on the perception of colour and textures of relief prints when they are lit or viewed from different directions is important to model their overall appearance. Such information can be captured by reflection distribution functions. Devices currently used for measuring local surface texture and reflection functions are not easily available and they often lack of colour information. Previous studies showed how a flatbed scanner can be used to measure 3D structures (Pintus et al. 2009). Our study demonstrates how Pintus' method can be applied to scan the surface texture of relief prints. As an extension of the setup proposed by Pintus, a case study is presented where the glossiness of different samples was estimated based on the specularity of the measured reflection distribution functions. By capturing a sample of the reflection distribution function, this method would allow an estimation of the Bidirectional Reflectance Distribution Function (BRDF). Furthermore, the reflection data can be used for print quality evaluation and colour apperance modelling.

1. INTRODUCTION

In Océ, through the use of two prototype printers, relief is created by printing multiple layers of ink that could be combined with special inks and varnish in order to create different effects and levels of glossiness on desired locations. An example of such a print task, based on a top view colour appearance and texture map, is shown in Figure 1 along with a 3D simulation of the actual printout. The bar on the right hand side of this print is composed of a cyan-coloured left side and a magenta-coloured right side which creates a different appearance when either viewed or illuminated from the left or right side. This shows how the combination of texture and colour can strongly influence the visual perception of relief prints.

The extra dimensionalities of texture and a spatially varying level of glossiness come with the challenge of evaluating the overall quality of these relief prints. In the research field of 3D quality metrics, evaluation is mostly based on combining metrics of 2D representations from the 3D image (e.g. for different illumination and viewing conditions). Although this approach is easily applicable with current metrics for 2D images, studies (e.g. Seuntiens 2005) have shown that due to the extra dimension of depth, the overall perceived image quality is not consistent with the quality measures based on 2D views.

As a first step to evaluate 2.5D prints, we could use a technique to measure their reflectance properties and create a model of the visual appearance of the prints for different environments. In our research, the reflectance properties are measurements of colour, surface normals (texture) and the degree of glossiness/specularity.



(a) (b) (c)

Figure 1: Illustration of 2.5D print with input of top view colour appearance (a), texture map (b) and simulation of 2.5D printout (c).

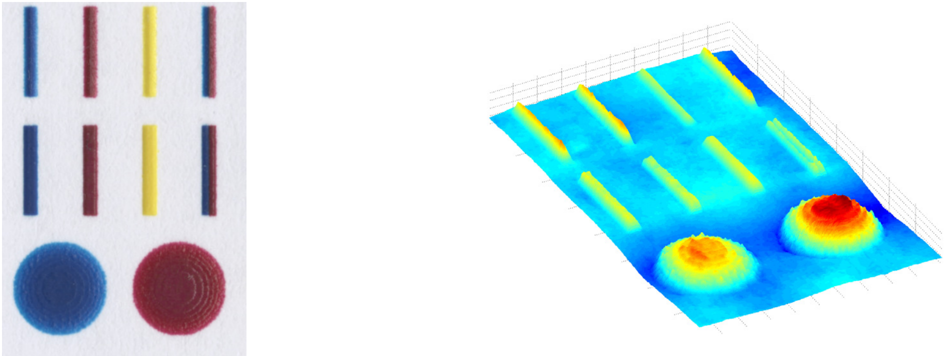
2. USING FLATBED SCANNER FOR 2.5D PRINT EVALUATION

Light reflection models used for colour appearance modelling require information of surface orientation (surface normals or actual height information, texture), parameters of colour dependent reflection and the specularity of the reflection. Currently, different techniques exist for texture measurement with the major disadvantage of using hardly-available equipment that may provide low resolution information of texture. Moreover, colour information and local reflectance distribution functions are often not retrievable. Here we describe our implementation of measuring surface texture characteristics using a flatbed scanner as an extension of the work done by (Pintus et al. 2009).

2.1 Measuring reflection properties and texture of relief prints

A flatbed scanner is suitable for measuring reflection properties due to its fixed angle of illumination which is not orthogonal to the scanned surface. This is evident for the scan of the printout from Figure 1 shown in Figure 2(a), where the sample is lit from the right, with a 15˚/0˚ geometry. In our implementation the result was combined with another scan where the sample was rotated over 180˚, and therefore lit from the opposite side. This photometric stereo approach enables the retrieval of the surface normal vectors of the sample.

Our setup consists of an inexpensive home scanner of which the glass cover was removed (to avoid possible distortions) and placed upside down over the sample. The RGB values of four different scans (each rotated over another 90˚) were gamma-corrected and converted to the CIEXYZ colour space from which the Y value was considered as the linear reflectance value for each pixel. Image registration was performed and per-pixel brightness differences were compared. As a way of simplifying our model, we assumed the surface to have Lambertian reflection properties. Each pixel p of the surface is described by the local surface normal $\mathbf{n_p}$ and the intrinsic diffuse reflection coefficient ρ_p. For each scan i, the illumination can be described by $\mathbf{s_i}$, which we assume is constant for every pixel in the surface. The perceived brightness $Y_{p,i}$ (which is image and pixel dependent) can be approximated by a simple model for the light reflection, where $Y_{p,i} = \rho_p \, \mathbf{n_p} \cdot s_i$. In our case, with four illumination directions, we recomputed the surface normal vector $\mathbf{n_p}$ as a linear least square solution using the four illumination directions $\mathbf{S} = [\mathbf{s_1}\ \mathbf{s_2}\ \mathbf{s_3}\ \mathbf{s_4}]$ and measured brightness values $\mathbf{Y_p} = [Y_{p,1}\ Y_{p,2}\ Y_{p,3}\ Y_{p,4}]$, by $\mathbf{n_p} = (\mathbf{S^T S})^{-1} \mathbf{S}\ \mathbf{Y_p}$.



(*a*) (*b*)

Figure 2: Scan (a) of printout from Figure 1 using flatbed scanner (illuminated from the right) and resulting texture map (b) after combining scans varying illumination direction.

In order to evaluate the printing process, the resulting surface normals can be compared to the expected surface normals from the input image. Another possibility for evaluation is to derive the surface height map from the surface normals. Figure 2(b) shows the result of an implementation that could be used to estimate the differences to the input height map of Figure 1. The surface colour reflectance ρ is calculated based on the surface normals and illumination direction. Note that this approach assumes non-specular behavior of the print, which is not always realistic, a more developed model and an increased number of illumination directions could be used to improve the results.

2.2 Glossiness measurement

The same property of the flatbed scanner, where the illumination is fixed under a fixed angle based on its design, can be used to measure the reflectance properties of some prints. Therefore scans of the printout for different orientations are performed and resulting reflectance profiles are combined to estimate its reflection properties. Three possible approaches are considered:

- Measuring isotropic reflectance properties: by combining scans parallel to the scan surface with different angles of rotation (as described in previous section)
- Measuring specularity of reflectance: by varying the distance between the sample and the flatbed scanner, as a result, images are obtained with a fixed angle of measurement and varying (decreasing) angles of illumination
- Measuring specularity of reflectance: by changing the angle between the sample and the flatbed scanner, for the acquired images, the angle of measurement and the angle of illumination vary simultaneously.

We performed a case study where the reflectance of ten samples was measured. Each sample showed different specular reflection in a range from matt to glossy, previously used in research by (Obein and Viénot 2007). The measured reflectance values are shown in Figure 3 for different angles of measurement and detection. The results show only a small sample of the BRDF, not sufficient for a full characterisation, but different specularities were easily distinguishable.

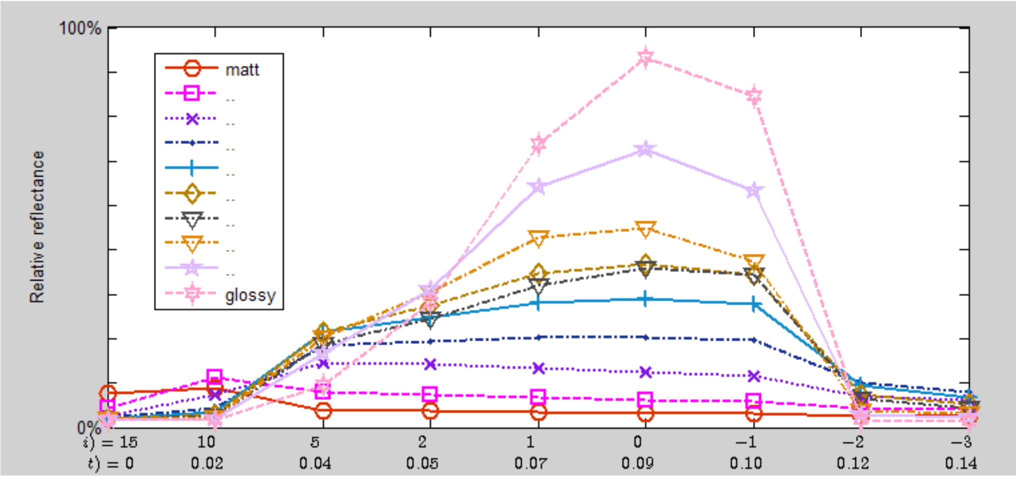


Figure 3: Graph with measured reflectance values of 10 patches in range from matt to glossy for different angles of illumination i) and measurement t).

3. CONCLUSION AND DISCUSSION

We described a method of measuring the surface texture and reflection properties of 2.5D prints using a readily available flatbed scanner with the goal of modelling their appearance. By performing scans with different orientation with respect to the device, the appearence for different illumination and measurement directions is obtained and then combined to result in an estimate of the surface normals and reflection parameters that can be used for appearance modeling. The early stage experiments showed the ability of the method to scan texture and measure the specularity of glossy samples. Future work could focus on combining measurements of surface texture and glossiness to better understand the correlation between the two.

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Color Reproduction Accuracy of Digital Printing in Oman

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ABSTRACT

This work is concerned with process of color management in digital printing for propose of realization of high accuracy in color printing process with the aim to realize what you see is what you get. Studying of color deterioration problems should help better to correct the process of color reproduction. It's known that the color deterioration through process of digital printing strongly affects the precision of color printing. This work manly aims to study the problem of color deference between input and output in the college print-lab. One of the major causes of such a problem is that the different students have to process of device color profiling differently. Normally the end product should deviate slightly from the original design. Our aim is develop a method to minimize such differences between final outputs of the individuals. A reference profile maybe created to deal with such a problem. Each student should refer to such a profile as a final reference to those of the designs made by different students. The second factor, which affects the accuracy of color reproduction, is the difference between individuals concerned with their monitor color settings at the stage of color judgment of the final Design or Artwork. Comparison between the color differences ΔE before and after correction is determined and corrected ICC standards. Also our research project is to look at what is currently being done with regard to color matching between media in higher education and to develop a resource that can be used to raise students' teaching process of all aspects of color in the digital print process, as a result of better equipping them to work productively with digital printing.

1. INTRODUCTION

In digital imaging systems, color management is the controlled conversion between the colors Representations of various devices, such as image scanners, digital cameras, monitors, TV Screens, film printers, computer printers, offset presses, and corresponding media. This abstract is a case study of colour management for digital printing in an academic environment in Oman using the ICC framework. In order to study Color in this academic environment we studied the printer's color gamut. The color gamut for printer is the volume of the color solid defined colorimetrically produced by a particular set of ink and paper, which contains all the colors that the printer can produce. The color gamut is affected by many factors including the ink formulation, printing process, substrate and halftoning. In this paper we will concentrate to study the reason of a huge color shift from the original image until the final print out.

In this paper we studied the reasons of color errors in our academic environment. First we calculated the average ΔE $L^*a^*b^*$ for the samples, then analysed the results in order to determine the reasons of this color error.

2. METHOD

The experimental method will be taken in this paper; a standard target reference will be printed out and measured to calculate ΔE before making any change. Then reprint the same target reference with the appropriate color method to increase overall ΔE.

2.1 Test Preparation

The parameters of the digital printing were optimized based on a modified HP Color Laserjet CP1515n laser printer. The inks used were CMYK process ink set. Samples were printed on hp photo quality laser glossy paper. The spectral reflectance of this paper was also used as the reflectance of the substrate in the printing process. The performance of the printer model was evaluated according to this printer and its CMYK ink set. 55 test samples were printed and their reflectance was measured using a high-accuracy spectrophotometer. Colorimetric Values were calculated for Illuminant D50 and the CIE 1931 2° standard observer.[2]

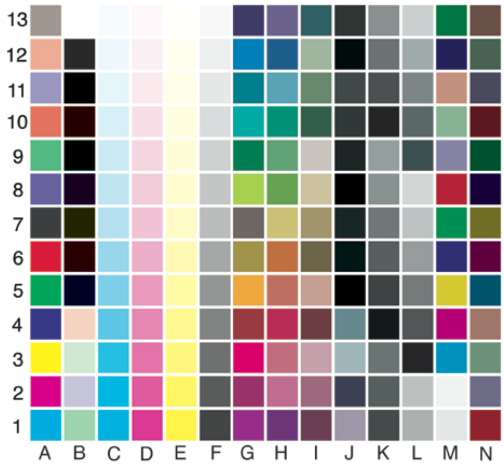

Figure 1: Flowchart illustrating the process of sample preparation.

2.2 Subjective Experiment

Although we recommend having a monitor profile produced by measurement, we created monitor profile by eye using ColorSync Utility (Mac OS) or Adobe Gamma (Widows). This allows our students to set the color temperature for their own display and gamma values. A key point is setting color temperature – the D50 graphic arts standard looks quite dull and yellow, but D65 is an acceptance value. Anything higher will look too blue and won't help in color comparisons. A 6500 monitor white point setting and 5000K viewing light for hard-copy work quite well, despite not being exactly the same color temperature.

Because we have mixed OS environments (Mac OS and Windows), so we recommend that Mac users can set their screen gamma to 2.2. A gamma of 2.2 is the same as on PCs, but colors managed applications like Photoshop will take into consideration system-level gamma settings to show images using the monitor profile – an image viewed on similar screens but with different system gamma settings will appear very similar.

3. RESULTS AND DISCUSSION

Eight different experiments was optimized to test the most used color adjust variables from the students. The values of ΔE are shown in (Table 1). As in the results the general color difference was too high, this can be considered from different factors.

Table 1. Summary of ΔE Values from the 8 experiments.

No.	R	G	B	C	M	Y	K	Gray	Average
Test1	22.3	19.5	20.5	12.5	13.5	12.5	10	12.5	15.4
Test2	22	25.3	15.8	9.1	12.5	32.5	10	2.5	16.1
Test3	22.5	20.5	16	15	8.7	16	10	5.7	14.3
Test4	24.8	22.3	18.3	17	9.9	24.1	13	5	16.3
Test5	24	24.8	14.1	16.8	11.5	1.4	12	2.7	15.2
Test6	22.7	22	21.1	17.5	23.8	22.5	10	1.6	18
Test7	24.9	27	16.2	18.6	8.8	16	9.8	1.1	15.2
Test8	20.5	29.7	18.7	17.6	16.9	26	9.6	10.9	18.7

Test1: Profile (U.S. Web Coated (SWOP) v2)

Test2: Profile (U.S. Web Coated (SWOP) v2) with simulation of black Inks

Test3: Profile (Printer Profile with normal printing conditions)

Test4: Profile (Printer Profile with working CMYK output)

Test5: Profile (Coated FOGRA27 (ISO 12647-2:2004))

Test6: Profile (Coated GRACoL 2006 (ISO 12647-2:2006))

Test7: Profile (Euroscale Coated v2)

Test8: Profile (Euroscale Coated v2) with simulation of black Inks

we used the CIE1978 equation to calcualte the ΔE values.

4. CONCLUSIONS AND FURTHER WORK

We made a simple scope to test each of the elements involved in the color quality of digital printing in a more detailed: the hardware and software used to create a digitally-printed product; and how these elements interact to manage color throughout the process. The further stage of this study will concentrate on digital printing at this educational environment, with stuff and students to be interviewed to understand their experiences of the digital print component in the course outline. Also input from industry will be obtained throw some questionnaires and interviews. This will provide a useful insight into what industry professionals consider to be essential knowledge regarding color in digital printing and will help to build a view of what expectations there are for graduates. Once the results have been analyzed, it is expected to have a model to add in the graphic design degree. For further study we recommend to solve this problem by establishing a professional colorimetry laboratory, which the college can depend on in any quality control color reproduction.

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The Effect of Media Interactions in Predicting Spectral Reflectance by Color Prediction Models

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ABSTRACT

Existing semi-empirical color prediction models (CPMs) are based on color measurements and mathematical optimization of model parameters. But little efforts have been spent on relating the influence of the actual physical properties such as lateral light scattering, ink spreading and absorption. The aim of this study is to relate the modelling to actual physical properties of the printed samples. By this approach, a more comprehensive understanding of the interaction between light, paper and ink is obtained. Furthermore, by building models on physical properties not only the performance of a particular system is achieved, but also the influence of the components used. In addition to Murray Davies model, the most important dot gain effect was included through actual determination of the physical printed dot size by analyzing transmitted and reflected halftone microscale images. For the experimental part a multichannel inkjet printer, a set of different color inks and paper grades were used. Finally the reflectance prediction accuracy of some common CPMs was evaluated. The results show a relation between model parameters and print media. The advantage by determining the physical dot size is a closer relation between print result and physical properties, as well as opportunities to develop alternative modelling approaches.

1. INTRODUCTION

The key technique of spectral color printing system is to combine multi colorants, in such a way, that the printed image has similar spectral reflectance as the original scene. The printed products thus would produce consistent colors in different viewing conditions. To achieve spectral color printing multi-colorant high resolution printers can be used. Moreover, the media (ink/substrate) properties must be considered as they might play the most significant role in achieving correct response (Norberg and Andersson 2003). Hence, a particular arrangement of inks, substrate, printer and printer model determines the color fidelity and color matching results. In this workflow, the spectral reflectance of *m* colorants combination is predicted by the forward printer model. The substrate receives and holds color creating components *i.e.,* inks. Depending on the properties and mechanical interactions, inks are absorbed into the substrate and spread at the surface creating dot deformation and thus mechanical dot gain (MDG). Another significant phenomenon is the lateral light scattering introducing optical dot gain (ODG), where the ink dots appear larger than intended (Gustavson 1995). The total dot gain (TDG) thus including both effect influences performances of color prediction models (CPMs). The standard CPMs (Wyble and Berns 2000) emulate this behavior of the system by fitting parameters to measured reflectance of color patches. However, this study investigates if there is any improvement with physically determined model parameters. Hence, this work includes an experimental setup and method to analyze the dot gain (DG) phenomenon for different types of paper and ink. In addition, current approach of estimating DG by Murray Davies (MD) and Yule Nielsen (YN) models have been compared. After compensating DG, the forward spectral Neugebauer (sNG) and YN modified sNG (YNsNG) models have been evaluated. The results show dependency on light scattering (S), absorption (K) and ink density (D).

2. METHOD

2.1 Materials

Canon ImageGraf ipf 6400 12 channels ink jet printer with a subroutine to avoid any color processing was used. The print resolution was 1200 *dpi*, screen frequency 150 *lpi* and AM halftoning was applied. Three commercial papers were chosen: *Canon Photo Paper Plus Glossy II* (Paper1), *Canon Matte Photo Paper* (Paper2), and *4CC uncoated 260 g/m^2 paper for color printing* (Paper3). To analyze DG, patches for each of Cyan (C), Magenta (M) and Yellow (Y) ink with reference coverage 0-100% in step of 5% (excluding 35, 65% and including 2 and 98%) were printed in each paper. For evaluating the prediction accuracy of CPMs, new set color patches with C, M and Y ink in combination of 0, 25, 50, 75 and 100% were printed. *GretagMacbeth Spectroliono* spectrophotometer was used with UV filter and D50 illumination to measure the reflectance. For capturing the microscopic images of half-tone dot pattern, both in reflectance and transmittance mode, the set up in Figure1 was employed. The set up has an *Olympus BH2* optical microscope, three light sources to illuminate samples from upside (reflectance mode) and downside (transmittance mode). The light from the sample goes through the microscope to a digital CCD RGB camera (*Canon EOS 7D*) which has 14-bit depth and spatial resolution 2592 × 1728. The viewing area is 1.5 mm × 1 mm which corresponds to 0.57 µm in each pixel.

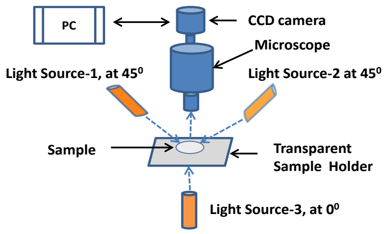

Figure 1: *Microscope-Camera set up for reflectance and transmittance imaging.*

2.2 Microscale Image Analysis (MIA)

The captured images had sRGB color information which was converted into CMYK space. By applying a global threshold in corresponding ink color plane the image was segmented. The image initially included a white part of the paper outside the dot area in order to make the thresholding more efficient. After segmentation, the image was cropped into (1 mm^2) size discarding the outside white stripe. From the segmented image, the number of foreground pixels was counted, and calculated the fraction of total area they covered. The calculated fractional area is the effective coverage (EC), and subtracting from the known reference coverage, the TDG was obtained from reflected images. The same procedure gives MDG in transmitted images, assuming that there is no ODG. The difference between TDG and MDG gives the ODG.

2.3 Use of Color Prediction Models (CPMs)

DG Estimation — Let is the fractional ink area coverage, and are the spectral reflectance of 100% ink coverage and of the paper, respectively, as functions of wavelength λ. Then the predicted spectral reflectance by *Murray Davies Model (MD)* is

$$\hat{R}_\lambda = a_i \, R_{\lambda,100i} + (1 - a_i) R_{\lambda,P} \qquad (1)$$

Replacing $\hat{R}_\lambda$ by measured reflectance, by the EC (a_{eff}), Eq. (1) was used to estimate the EC for different reference coverage (a_{ref}). Then TDG was obtained as ($a_{eff} - a_{ref}$).

Adding an exponential *n-factor* to compensate for the lateral light scattering, *Yule-Nielsen Model (YN)* is defined as follows.

$$\hat{R}_{\lambda} = \left[a_{eff}\, R_{\lambda,100i}^{1/n} + \left(1 - a_{eff}\right) R_{\lambda,P}^{1/n}\right]^{n} \tag{2}$$

The YN corrected EC was estimated by an iterative approach, minimizing the difference between measured and estimated reflectance, changing the n-factor in Eq. (2). In this process, the initial a_{eff} was estimated by MD model (i.e., n = 1), and a_{eff} were updated each time to get the best n-factor (Wyble and Berns 2000). The spectral root mean squared (sRMS) error was used as the optimization metric.

Reflectance Prediction Accuracy — The descriptions of *spectral Neugebauer (sNG)* and *Yule Nielsen modified spectral Neugebauer (YNsNG) models* are available in the classical study (Wyble and Berns 2000). These models were evaluated by giving DG compensated colorant coverage. However, in the current study, 8 Neugebauer Primaries (NPs) were chosen which are the reflectance spectra from 100% of C, M, Y, C over M (Blue), C over Y(Green), M over Y(Red), CMY (Black), and paper white.

3. RESULTS AND DISCUSSION

DG Analysis — The average rms differences between estimations of DG by MD model and MIA (reflected) are 1.4%, 1.5% and 1% for Paper1, Paper2 and Paper3, respectively. Figure2 illustrates TDG, MDG (dotted line) and ODG (dashed line) behavior for Y ink.

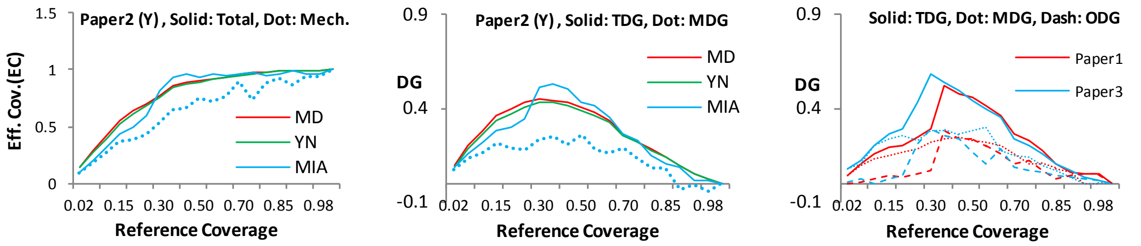

Figure 2: (Left) EC vs. the methods, (middle) corresponding DG, (right) DG by MIA.

For Y ink the highest MDG and ODG (see Figure2, Right) is for paper3 (uncoated high grammage) having S (62.59 m²/kg) and K (0.62 m²/kg). The lowest DG is for Paper1 (glossy coated) having S (37.27 m²/kg) and K (0.12 m²/kg). Furthermore, the Y ink density D was in paper3 (1.22) and Paper1 (1.65), which means ink absorption is higher in paper3. So measured DG was in accordance with the physical properties of the papers. Prediction Performance Figure 3 shows the accuracy of reflectance prediction by sNG model without (-DG) and with variously corrected DG. In general, all approaches have almost similar accuracy for high colorant coverage (>50%). For MIA, the worst and best accuray was for C (D=2.08) and Y (D=0.98), respectively, in paper2.

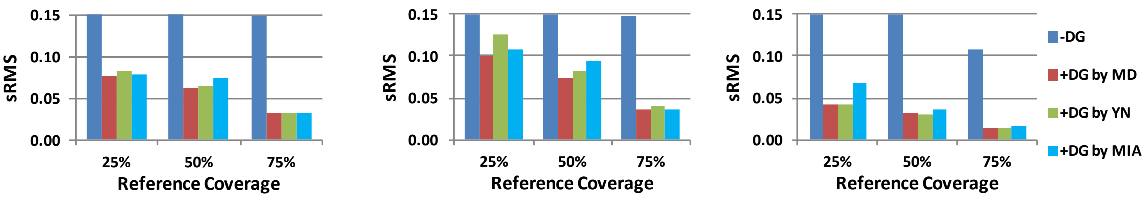

Figure 3: sNG accuracy; Left (Paper1, C), Middle (Paper2, C) Right (Paper2, Y).

The overall performance further improves by inroducing n in YNsNG model (Figure 4). Starting from 1, the n-factors were determined by optimizing sRMS (<0.04) errors.

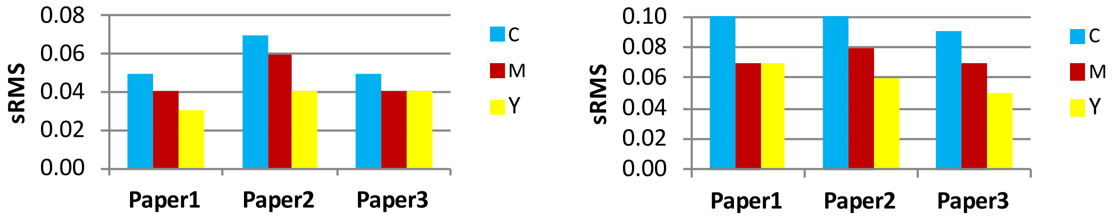

Figure 4: YNsNG accuracy with compensated DG; (Left) by MD, (Right) by YN.

Figure 5 shows the spectral and colorimetric errors with corrected DG and n-factors determined by MIA approach. The n-factors were in order of C, M, Y in Paper1 (1.7, 1.4, 2.4), Paper2 (1.6, 2.2, 1.8) and Paper3 (1.7, 2.4, 1.6). The average difference between model based approach and MIA was 1%. But for any approach the best accuracy was found for Y ink (average D=1.35) and worst for C ink (average D=1.50).

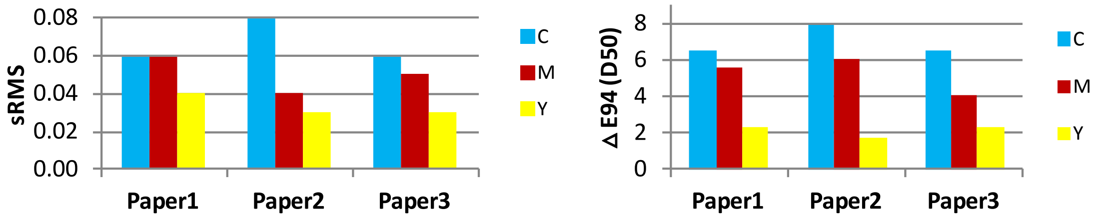

Figure 5: YNsNG accuracy; MIA compensated DG and n-factors.

4. CONCLUSIONS

The dot gain behavior of C, M, Y inks on 3 different paper grades was studied by microscale image analysis and correlated with physical properties of the media. By correcting dot gain, YN model was used to calculate the n-factor for each ink/paper. In addition, common semi-empirical method was also implemented to estimate dot gain and corresponding n-factors. All these parameters were used to evaluate two spectral color prediction models seperately. The factors that affected the prediction accuracy are light scattering, absorption and ink penetration properties. The results show multi-colorant spectral printing can be improved by choosing individual n-factor instead of using an average value. Eventhough the experimental approach where the input parameters are based on physical properties did not improve the prediction accuracy, it opens up to new modelling opportunities and the possibility of dividing the influence of the different components involved, such as halftoning, paper and ink.

ACKNOWLEDGEMENTS

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Multi-channel Printing by Orthogonal and Non-orthogonal AM Halftoning

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ABSTRACT

Multi-channel printing with more than the conventional four colorants brings numerous advantages, but also challenges, like implementation of halftone algorithms. This paper concentrates on amplitude modulated (AM) halftoning for multi-channel printing. One difficulty is the correct channel rotation to avoid the moiré effect and to achieve colour fidelity in case of misregistration. 20 test patches were converted to seven-channel images and AM halftoning was applied using two different approaches in order to obtain a moiré-free impression. One method was to use orthogonal screens and adjust the channels by overlapping the pairs of complimentary colours, while the second was to implement non-orthogonal halftone screens (ellipses). By doing so, a wider angle range is available to accommodate a seven-channel impression. The performance was evaluated by simulating misregistration in both position and angle for a total of 1600 different scenarions. ΔE values were calculated between the misregistered patches and the correct ones, for both orthogonal and non-orthogonal screens. Results show no visible morié and improvement in colour fidelity when using non-orthogonal screens for seven-channel printing, producing smaller colour differences in case of misregistration.

1. INTRODUCTION

The great advantages of multi-channel printing, like colour fidelity and colour gamut expansion, are the reason for the emphasis on this type of printing. When expanding from the conventional four colorants, one must choose and adjust the halftoning algorithms used for obtaining suitable binary images. In frequency-modulated halftoning (FM), the screen dots have constant size and the frequency changes to create an effect of a lighter or darker shade. In this research we focus on amplitude-modulated halftoning (AM), where the screen size varies while the frequency stays the same. The challenge is the possibility of moiré optical effect appearance in the prints in case of misregistration. To avoid it, the common practice is to lay each channel under a certain angle, creating a rotated screen scheme, which also demonstrates to exhibit very little colour shifts in case of misregistration, as shown in Basak et al. (2005). The channels are laid so that each one is separated from the others as much as possible, while keeping all high contrasting colours at least 30º apart. One has to bear in mind the limitation of a round screen element, whose symmetrical shape allows a rotation of up to 90º. This 90º constraint is an obstacle for incorporating more than four channels using AM halftoning.

Previous work in this area has been oriented towards adjusting the colour separations so that they fit in the 90º-angle range. In the work by Ostromoukhov (1993) the suggestion was to use a modified compound Neugebauer equation to adjust the channel on each screen vertex, suppressing any odd ink number of channels into a three-layer system. Balasubramanian and Eschbach (2001) used the approach of colour replacement strategies to adjust four channels on low resolution printing devices, using both undercolour removal (UCR) and grey component replacement (GCR), controlling the input data so that at least one of the ink components is set to a high value, adjusting accordingly the rest. In the area of moiré analysis, Amidor et al. (1994) observe the moiré phenomenon by using a Fourier-based spectral model. They determine that moiré appearance is related to the relative ink superposition angles, not the absolute ones, finding the optimum angle separation within four inks. Their work encourages to adjust the channels on a slightly off symmetry axis in order to break the moiré symmetry microstructure. Wang et al. (2003) introduced the application of asymmetric, non-orthogonal screens as an aid to a moiré-free solution. By searching for a rational tangents angle, a non-orthogonal screen gives a wider choice, and can therefore provide a visually more pleasant solution.

2. PROPOSED METHOD

In AM halftoning, the commonly used angles are 45º for black, 75º for magenta, 15º for cyan and 0º/90º for yellow. The highest contrasting colour, black, is laid in the furthest possible angle from the plane, 45º. The next two high contrast colours are magenta and cyan, which are laid apart from black by a 30º angle. The remaining colorant, yellow, would optimally be separated by another 30º, which is not possible because of the symmetry of the round screen. Instead, it is shifted by 15º, which proved to be enough to mask moiré due to the low contrast of yellow. If one would want to increase the number of channels in AM halftoning, the encountered limitation would be finding suitable angles for a moiré-free solution.

We propose a method using non-orthogonal screen elements, i.e. ellipses. Their symmetry of only 2 quadrants allows the expansion of the available angle to 180º, which gives the possibility to accommodate more than the conventional 4 channels. Figure 1 displays the available angles in an orthogonal and non-orthogonal screen element plane.

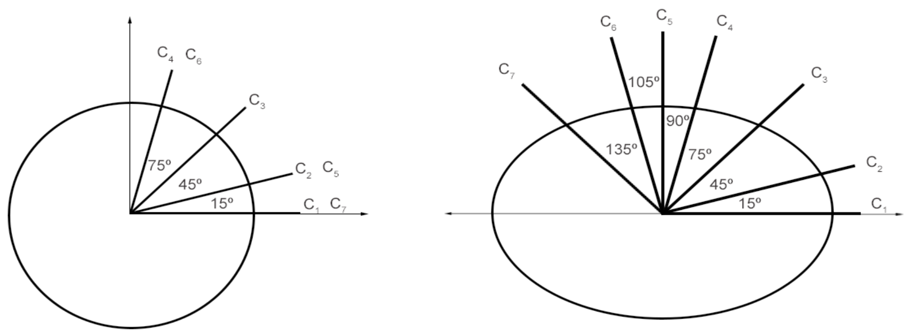

Figure 1: Orthogonal and non-orthogonal screens and channel angle dependency.

The approach is to adapt the channel angles into a 180º plane, in which the channels with highest contrast (black, blue) would be furthest apart, medium high contrast (magenta, red, cyan, green) 30º apart from the remaining ones, and the lowest contrast channel (yellow) separated by the remaining 15º. This leads to 0º yellow, 15º cyan, 45º black, 75º green, 90º blue, 105º red and 135º magenta. In the regular, orthogonal case, the complementary colours are laid in the same angle – 0º yellow and blue, 15º cyan and red, 45º black, 75º magenta and green.

2.1 Method assessment

Once the angles for each channel have been chosen for the CMYKRGB channels, their correctness must be verified by experiments. In case of misregestration, the inevitable color shift should be as small as possible, and preferably no moiré should be visible. From a set of patches and ramps that was used for visual assesment, 20 patches were selected with arbitrary CMYKRGB values, having 5-45% coverage for each channel, at 300 dpi 20 lpi. Each patch has been halftoned using AM halftoning with othogonal, as well as non-orthogonal screens, using the proposed angles.

To evaluate the results, spectral data for a Canon iPF5100 multi-colorant inkjet printer has been used. In this way, focus could be on the halftoning, avoiding the dot gain that would be inevitable in an actual print. Spectral data for the 2^7 =128 Neugebauer primaries for the seven-channel printer have been measured and used to compute sRGB values to visualize the results, and CIELAB values for colorimetric computations. All computations were performed using the CIE 1976 colour difference, and CIE standard illuminant D65. To simulate misregistration, one to three of the 7 digital bitmaps were slightly translated or rotated in relation to the others. For each patch, the results of 40 different variations of misregistration were computed, leading to a total of 1600 different scenarios.

3. RESULTS AND DISCUSSION

Figure 2 displays the resulting color shift in case of misregistration, calculated as the mean ΔE difference between the original and the 40 variations of misregistration for each patch. Clearly, all of the 20 patches show lower ΔE values for non-orthogonal screens than for orthogonal ones, illustrating that the non-orthogonal screens are more robust to misregistration. The mean ΔE value of the 800 misregistered orthogonal halftone screens is 2.67, and 1.98 for the corresponding 800 non-orthogonal screens.

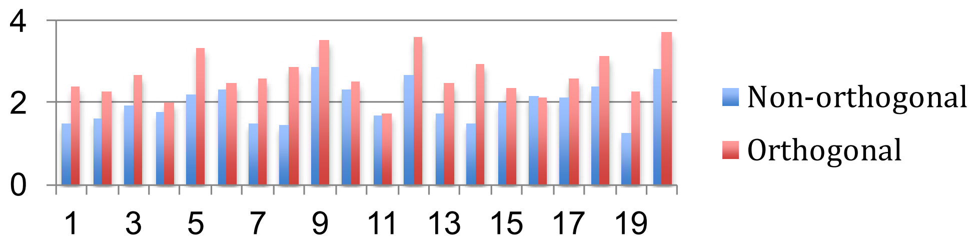

Figure 2: Results of mean ΔE values for orthogonal and non-orthogonal screens.

The halftoned patches show a regular rosette pattern with no visible moiré even in case of some misregistration. To illustrate this we have halftoned a ramp ranging from 0-30% colorant coverage for each channel, shown in Figure 3. Apart from no moiré appearance, one can verify that there is not significant colour shift in case of some misregistration.

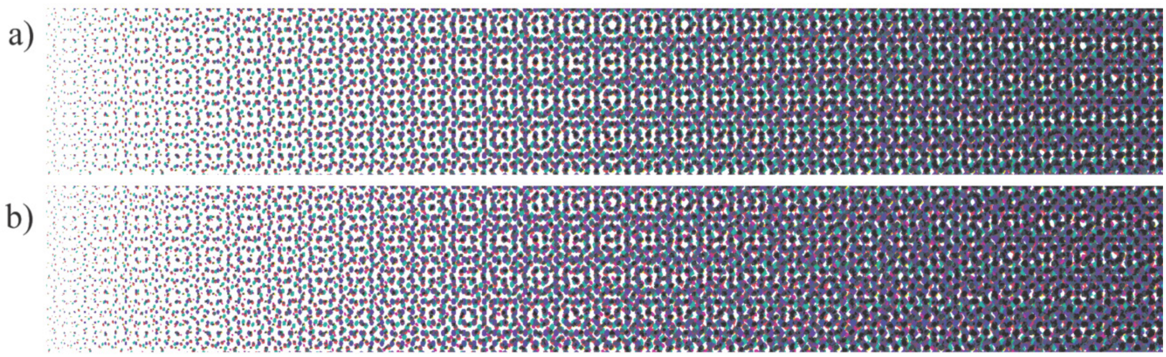

Figure 3: Non-orthogonal AM halftoning with our proposed angle setup a) without misregistration, b) with 8º magenta misregistration.

4. CONCLUSIONS

In this paper, we proposed a non-orthogonal AM halftoning angle setup, suitable for seven-channel printing. By using non-orthogonal elliptic halftone screens, the available angle range doubles compared to round screens, leaving the necessarry space to separate almost all channels by a 30º angle. The experimental results indicated that the non-othogonal screens produced a moiré free impression, and further proved to be less sensitive to misregistration, giving smaller color shifts compared orthogonal multi-channel screening technique.

ACKNOWLEDGEMENTS

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Novel Reactive Colorants and Their Application onto Textile Substrates by Inkjet Printing

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ABSTRACT

The paper describes the synthesis and evaluation of magenta, yellow and blue reactive dyes based on dichloro-s-triazine reactive systems. The dyes were synthesised stepwise from specially synthesised dichloro-s-triazine dyes. The mono and di substituted modified dyes were synthesised by reacting one or both of the labile chlorine atom(s) in the parent dyes with "selected leaving group" under specific parameters of pH and temperature. Capillary electrophoresis and thin layer chromatography were used to monitor both the course of the above reactions. Inks containing the modified dyes were printed on wool fabrics through inkjet printing and fixation achieved by 'batching' the prints at 65° C; high fixation values were obtained for all modified dyes. These prints exhibited excellent colour fastness to light.

1. INTRODUCTION

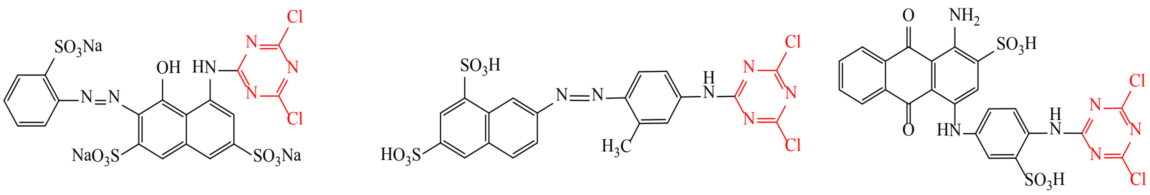
Inkjet printing is rapidly becoming promising technique for textile coloration (Fryberg 2005). It provides a favourable method for wool printing because of the ability to produce economical short print runs, providing flexibility in print design and high fastness prints.

This study describes the preparation of a specially modified reactive dyes based on replacing the leaving groups, formulation of modified dyes into inks, application of these inks onto wool substrate through inkjet printing and evaluation of fixation and light fastness.

2. EXPERIMENTAL

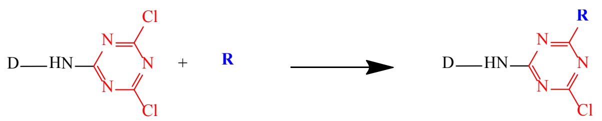
2.1 Synthesis and modification of Dyes

The synthesis of the magenta, yellow and blue dyes based on replacing the leaving group involved a one-step modification starting with the synthesis of the dichloro-s-triazine reactive dyes shown in Figure 1, followed by the substitution of the halogen on the triazine ring with other liable group(s) to produce both mono and di-substituted dyes, shown in Scheme 1 and Scheme 2.

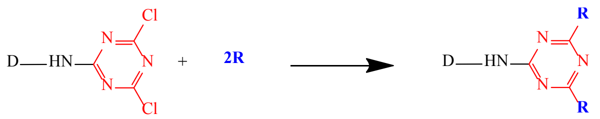


Magenta dichlorotriazine Dye   Yellow dichlorotriazine Dye   Blue dichlorotriazine Dye

Figure 1: Fibre-reactive dyes based on dichloro-s-triazine.



Scheme 1: Synthesis of modified dye by replacing one labile chlorine atom by another leaving group.



Scheme 2: Synthesis of modified dye by replacing both the labile chlorine atoms by another leaving group.

2.2 Analytical Techniques

The analysis of the starting materials and monitoring of the different stages of the synthesis reaction were carried out by using capillary electrophoresis and thin layer chromatography. Fourier transform infrared spectrometry was used for the determination of molecular structure. UV/Vis spectroscopy and Woolmark TM 5 were used to determine %fixation and colour fastness to light of the synthesised and applied inks respectively.

2.3 Application of the dyes to wool through Inkjet printing

The sequence of substrate preparation and ink jet printing can be summarised as follows: (1) Fabric pretreatment; (2) Ink-jet printing; (3) Fixation; (4) Washing off.

Fabric Pretreatment

Wool fabric was padded at 100% wet pick-up using a Werner Mathis HVF padder with the pretreatment solution, described in (Clark, Yang et al. 2009);following padding the fabric was dried at 70 °C using a Werner Mathis dryer.

Inkjet Printing

Inkjet printing was carried out on *Hewlett-Packard (HP)* Deskjet 6940 thermal drop on demand Color Inkjet Printer with a single pass at a resolution of 1200 dpi as a solid rectangle print pattern using the ink, formulated according to the recipe given in Recipe 1. For the purpose of passing the fabric samples through the ink-jet printer, they were glued to a sheet of A4 transparency by applying double sided tape to the fabric edges. Printed samples were allowed to air dry for 5 minutes and then batched for the appropriate times.

Recipe 1: Ink Recip*e*

Dye	60 g-dm^{-3}
N-methylmorpholine N-oxide	300 g-dm^{-3}
2- pyrrolidone	20 g-dm^{-3}
Propan-2-ol	25 g-dm^{-3}
Water	X dm^{3}
	1 dm^{3}

Fixation

The printed samples were batched at 65 °C under moist conditions for 0, 30, 60, 90, 120 and 150 mins. The moist conditions were provided by interleaving the printed wool fabric with a moist cotton fabric padded with distilled water at a wet pick-up of 80%.

Washing Off

The printed samples were washed according to the following three-step procedure:

- 5 min cold rinsing until no colour could be removed;
- 10 min hot washing at 65° C with the addition of 2 g/dm^3 Sandozin NIE and 5 g/dm^3 sodium bicarbonate;
- 10 min rinsing in running tap water

2.4 Determination of % fixation (fibre-dye bond)

The percent fixation was determined using a Perkin Elmer Lambda 40 UV-vis Spectrophotometer (UK) in order to calculate dye concentration in the various wash-off solutions.

After printing, the first sample was washed off immediately to obtain the total amount of the dye printed on the fabric and the solution was diluted to 100 cm^3. The remaining samples were used for batching followed by washing to obtain the amount of the hydrolysed and unreacted dye after the fixation process; the washing solutions were diluted to the same volume of 100 cm^3 individually. The absorbance of the printed dye solution A_0 and absorbance of the wash-off solution A_i at the wavelength of maximum absorption λ_{max} were used to obtain the percent fixation (%F) according to *Equation 1*;

$$\%F = \frac{Ao - Ai}{Ao} \text{ x } 100\%$$

Equation 1: Equation to calculated percent fixation of printed dye.

3. RESULTS AND DISCUSSION

3.1 % Fixation of Inks containing modified dyes

Significant improvement in the extent of covalent dye fixation (%F) was observed when the modified magenta, yellow & blue dyes were applied by a print (Ink-jet)–batch technique. The highest level of percent fixation observed with inks based on parent dyes were 82.9% for magenta, 80.1% for yellow and 79.8% for blue. Whereas, for modified dye based inks they were 89.0% for magenta, 84.8% for yellow and 91.4% for blue.

Moreover, when results are compared with commercially available Dystar Jettex R inks[1]; the modified magenta, yellow and blue dyes showed 5%, 6% and 10% better results respectively, shown in Figure 2, Figure 3 and Figure 4.

3.2 Light Fastness Test

Light fastness was carried out using a QSun 1000 Xenon test chamber with irradiance of 0.65 W/m^2 at a temperature of 45° C. The printed samples were tested to Blue Wool reference number 5 and 6. All of the dyes used in this work pass grade 6. In general, the parent dye-based inks were either the same grade or 0.5 grade lower when compared with the modi-

1 The Dystar Jettex R inks were applied onto pre-treated wool substrate as mentioned above for parent and modified dye based inks.

fied dye ink prints for light fastness test. However, the commercial Dystar Jettex R inks were not tested for light fastness.

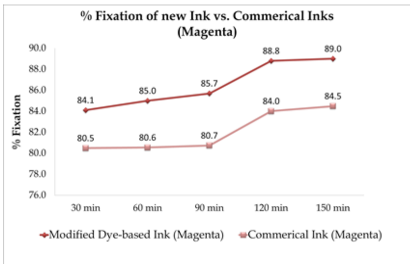


Figure 2: %Fixation of modified dye based magenta ink vs. commercial ink.

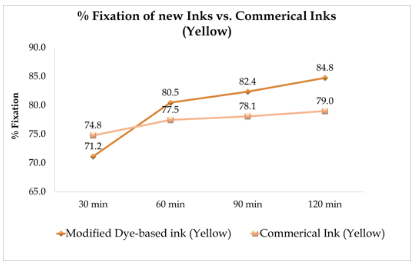


Figure 3: %Fixation of modified dye based yellow ink vs. commercial ink.

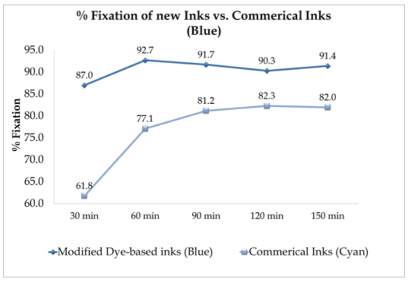


Figure 4: %Fixation of modified dye based blue ink vs. commercial ink.

4. CONCLUSIONS

The research has shown that reactive dyes can be modified by the incorporation of other labile atoms onto the dichlorotriazine reactive group of the dye. The modified dyes, when inkjet printed onto the wool, are able to reactive with the fibre and show good fixation results. Moreover, all the samples printed with modified dye based inks showed excellent light fastness.

ACKNOWLEDGEMENTS

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colour vision

Colorfulness Adaptation to Scenes through Optical Haze

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ABSTRACT

It would be important for us to obtain the same appearance of objects and scenes even when the saturation of visual environment changes due to natural causes, such as fog or the aging of lens. Are we actually able to compensate those saturation changes and maintain a stable appearance of an image? We examine whether the colorfulness perception of a scene is stable after adaptation to scenes through optical haze. Observers adapted to a series of natural images through foggy filters, then judged the colorfulness of a test image. The metric chroma of the test image was modified by multiplying a modulation coefficient to control its saturation. Three haze levels were examined as well as a condition with no foggy filters. Results showed that the range of natural colorfulness was different among five test images we tested. However, the range showed little change depending on the haze levels of foggy filters. This means that observers perceived the similar colorfulness to the test images even when they looked the images through the different levels of optical haze after the adaptation. These suggest that the colorfulness perception of natural scenes is stable under its saturation change in due to optical haze.

1. INTRODUCTION

It is known that colorfulness perception changes with adaptation to chromatic contrast modulation (Krauskopf et al. 1982, Webster and Mollon 1997) and to surrounding chromatic variance (Brown and MacLeod 1997). We previously showed that the impression of an image was less colorful after exposing to saturated images and vice versa, suggesting colorfulness adaptation also worked in natural images and actual environments (Mizokami et al. 2012). However, the effect was weaker when shuffled images were used for adaptation instead of natural images. These imply that the adaptation is an active process to stabilize the appearance of natural scene. If we consider the functional meaning of the adaptation, it would be important to maintain the same appearance of objects and a scene even when the saturation of visual environment changes due to natural causes, such as fog or the aging of lens and other optical factors of our eyes. Thus, it would be predicted that the appearance of an image or a scene is kept the same for a plausible saturation change in the environment if such compensation works. Here, we examine whether the colorfulness perception of a scene is stable after adaptation to scenes through optical haze.

2. METHOD

We conducted psychophysical experiments in which observers adapted to a series of natural images through foggy filters with different haze levels, and then judged the colorfulness of test images to examine whether the colorfulness perception changes depending on the haze levels.

Figure 2: Example of Chroma modulation.

Figure 1: Test images for colorfulness judgment.

2.1 Images and Modulation Method

Ten images adopted from the Color Image Data Sets (SHIPP and JIS X 9204: 2004) were used for adaptation images. They were chosen to have a variety of indoor and outdoor scenes to avoid any bias in particular characteristics of images. The resolution of images was 512×410 pixels. Each image had the different distribution of metric chroma and average color. Five test images used for the judgment of colorfulness are shown in Figure 1. Each image was not included in the adaptation images when it was used as a test image.

The modulation of test images was done in the CIELAB space and metric chroma C^* defined by Equation (1) was used as a parameter of saturation.

$$C^*_{ab} = \sqrt{a^{*2} + b^{*2}} \qquad (1)$$

Metric chroma of images was modified by multiplying a modulation coefficient k (Eq. 2) while the lightness of images was kept the same.

$$C^*_{\mathrm{modified}} = kC^*_{\mathrm{original}} \qquad (2)$$

The test image with chroma levels ranged from $k = 0.3$ to $k = 1.3$ in 0.2 step were prepared for the judgement. Figure 2 shows the examples of images with the modulation coefficient $k = 0.3$, 1.0 and 1.3.

The experiments were conducted in a dark experimental booth. Stimulus images were generated on a VSG 2/5 graphic board (Cambridge Research Systems), controlled by a PC and presented on a 21-inch CRT display. An observer sat with their head in a chin-rest at 80 cm from the display and the visual angle of images was 18.1 × 14.5 degrees.

Kenko foggy filters were used for conditions with different optical haze. As shown in Figure 3, condition with no filter, foggy filter A, B, Combination of the A and B were tested. Chroma of image changed according to the haze levels.

2.2 Psychophysical Experiment

After 3 minutes of dark adaptation, an observer adapted to a series of images on a black background. Each adaptation image appeared randomly for 2 seconds for a total of 3 minutes, and then a test image at a certain saturation level was presented for 3 seconds. Observers judged whether the test image was too colorful or natural, or natural or too faded. There was no reference and the judgement was made based on his/her internal criterion. The judgement was made each time a test image was presented, and then the next test image was presented following to 6 seconds re-adaptation.

The method of constant stimuli was used to measure the upper and lower limit of colorfulness. A psychometric curve was drawn based on a total of ten judgments. A modulation coefficient at 50 % on the curve from the judgements of "natural vs. too colorful" and "natural vs. too faded" was considered as the upper and lower limit of natural colorfulness, respectively.

The same procedure was repeated for three haze conditions and for each test image. A condition with no image adaptation was also tested as a control. In the control condition, observers adapted to the dark monitor during the pre-adaptation phase and between test images. Three observers with normal color vision participated.

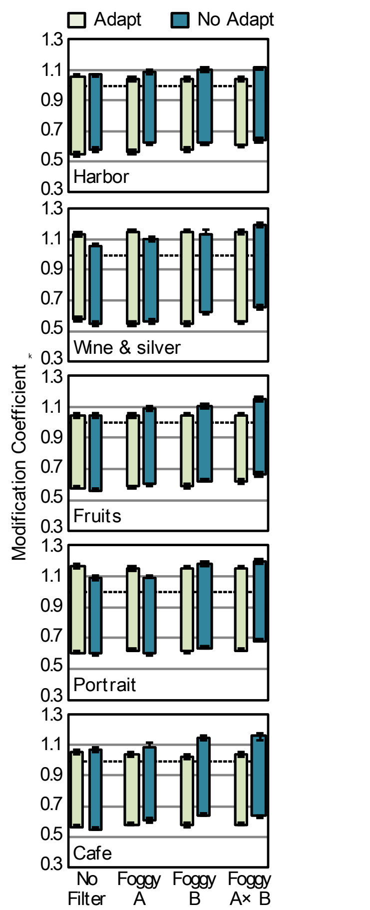

Figure 4: Average results of three observers for 5 test images.

3. RESULTS T DISCUSSION

Figure 4 shows the results of all viewing conditions for five test images. Light and dark shaded bar indicates the result from adaptation and no adaptation (control) condition, respectively. Top and bottom of the bar corresponds to the upper and lower limit of natural colorfulness. Thus, the length of the bar means "the range of natural colorfulness". They are the average of three observes and error bars show standard deviations. They show that the range of natural colorfulness was different among five test images. This would be because the chroma of each original image was different, and images with high chroma tend to appear too colorful even though the modification of chroma was small.

In the conditions with adaptation, the ranges of natural colorfulness are almost the same among the different haze levels of foggy filters on all five images. This means that observers perceived the similar colorfulness to the test images even when they looked the images through the different levels of optical haze. In the condition without adaptation, on the other hand, the ranges shift to higher modification coefficient or higher chroma direction as haze levels of the filter become stronger. These suggest that a colorfulness adaptation mechanism works for the saturation change in visual scene due to optical haze and the colorfulness perception to the scenes is maintained stable under this type of natural change in visual environment. In contrast, it was shown that the appearance of color samples became desaturated under a condition simulating the view of elderly people (Ikeda and Obama 2008). Our results imply that cataract eye may influence color discrimination or color judgement for individual objects, but may not change "the impression of the visual world".

It should be noted that the image modulation we used changed only the overall chroma of test images by a modification coefficient. Optical change by foggy filers was both in saturation and in blur. There would be number of factors which are not clear, such as the influence of blur adaptation, influence of the method of image modification (e.g. the combination of blur and chroma change). We need to investigate further to clarify the characteristics and the mechanism of colorfulness adaptation.

4. CONCLUSIONS

We examined whether the colorfulness perception of a scene was stable after adaptation to scenes through optical haze. After adaptation to natural images, the range of natural colorfulness of an image showed little change depending on the haze levels of foggy filters. This suggests that a colorfulness adaptation mechanism works for the saturation change in visual scene due to optical haze and the colorfulness perception to the scenes is maintained stable under natural change in visual environment.

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The Role of Colour, Shape and Texture in Natural Object Identification

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ABSTRACT

The relative role of shape, colour and texture in guiding object recognition when all cues are diagnostic is unclear. We assessed shape, colour and texture diagnostic cues using speeded 3-alternative forced choice classification paradigms. Target objects were familiar fruits and vegetables, presented singly in seven different image types, consisting of each cue in isolation and all possible cue combinations. The first experiment compared different stimulus presentation times without masking and the second experiment compared different stimulus onset asynchronies (SOAs) of a backward mask to assess relative temporal processing requirements.

Target object recognition was significantly better for images containing diagnostic chromatic information compared to luminance-only images. Performance was higher for single-cue colour than shape or texture image types. For combined-cue images performance was better for images containing colour information. Varying the SOA of the mask revealed that shape cues are extracted faster than surface cues, that colour combines more effectively with shape than texture, and that texture cues are slowest to drive classification. Collectively, the results suggest that shape is more effective than colour in driving object identification only at the earliest stages of visual processing.

1. INTRODUCTION

Whether diagnostic colour plays a primary role in object recognition is debated. Shape is recognized as a primary cue for object identification (Biederman & Cooper, 1991), and it is known that colour, as a low–level visual feature, can successfully serve as a 'pop-out' cue to direct an observer's attention to an object's geometric shape (Treisman, 1986), thus facilitating its recognition. Yet whether diagnostic colour and other surface features, such as texture (Julesz, 1991), contribute directly to object recognition is unclear (Naor-Raz, Tarr & Kersten, 2003).

Response latency and accuracy in a scene recognition task are affected by colour content rather than chromaticity cues (Goffaux et al, 2005) suggesting that colour aids pattern recognition (Oliva & Torralba, 2001). It is postulated that surface-based cues are used to categorize scenes without the need for identifying particular objects in those scenes (Ehinger & Brockmole, 2008). Nonetheless, diagnosticity as a prerequisite for a critical role in object recognition has been suggested (Therriault, Yaxley & Zwann, 2009). Faster classification and naming times are recorded for objects with diagnostic colour (Tanaka and Presnell, 1999), implying that a colour-first strategy may be employed when colour information is highly diagnostic and available whereas a shape-first strategy is operative for objects with low colour diagnosticity.

Though it intuitively makes sense that surface based cues should contribute to the recognition of objects which possess diagnostic surface colours and textures, the relative efficiency of surface and shape cues in driving recognition remains unclear. Similarly, although we know that most visual processing occurs quickly (Sharan et al., 2009) and unconsciously

(Rousselet et al., 2003), it is unknown whether different cues are processed at different speeds. While fMRI studies on form, colour and texture suggest that the extraction of information about object colour occurs relatively early compared with the extraction of information about surface texture (Cant & Goodale, 2007), the specific implications for object recognition are not understood. To assess the relative role of shape, colour and texture diagnosticity, their possible interactions, and temporal constraints in object recognition, we conducted two experiments using a speeded classification paradigm.

2. METHOD

All images were acquired with a trispectral-calibrated digital camera and displayed on a colorimetrically calibrated CRT display, so that accurate metamers of the light reflected from the objects under natural conditions were reproduced.

In two separate experiments observers were requested to identify natural objects displayed on a computer monitor as rapidly as possible. On each trial, a fixation cross was followed by an image of a single object against a neutral background in a central position. The observer's response was recorded as a key press of one of three designated keys (3AFC). Experimental trials were blocked by a) object set, b) image type and c) the duration of stimulus presentation. Each image position was jittered (~1.5 degrees around the central fixation) to avoid possible afterimage effects.

a) Both experiments used the same objects, all derived from familiar fruits and vegetables which possess natural shape, colour and texture diagnosticity: Set 1= Banana, Courgette, Carrot; Set 2=Potato, Lime, Carrot; Set 3=Strawberry, Kiwi, Carrot. The carrot was the control object.

b) In both experiments image type was defined by one of seven conditions: whole-object shape [S], colour-only patch [C], achromatic texture-only patch [T], whole-object uniform-coloured shape [S+C], whole-object achromatic textured shape [S+T], colour-texture patch [C+T] or whole-object coloured textured shape [S+C+T]. See Table 1.

c) Images in Experiment 1 were presented at 48 ms or 267 ms durations. Images in Experiment 2 were presented at 27 ms duration, followed by a mask of duration 267 ms with a stimulus onset asynchrony (SOA) of 40 ms or 267 ms. The backward mask consisted of a quadrilateral image of random multi-coloured dots (Breitmeyer & Ogmen, 2000). The mask's size was matched to the size of the preceding stimulus, i.e. whole object or patch.

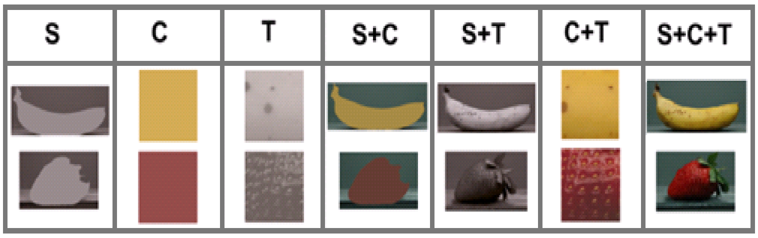

Table 1: The seven stimulus conditions consist of single-cue, combined-cue and whole image types.

All participants (Experiment 1, n=34; Experiment 2, n=12) were tested with the Neitz and Farnsworth-Munsell 100 hue tests to confirm normal trichromacy. Tasks were conducted in a darkened room with the observer's head position controlled by a chin rest. At the start of each block observers adapted to a uniform grey screen background for 60 seconds. Specific block-related instructions were then presented. Accuracy, as the proportion of correct responses over all trials, and reaction time (RT) in milliseconds, measured from image stimulus onset, were recorded.

3. RESULTS AND DISCUSSION

Because the RT and accuracy data followed the same pattern (where RT was lower, accuracy was higher), we defined our measure as performance, equal to accuracy/RT.

An ANOVA on Experiment 1 data revealed a significant effect of condition for both the 48msec [F(6,192)=65.874, p<0.001] and 267msec [F(6,96)=15.745, p<0.001] timings. While performance for the longer stimulus duration was enhanced compared to performance at the shorter duration (p<.001), performance to 'Colour only' was significantly better than performance to 'Shape only' (p<0.01) and 'Texture only' (p<0.01) stimuli, for both durations. Performance was at its optimum when all three cues were presented in the image and significantly enhanced when combining surface cues with shape information (i.e. S vs S+C, p<.01; S vs S+T, p<.01). Adding 'Colour' cues to 'Shape' cues was significantly (p<.001) more faciltatory than adding 'Texture' cues to 'Shape'. Results indicate that diagnostic visual cues to object recognition are not all equal; overall, the addition of colour is more faciltatory than the addition of either shape or texture.

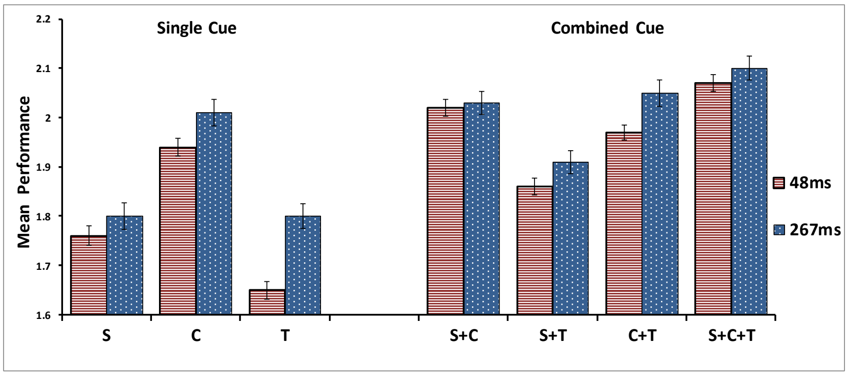

Figure 1: Condition performance in Experiment 1 with stimulus duration of 48 and 267ms.

An ANOVA on Experiment 2 data revealed a significant effect of Condition [F(6,36)=32.189, p<.001] and SOA [F(1,6)=11.781, p=0.014]. Performance for the longest SOA was significantly enhanced compared to the shortest SOA (p<.001). At the shortest SOA, 'Shape' was the most effective cue (p<.05) in the single-cue image types, while at the longest SOA (267msec) 'Colour' yielded the highest performance of the single cue image types and was significantly better than 'Shape' (p=.01). 'Texture' at SOA 40msec was the least effective (p<.01) of the single cue image types, but while performance for the 'Texture only' cue was significantly worse than 'Colour' at both 40ms and 267ms SOAs, it was only significantly worse than Shape at SOA 40ms, implying that performance for surface cues improves with a longer processing time. Performance for 'Shape only' images did not differ across the SOAs, but for both surface cues performance increased at the longer SOA; performance for 'Colour only' (p<.001) and 'Texture only' (p<.001) images at the longer SOA was significantly better than at the shorter SOA.

Colour seems to combine more effectively with shape than does texture at the shorter SOA (a significant difference exists between 'S+C' and 'S+T', p=0.01), although at the longer SOA this effect is diminished and both surface cues appear to combine with shape equally effectively.

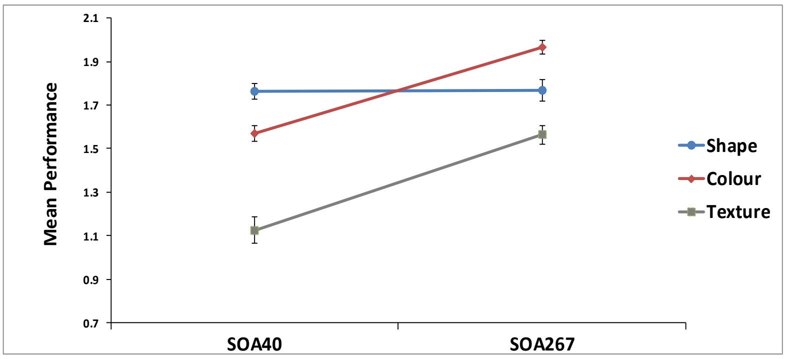

Figure 2: Performance in Experiment 2 to single cue conditions with masks at both SOAs.

4. CONCLUSIONS

The recognition of natural objects may be facilitated by diagnostic chromatic texture beyond the level attained from shape information alone. Surface cues combine with shape information at an early stage of visual processing. Shape is processed earlier than other surface property cues and benefits more from the combinatorial effect of other visual cues than from longer processing times. Surface cues benefit more from longer processing times. Both surface colour cues and shape cues have an advantage over texture cues in tasks of natural object recognition.

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Chromatic Discrimination across the Lifespan Assessed by the Cambridge Colour Test

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ABSTRACT

Effects of ageing on chromatic discrimination were assessed using the Cambridge Colour Test (CCT) in healthy normal trichromats (N=250), aged 20–89. The CCT Trivector test estimated thresholds along the Protan, Deutan and Tritan confusion lines and the Ellipses test parameters of three MacAdam Ellipses (major axis, major-to-minor axis ratio and major axis angle). Both tests showed a significant correlation (ρ=.30–.72) between age and all chromatic discrimination parameters (except Ellipses angle). Post-hoc comparisons between life decades revealed a significant increase of thresholds after the age 60, with dramatic acceleration of Tritan discrimination loss, in particular. The present findings are consistent with the notion of parallel decline in sensitivity in all chromatic systems with advancing age and greater vulnerability of the Tritan system (J. Werner et al. 1990; Knoblauch et al. 2001). Our earlier findings for a 20-59 y.o. cohort (Paramei 2012) indicated initial benign deterioration of colour discrimination: an incremental loss of Deutan discrimination, in the 40+, and of Tritan discrimination, in the 50+. Results of the present study of the extended age range single out the 60+ decade as displaying substantial discrimination loss in all chromatic systems, with prevailing Tritan senescence.

1. INTRODUCTION

With ageing, chromatic sensitivity manifests generalised decline in all three chromatic systems, although initially it reveals itself as losses along tritan axes (Knoblauch et al. 2001). This results from senescent changes that occur at various visual system loci. In the ocular media, the tritan-like effect is caused by increasing opaqueness and yellowing of the crystalline lens, which progressively curtails light transmission in the short-wavelength part of the spectrum. At the photoreceptor level, reduced photopigment optical density and misalignment of part of photoreceptors ensues decrease in the probability of light absorption (J. Werner et al. 1990). Upstream in the visual system, the neural changes account, too, for a considerable amount of sensitivity loss: At the post-receptoral level, the number of retinal ganglion cells decreases (A. Werner et al. 2010); at the cortical level, some neurons reveal a loss of dendritic spines and changes in the morphology of myelin sheaths and axons leading to decrease in neuron efficiency.

In focus of the present study, an extension of our previous work for four life decades (Paramei 2012), are changes of discriminative capacity in normal trichromats (NTs) with advancing age. We measured chromatic discrimination thresholds in a representative sample of healthy NTs of the age range spanning seventy years. We questioned (i) whether the rate of sensitivity decline along the Protan, Deutan and Tritan confusion lines, pointing to the L-, M- and S-cone systems respectively, is comparable and (ii) what life decade reveals onset of an accelerated ageing. An additional aim was to provide normative data for the CCT for each life decade that can be used in clinical studies of mature patients for diagnostic and monitoring purposes in diabetes, glaucoma, ocular hypertension etc.

2. METHOD

2.1 Participants

Observers were normal trichromats (N=250; 128 females) of seven life decades, 20–89 years old, with the equal number of both genders in (almost) all decades. Exclusion criteria were congenital colour abnormality; history of ophthalmological pathology (ocular/retinal disease); cataract (surgery or awaiting surgery); neurological diseases or diabetes. Data of participants with monocular vision and of those who wore tinted glasses was excluded too.

To assure normal colour vision of the observers, prior to the experiment, all were assessed using the Ishihara Pseudoisochromatic Plates, D-15 and D-15d tests.

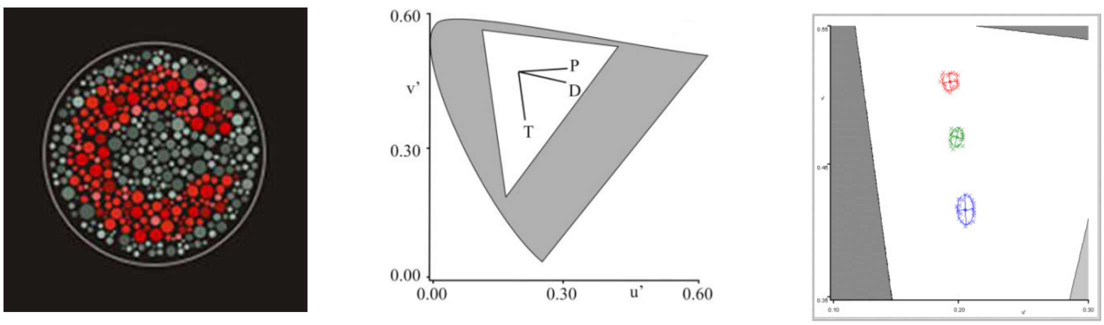
2.2 Apparatus, Stimuli and Procedure

For measuring chromatic discrimination, the Cambridge Colour Test (CCT), v1.5, was used (Cambridge Research Systems Ltd., Rochester, UK). Implementation and calibration procedures were performed with the provided software and hardware (OptiCAL; VSG interface version 8.12; graphics card VSG 71.02.01E9). Stimuli were presented on a high-resolution gamma corrected 21-inch colour monitor (Mitsubishi Diamond Pro 2070SB).

The CCT varies chromaticity parameters of the figure, Landoldt ‘C’, and of the background composed of elements of differing luminance and size (Figure 1a). The CCT protocol randomises figure–background chromaticity differences (defined in the CIE 1976 *u’v’* units) while applying a staircase psychophysical procedure.

The gap in the ‘C’ opening subtends 1° at the viewing distance 4 m. The target’s gap is randomly presented in one of four positions: up, bottom, right or left (4AFC). Participants were instructed to identify the position of a gap and press the corresponding button of the response box (CT6). In the present study they were dark adapted and tested binocularly.

In its commercial version, the CCT includes two tests (Mollon and Reffin 2000). The Trivector test estimates discrimination thresholds along the Protan (P), Deutan (D) and Tritan (T) confusion lines, to probe the sensitivity of the L-, M- and S-cones respectively (Figure 1b). The Ellipses test maps three MacAdam discrimination ellipses whose centres lie along a Tritan confusion line, in different CIE1976 sectors (Figure 1c); the test outcome indicates ellipse’s major axis, major-to-minor axis ratio and major axis angle.

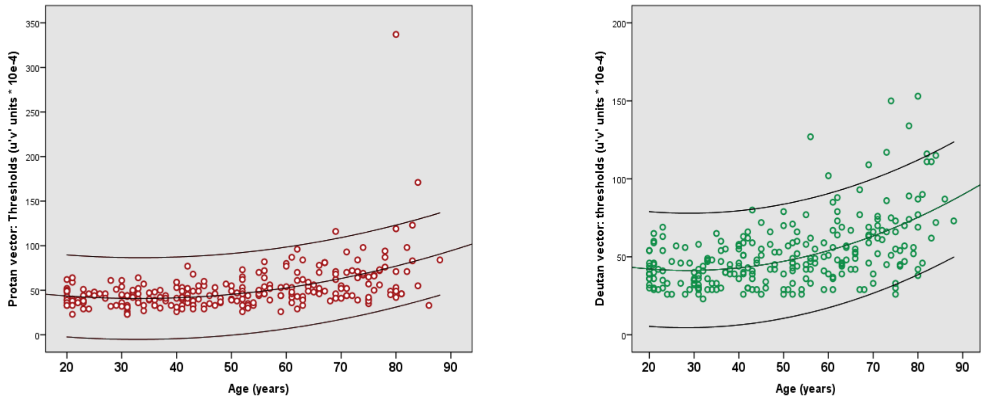


(a) *(b)* *(c)*

Figure 1: The Cambridge Colour test. (a) An example of the chromatic target embedded in the luminance noise background; (b) Trivector test: Protan (P), Deutan (D) and Tritan (T) vectors; (c) Ellipses test: MacAdam ellipses (for young) normal trichromats.

3. RESULTS

A moderate correlation (ρ=.47–.60, $p<.001$) was found between age and discrimination thresholds along the three confusion lines, Protan, Deutan and Tritan (Figure 2).



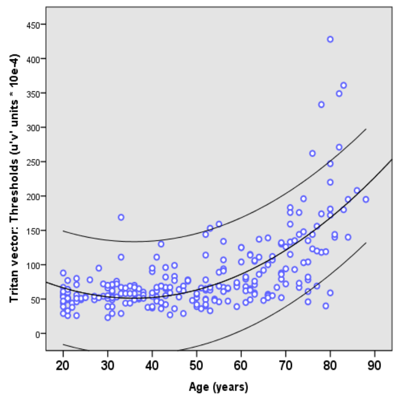


Figure 2: Age-dependent thresholds along the Protan, Deutan and Tritan vectors.

The Ellipses test showed elongation of major axes of all three Ellipses reflecting incremental elevation of thresholds (ρ=.53–.72, $p<.001$). Significant correlation was also found between age and major-to-minor axis ratios of the Ellipses (ρ=.30–.58, $p<.001$).

Table 1. Medians of the P, D. and T vectors (in 10-4 u'v' units) for the seven age decades.

Trivector test	20+	30+	40+	50+	60+	70+	80+
Protan	40.0	40.5	41.5	46.0	53.5	57.0	71.0
Deutan	40.5	38.5	46.0	46.0	54.0	62.0	87.0
Tritan	53.0	58.0	64.0	65.0	82.0	120.0	195.0

Table 1 presents medians of the P, D and T vectors for each life decade. Cross-cohort comparisons (Kruskal-Wallis *H* test) indicated significant age-dependent increase of all CCT measures ($p<0.01$), with an exception of the Ellipses angle. Notably, for the Trivector test, post-hoc between-decade comparisons revealed a significant increase of thresholds after the age 60, with particular acceleration of Tritan and Protan loss. For the Ellipses test, significant elongation of major axis falls, too, into the 60+ decade; in comparison, significant increase of the axis ratio falls into the 70+ decade. No gender differences were found for any age cohort.

4. CONCLUSIONS

The present findings are consistent with the notion of parallel decline in sensitivity in all chromatic systems with advancing age and greater vulnerability of the S-cone system (J. Werner et al. 1990; Knoblauch et al. 2001). Our earlier findings for the 20-59 y.o. (Paramei 2012) indicated initial benign deterioration of chromatic discrimination in the 40+ decade, as an incremental loss in the Deutan system (Trivector test), and, in the 50+ decade, as a minor elongation of the major axes of all three Ellipses (Ellipses test) reflecting Tritan loss. Results of the present study single out the 60+ decade as manifesting significant loss of discrimination in all three systems, with prevailing Tritan senescence.

Furthermore, dramatic acceleration of Tritan losses after the age 70 pinpoints the lifespan 'knee', in accord with the estimation obtained with the D-15 test (Haegerstrom-Portnoy et al. 1999). The two significant increments of the Tritan thresholds, in the 50+ and then in the 70+ decade, might reflect onsets of two deterioration processes of different aetiology, lenticular senescence (cf. Nguyen-Tri et al. 2003) and losses in the S-cone pathway (cf. A. Werner et al. 2010).

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Colour Constancy across the Life Span: Effect of Ambient Illumination

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ABSTRACT

It is well known that the peripheral visual system declines with age: the yellowing of the lens causes a selective reduction of short-wavelength light and sensitivity losses occur in the cone receptor mechanisms. At the same time, our subjective experience of colour does not change with age. The main purpose of this large-scale study was to assess the extent to which the human visual system is able to compensate for the changes in the optical media. Our main finding is that supra-threshold colour perception remains largely unaffected by the age-related changes in the optical media (yellowing of the lens). Significant changes in colour appearance are only found for unique green settings under daylight viewing condition which is consistent with the idea that the yellow-blue mechanism is most affected by an increase in age due to selective attenuation of short-wavelength light.

1. INTRODUCTION

The purpose of this study was to assess in a large sample of adult colour-normal observers whether higher-order colour appearance mechanisms are affected by ageing. The cortical colour mechanisms that mediate the unique hues have been characterised using behavioural methods (Wuerger et al, 2005; Wuerger, 2013), but the neural basis of the unique hues is still an unresolved issue (Parkes et al, 2009). In our study we use unique hue judgements as a way to gauge higher-order colour appearance mechanisms since unique hue judgments allow us to obtain absolute appearance judgements without the need for a reference.

Previous studies suggest that hue perception is fairly constant across the life span (Schefrin and Werner 1990; Werner 1996). At the same time age-related changes in the optical media (yellowing of the lens; Pokorny, Smith et al. 1987) occur. A possible explanation for hue constancy with an increase in age is that the higher-order colour mechanisms that mediate hue perception take the difference between the cone signals and are therefore not greatly affected by a signal loss in the peripheral system. For example, an L-M mechanism will stay roughly constant with age, if the decline in the L and M cone signal is parallel.

Here we test this hypothesis directly by assessing hue perception for observers spanning a wide age range and then compare the hue settings with the prediction derived from the changes in the optical media. Our second aim was to evaluate whether adaptation mechanisms that ensure constancy across different ambient viewing conditions, are affected by age. We find that, to a large extent, hue perception is invariant with age; the direction but not the magnitude of the small observed age-related hue changes are predicted by the yellowing of the lens. Our results are consistent with compensatory mechanisms that operate on higher-order colour vision.

2. METHOD

We report a series of three experiments conducted with the same set of colour-normal observers (n=185) covering a wide age range (18-75 y.o.a). All observers made settings under three different ambient illumination conditions, with each condition being tested on a different occasion: under dark viewing conditions, under a day-light simulator (close to D65), or under typical cool white office lighting (CWF). Stimuli were displayed on CRT monitor (21-inch Sony GDM-F520) which was controlled by a DELL PC with a ViSaGe stimulus generator (Cambridge Research System, Ltd.). The experiments were conducted in a sound-attenuated booth the ceiling of which was equipped with a GTI ColorMatcher GLE M5/25 to generate two ambient lighting conditions: a D65 simulator for daylight and CWF for typical office light. The inside of the booth (2m × 2m) is dark grey reflecting only a small amount of light. A white tile (100% reflectance) was placed underneath the light sources and measured by a PhotoResearch PR-650 telespectroradiometer (TSR).

To obtain settings of the unique hues we used a modified hue selection task (Wuerger et al, 2005; Wuerger, 2013). Patches of slightly different hues were arranged along an annulus at constant eccentricity and the task of the observer was to select a patch that contains neither yellow nor blue (to obtain unique red and green). Unique yellow (blue) was obtained by asking observers to select a patch that contains neither red nor green. Each patch had a diameter of 2º of visual angle and was presented at an eccentricity of 4º. Each unique hue was determined at nine combinations of different saturation and brightness levels (ranging from 8.5 cd/m^2 to 60 cd/m^2).

To calculate the cone absorptions in the long-, medium-, and short-wavelength-sensitive cones, we used the 2-deg cone fundamentals derived by Stockman and Sharpe (2000). To estimate the cone coefficients, we followed the procedure outlined in Wuerger (2013). The lens model by Pokorny et al (1987) was used to predict the changes in lens transmission as a function of age. To calculate the age-related relative loss in the three cone classes (L,M,S), the tabulated 2-deg cone fundamentals derived by Stockman and Sharpe (2000) were multiplied with the linear lens transmission. The resulting loss in the L,M,S cone signals a function of age is normalised to unity at 32 years of age (Figure 1).

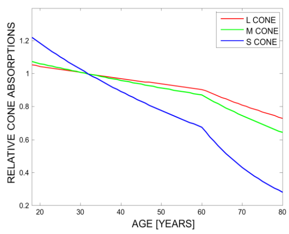

Figure 1. Lens transmission as a function of age. Relative L,M,S cone absorptions as a function of age were derived from the lens model by Pokorny et al (1987) and normalised to unity at 32 years of age.

3. RESULTS AND DISCUSSION

Our main finding is that the cone coefficients are almost constant with age (OBS; Table 1) whereas the coefficients predicted by the lens model (PRED; Table 1) show a significant age dependency for all hues and all illumination conditions ($p<0.001$ for all predictions). Slopes, coefficients of determination and p-values are listed in Table 1 for all hues and all ambient illumination conditions.

Table 1: Regression analysis: Cone coefficients versus age.

IL-LUM	HUE		L COEFF SLOPE	L COEFF R^2	L COEFF p	M COEFF SLOPE	M COEFF R^2	M COEFF p	S COEFF SLOPE	S COEFF R^2	S COEFF p
DARK	YB_R	OBS	-1.57E-05	0.002	0.539	4.00E-05	0.003	0.426	2.73E-06	0.003	0.466
		PRED	-1.14E-04	0.118	0.000	7.17E-04	0.459	0.000	5.20E-05	0.501	0.000
	YB_G	OBS	-8.34E-05	0.005	0.343	1.21E-04	0.003	0.435	-9.60E-06	0.001	0.726
		PRED	-1.06E-03	0.461	0.000	1.17E-03	0.256	0.000	-2.16E-04	0.267	0.000
	RG_Y	OBS	-1.98E-04	0.012	0.138	4.17E-04	0.014	0.103	1.72E-04	0.011	0.152
		PRED	-1.67E-03	0.475	0.000	3.24E-03	0.481	0.000	1.36E-03	0.410	0.000
	RG_B	OBS	-5.55E-07	0.000	0.993	3.40E-05	0.001	0.743	2.66E-06	0.000	0.938
		PRED	-1.09E-03	0.658	0.000	2.30E-03	0.728	0.000	6.76E-04	0.694	0.000
DAYLIGHT (D65)	YB_R	OBS	-1.15E-05	0.002	0.564	2.84E-05	0.003	0.447	1.07E-07	0.000	0.973
		PRED	-1.10E-04	0.156	0.000	7.15E-04	0.573	0.000	5.18E-05	0.594	0.000
	YB_G	OBS	-2.46E-04	0.031	0.016*	4.03E-04	0.026	0.028*	-6.25E-05	0.023	0.040*
		PRED	-1.16E-03	0.422	0.000	1.36E-03	0.238	0.000	-2.37E-04	0.261	0.000
	RG_Y	OBS	-1.38E-04	0.004	0.379	2.99E-04	0.006	0.313	1.25E-04	0.003	0.430
		PRED	-1.65E-03	0.388	0.000	3.17E-03	0.398	0.000	1.37E-03	0.299	0.000
	RG_B	OBS	4.76E-05	0.003	0.424	-5.32E-05	0.001	0.610	4.27E-06	0.000	0.895
		PRED	-1.05E-03	0.636	0.000	2.21E-03	0.710	0.000	6.47E-04	0.665	0.000
COOL WHITE FLOURSE-CENT (CWF)	YB_R	OBS	-1.94E-05	0.004	0.367	2.78E-05	0.002	0.577	2.10E-06	0.002	0.541
		PRED	-1.17E-04	0.148	0.000	7.34E-04	0.540	0.000	5.30E-05	0.556	0.000
	YB_G	OBS	-1.73E-04	0.018	0.069	2.52E-04	0.012	0.138	-3.24E-05	0.006	0.290
		PRED	-1.11E-03	0.448	0.000	1.25E-03	0.243	0.000	-2.32E-04	0.251	0.000
	RG_Y	OBS	-1.42E-04	0.006	0.299	2.95E-04	0.007	0.251	1.06E-04	0.004	0.397
		PRED	-1.60E-03	0.443	0.000	3.10E-03	0.456	0.000	1.26E-03	0.377	0.000
	RG_B	OBS	-4.54E-06	0.000	0.925	3.28E-05	0.001	0.699	5.64E-06	0.000	0.839
		PRED	-1.04E-03	0.700	0.000	2.20E-03	0.758	0.000	6.34E-04	0.729	0.000

We asked whehter the adaptation mechanisms that underlie the hue constancy across age operate in a similar manner for different ambient viewing conditions. Here we find that unique green settings show an age dependency but only when viewed under D65: (Daylight (D65), row for YBG); observed slopes that differ significantly from zero are indicated with a star (*) and printed in bold face in Table 1. The origin of this age-related hue change under daylight viewing conditions is unclear and requires further experiments.

4. CONCLUSIONS

Our main finding is that colour appearance mechanisms are to large extent unaffected by the known age-related changes in the optical media (yellowing of the lens) suggesting that the visual brain can can re-calibrate itself to compensate for these peripheral changes.

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Chromatic Adaptation in an Immersive Viewing Environment

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ABSTRACT

A hollow fibreglass sphere of 750 mm diameter was used to create an immersive mesopic viewing environment. Light was projected through a series of 20nm-bandwidth filters to illuminate the interior of the sphere with a near-monochromatic adapting field. The task of the observer was to set a target to appear neutral grey, using two interactive slider controls. The results suggest that chromatic adaptation is continuing even after an hour, suggesting the influence of retinal mechanisms with a very long time period.

1. INTRODUCTION

Chromatic adaptation is the visual process whereby approximate compensation is made for changes in the colours of stimuli, especially in the case of changes in illuminants (Hunt, 2011). The human visual system tends to adjust colour perception on the assumption that an object of constant reflection spectrum is illuminated by a light source of varying intensity and spectrum, as is usually the case in the natural world. There are many theories about the underlying visual mechanisms of colour constancy (Smithson, 2005). Chromatic induction is the change in perceived color of a light caused by a nearby inducing stimulus (Shevell, 1998) and is at its strongest when the inducing field completely surrounds the target. It is generally assumed that under photopic conditions chromatic adaptation of the cone photoreceptors is complete within a few seconds (Pattanaik *et al*, 2000), whereas for mesopic and scotopic (low-light) conditions at least 15, preferably 25, minutes are needed before the bleached rods become fully active. In all psychophysical experiments observers are allowed an initial period in which to adapt, but then it is invariably assumed that no further changes occur and that the observer's visual operating state remains constant.

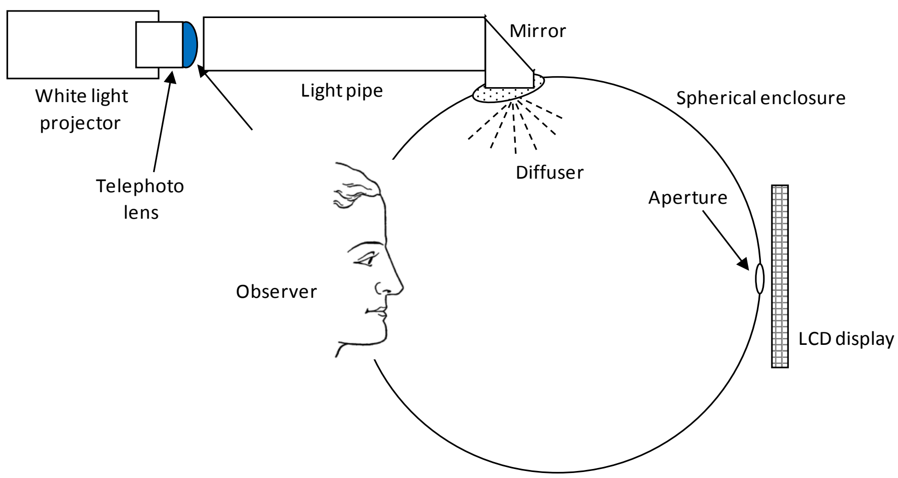

Figure 1. Schematic arrangement of apparatus for experiment.

2. EXPERIMENTAL METHOD

In a novel study a hollow fibreglass sphere of 750 mm diameter was used to create an immersive viewing environment (Fig. 1). The interior surface was painted matte grey, of approx. 38% reflectance factor. The shell was cut away on one side to allow an observer's face to be inserted, from above the top of the head to below the chin and in front of the ears. On the opposite side was a circular aperture of 45 mm diameter, subtending a visual angle of 4° to the seated observer at an eye distance of ~650 mm, through which visual stimuli were presented from a flat-panel LCD display. Above the observer's head was a source of near-monochromatic illumination, passing white light from a Kodak 35mm slide projector with an open gate and 150mm telephoto lens through a single 20nm narrow-band filter. The light was conveyed through a pipe silvered on the inside and through a diffuser to produce approximately uniform illumination throughout the interior of the sphere, and therefore across the observer's entire visual field. The experiment was conducted in a completely darkened room, with the projector screened to minimise stray light. The viewing mode was binocular, without fixation or any other restrictions on eye movement.

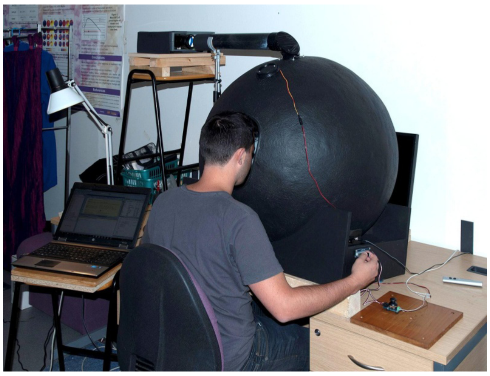

Figure 2. Experimental apparatus in use.

The observer's task was to set the colour seen through the aperture to neutral, by adjusting two linear slider controls (Fig. 2) for independent red-green and yellow-blue variation. The sliders were linked through a micro-controller via a USB interface to a PC running Matlab to update the colour patch interactively on the display. No time restriction was placed on the observer while adjusting the controls, and when a satisfactory visual neutral was achieved a button was pushed to indicate completion. Each 'match' was time-stamped and the R,G,B display values saved. The starting colour for each match was randomised. The task was repeated ten times over for 16 display lightness levels (5-unit decrements of L^* from 85 down to 15) for a fixed adapting wavelength in a single session. For the 16 filter wavelengths, at 20 nm intervals from 400 to 700 nm spanning the visible spectrum, a total of 2560 judgements were recorded.

3. RESULTS

Two observers (LM and TR) completed the full cycle of sixteen sessions. The same procedure was used by both observers, but the white point of the display was changed from 'cool white' for LM (XYZ=99.04,100,151.30) to 'warm white' for TR (XYZ=94.97,100,98.15). Session lengths for the individual wavelengths ranged from 45 to 59 with a mean of 54 minutes (LM) and from 72 to 118 with a mean of 93 minutes (TR), corresponding to average match times of 20 seconds (LM) and 35 seconds (TR).

The spectral power distributions of both surround and display were measured with a PhotoResearch PR-650 spectroradiometer (Fig. 3). The average luminance of the surrounding chromatic adapting field ranged from a maximum of 0.75 cd/m^2 at 560 nm to less than 0.05

cd/m² at the ends of the spectrum, corresponding to a retinal illuminance through a pupil of diameter 8mm ranging from 38 trolands (max) to less than 2.5 trolands, meaning that the viewing environment was in the upper mesopic range.

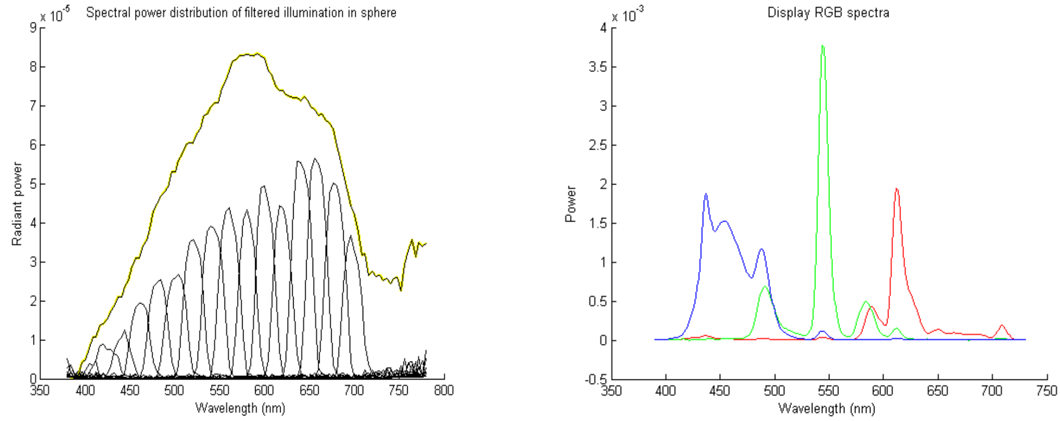

Figure 3. Spectral power distribution measured by PR-650 of: (left) projector light source unfiltered (yellow) and through each filter; and (right) LCD display primaries.

The tone reproduction curve (relationship between 8-bit signal and display luminance) for each channel was determined by interpolating the 21 measured luminance values to give a lookup table of 256 entries. For analysis, the saved display R,G,B signals for each match were converted to L,M,S cone excitations by multiplying the spectral power distribution of each display primary by the corresponding luminance factor (from the LUT), weighting by the spectral sensitivities of the 10° cone fundamentals (Stockman *et al*, 2000), and summing over the full spectrum at 1nm intervals. For visualisation, the data was also interpolated along the time axis to 1-minute intervals and on the wavelength axis to 5nm intervals. Colours are shown as sRGB for a D65 white reference.

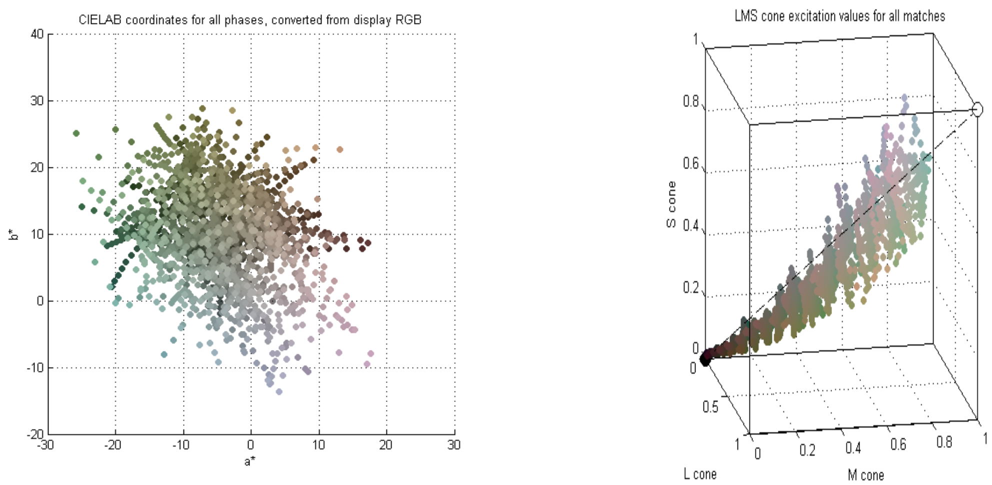

*Figure 4. Display colours selected as neutral: (left) in the CIELAB *a*b* plane; (right) in a cube of normalised L,M,S cone response signals (observer LM).*

4. DISCUSSION

The colours selected as neutral cover a remarkably large colour gamut: -25<*a**<+15 and -15<*b**<+25. Similar variability around the neutral axis is apparent when the corresponding L,M,S cone responses are plotted in a unit cube (Fig. 4). The variation of cone responses against adapting wavelength clearly shows the influence of the chromatic opponent pathways (Hurvich and Jameson, 1957). Plotting the results against time (Fig. 5) also shows the process of adaptation to the coloured surround, with the intrusion of the rods after 10-15 minutes strongly influencing L-cone and S-cone responses. What was surprising, however, was that after 30 minutes the influence of the rods diminished, as if some over-riding mechanism were restoring the chromatic balance to its cone-mediated state. Also the L-cone excitation steadily continued to diminish in the region 480-520 nm, even after 70 minutes for observer TR. To investigate this phenomenon, five consecutive sessions were conducted under the same conditions with a fixed adapting wavelength of 500 nm. The time course of the adaptation was different in every case, with the colour balance (relative output of L,M,S) continuing to fluctuate, but the trend was always downward, indicating the influence of some retinal mechanism with a time constant in excess of one hour. If it can be shown that this is true in general, the result has profound implications for the design of experiments and validity of data from all psychophysical studies where judgements of colour stimuli are made.

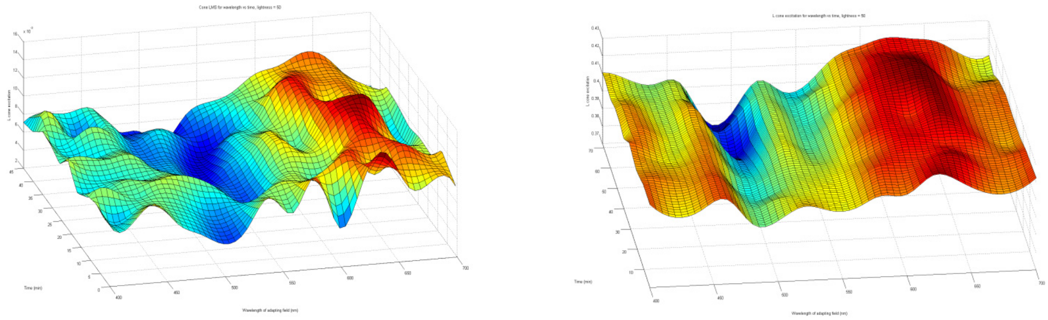

Figure 5. 3D plots of L cone excitation (Z axis) vs adapting wavelength (X axis) and time (Y axis) for two observers: (left) LM and (right) TR.

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Colour, Music, and Emotion

keynote

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BIOGRAPHY

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symposium: human colour vision

Estimating Limits on Colour Vision Performance in Natural Scenes

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ABSTRACT

The aim of this work was to estimate some of the basic limits on human colour vision performance over a range of natural scenes. Computational simulations of colour processing were carried out with 50 hyperspectral images of rural and urban scenes under different daylights. For each scene, three limits were estimated: the number of discriminable coloured surfaces under a single daylight, the relative frequency of metamerism across two daylights, and the mean error in colour matches across two daylights. All three limits were found to vary over scenes by 1–2 orders of magnitude. Some or all of the variation could, however, be explained by a measure of the randomness of the colours in each scene.

1. INTRODUCTION

Colour vision is often characterized by the limits on its performance, for example, the smallest detectable difference in the wavelength of two spectral lights or the largest number of surface colours that can be discriminated from each other. Such estimates are based on simple experimental stimulus arrangements or theoretical abstractions which are easy to specify, but which may have uncertain relevance when used to represent the natural world. One reason is that natural scenes are generally difficult to describe or analyse theoretically, owing to their complex spectral and spatial variation. This variation affects both detection and discrimination performance.

The aim of the work reported here was to estimate some of the basic limits on human colour vision performance over a range natural scenes. Computational simulations of colour processing were carried with 50 hyperspectral images of rural and urban scenes under different daylight illuminants. Each hyperspectral image provided a reflectance spectrum at each point or pixel in the scene, and a basis for estimating the signal arriving at the eye for any particular daylight illuminant.

Three limits on colour vision performance were considered: first, the number of visually discriminable coloured surfaces under a single daylight; second, the relative frequency of metamerism across two daylights; and third, the mean error in surface-colour matches across two daylights. Large variations in each of these limits were found over scenes. This variation was modelled by a measure of the randomness of the colours in each scene.

Part of this work is based on material in Marín-Franch and Foster (2010) and Feng and Foster (2012).

2. METHOD

Details of the methods used for the simulations have been described elsewhere (Foster et al. 2006; Marín-Franch and Foster, 2010). In brief, each hyperspectral image had dimensions ≤ 1344 ´ 1024 pixels and spectral range 400–720 nm sampled at 10-nm intervals, providing an effective spectral reflectance r(l; x, y) at each wavelength l and pixel position (x, y). For a given daylight illuminant with radiance spectrum e(l), the reflected radiance c(l; x, y) at each

(x, y) was simulated by the product $c(l; x, y) = e(l)r(l; x, y)$. The assumptions underlying this description and their validity are discussed in Foster et al. (2006).

The reflected spectrum $c(l; x, y)$ at each (x, y) was converted to tristimulus values X, Y, Z according to the CIE 1931 standard observer and then to colour values J, a_C, b_C, corresponding to lightness and the red-green and yellow-blue components of chroma in the colour space CIECAM02 (CIE 2004). This space has the property that constant Euclidean differences DE = $(\mathrm{D}J^2 + \Delta a_C^{\;2} + \Delta b_C^{\;2})^{1/2}$ in colour values correspond to almost constant perceptual colour differences (Luo, Cui and Li 2006; Melgosa, Huertas and Berns 2008). The values J, a_C, b_C were calculated at each pixel in each scene according to the CIECAM02 specification (CIE 2004) with default parameters, but with full chromatic adaptation. Integrations were performed numerically over 400–720 nm with the given 10-nm sampling interval.

2.1 Number of discriminable surfaces

The number N of visually discriminable coloured surfaces was estimated with the aid of Shannon's channel-coding theorem (Cover and Thomas 2006). For any particular illuminant on a scene, the values (J, a_C, b_C) may be treated as instances of a trivariate continuous random variable U and similarly the observer's response, in the same coordinate system, as a trivariate continuous random variable V (Marín-Franch and Foster 2010). The logarithm of N is then given by the mutual information I between U and V.

The mutual information was derived from estimates of the differential entropy of the colours of each scene under a standard daylight with correlated colour temperature (CCT) of 6500 K and the differential entropy of the observer's response, as in Marín-Franch and Foster (2010). The differential entropy was estimated with an asymptotically bias-free, k-nearest-neighbour estimator due to Kozachenko and Leonenko (1987).

2.2 Frequency of metamerism

The relative frequency of metamerism is the probability of a pair of surfaces that are not visually discriminable under one illuminant being discriminable under another illuminant. Estimates of the relative frequency of metamerism were obtained as in Foster et al. (2006).

Thus, with spatially uniform random sampling, $n = 10^9$ pairs of pixels were drawn from each scene, and from this set, the subset of n_0 pairs with colour differences less than a nominal threshold $\Delta E^{\mathrm{thr}} = 0.5$ was found for a daylight with CCT of 4000 K. From this set of n_0 pairs, the subset of n_1 pairs with colour differences greater than ΔE^{thr} was then found for a second daylight with CCT of 25,000 K (on a mired scale, these two CCTs are roughly equidistant from a CCT of 6500 K). The relative frequency of metamerism in the scene was estimated by the quotient n_1/n.

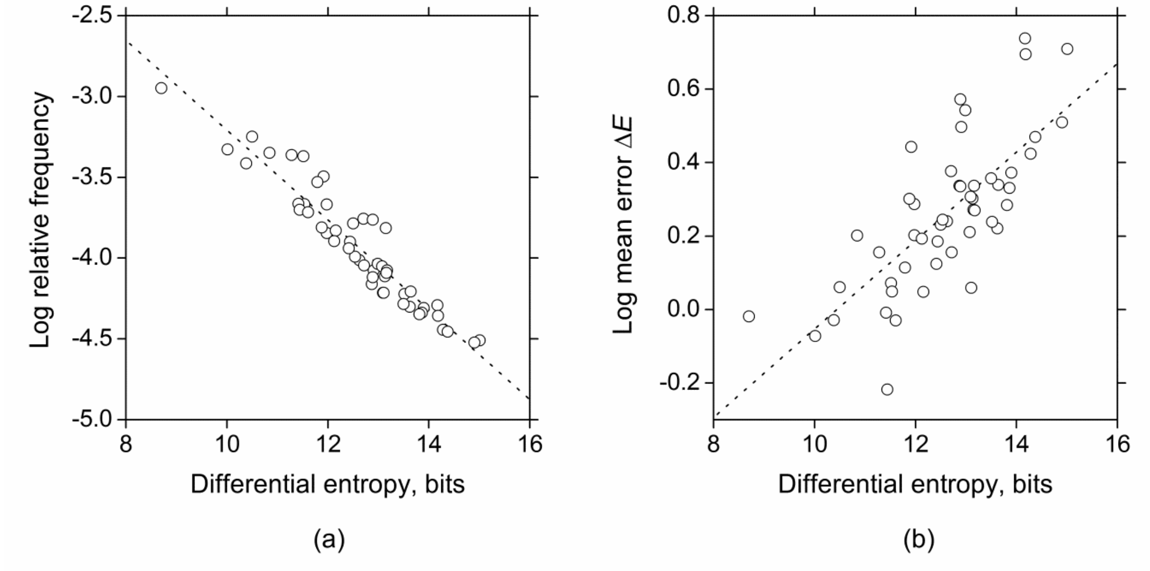

Figure 1: Logarithm of (a) relative frequency of metamerism and (b) mean colour-matching error as a function of differential entropy of scene colours. Each symbol represents data from a different scene and the dotted line is a linear regression.

2.3 Frequency of errors in colour matches

Surface colour matching gives a measure of colour constancy. It was quantified by the errors in matches made by a standard observer across the two daylights with CCTs of 4000 and 25,000 K. For each pixel in each scene, the difference $\mathrm{D}E = (\mathrm{D}J'^2 + \Delta a_C^2 + \Delta b_C^2)^{1/2}$ in colour values under the two daylights was calculated and averaged over the scene.

3. RESULTS

The estimated number N of discriminable coloured surfaces varied strongly over scenes, from 3.5×10^3 with a scene containing grey-white buildings to 2.7×10^5 for a scene containing coloured flowers. By construction of the estimator, the logarithm of N depended linearly on the differential entropy of the colours in the scene under the selected daylight. Results are not plotted here, but the proportion R^2 of variance accounted for by differential entropy was 99%.

The estimated relative frequency n_1/n of metamerism also varied strongly over scenes, from 3.0×10^{-5} to 1.1×10^{-3} (cf. Foster et al. 2006). Although the relative frequency, unlike the number of discriminable coloured surfaces, does not in principle bear the same relationship to the entropy of the colours in a scene under a single illuminant, differential entropy remained a powerful explanatory variable. In Fig. 1(a), the logarithm of the relative frequency of metamerism is plotted against the estimated differential entropy of the colours under the first selected daylight. The proportion R^2 of variance accounted for was 90%.

The mean colour error DE in colour matching under the two daylights varied less strongly over scenes, from 0.61 to 5.5. This measure is in principle even less closely related to the differential entropy of the colours in a scene under a single illuminant, but differential entropy retained some explanatory power. In Fig. 1(b), the logarithm of the mean colour error is plotted against the estimated differential entropy of the colours under the first selected daylight. The proportion R^2 of variance accounted for was 55%.

4. DISCUSSION

Natural scenes are complex and their properties are difficult to predict. Variations in scene colour gamut and in the relative abundances of colours within each gamut (Burton and Moorhead 1987) set basic limits on colour vision performance in any given scene.

Nevertheless, some or all of the large variation in performance over scenes can be explained simply by the differential entropy of the colours in each scene under a single daylight. Thus differential entropy accounted for 99% of the variance in the number of discriminable coloured surfaces and for 90% of the variance in the relative frequency of metamerism, despite the latter involving two daylights rather than one. But differential entropy does not offer a complete explanation, and it accounted for only 55% of the variance in the mean error in colour matching across two daylights. As indicated in Feng and Foster (2012), a better description of colour vision performance in natural scenes requires a fuller model, one with more than a single explanatory variable.

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interior design and lighting

Psychological Effects of White or Off-white Base Colours of a House Interior: A Comparative Study of the Elderly and the Young

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ABSTRACT

This study was conducted on the elderly and the young to evaluate the psychological effects of white or off-white base colours on residents of houses by using computer-generated (CG) images. As a result of the factor analysis, extracted factors were shown to be common to the two generations. Warm-coloured walls are comfortable while too white or too bright a space is uncomfortable and intolerable. However, with regard to the relationships between psychological and physical factors, evaluations differ between the two generations: The elderly needed lower valued floors for comfort. The young are tolerant towards walls coloured in variety of hues and in higher chroma.

1. INTRODUCTION

In recent times, white or off-white colours have often been used as base colours on ceilings or walls of house interiors. According to a survey of the last fifteen years conducted by the authors, most ceilings and the walls of living rooms are white or off-white. This trend is significant in a house for sale, because for many people white is hardly dislikable. However, it is not clear whether a resident truly accepts the white or off-white interior. In addition, recently it has been required that the lighting efficiency of a house be increased in order to save energy. Since it increases the reflectance of surfaces, this base colour trend for interior spaces will continue for some time. However, the psychological and physiological effects of white or off-white base colours on residents of houses have not been investigated. This study was conducted to evaluate such an effect on the elderly and the young using computer-generated (CG) images.

2. EXPERIMENTAL METHOD

The experimental factors adopted were the colour of a wall and a floor. For the wall, 23 white or off-white colours often used as base colours in home interiors were chosen, and for the floor, three achromatic colours were selected, namely N7, N8, and N9. A total of 69 experimental patterns were made with a combination of the wall and the floor colours. The colour of the ceiling adopted was white only. Table 1 shows the colours of the experimental patterns in the Munsell colour notations. CG images were created with high accuracy with three-dimensional software, the 3ds-Max. An interior space sized 4.5 m in width, 4.5 m in depth, and 2.4 m in ceiling height was modelled in the CG space. Subjects were asked to evaluate the impression of CG images that appeared on computer monitors. Fifteen semantic differential seven point rating scales and a tolerance seven point rating scale were used as the subjective appraisals. In terms of participants, 40 female observers, comprising 20 young and 20 elderly people, were asked for their evaluations.

Table 1. The colours of the experimental patterns.

No.	Wall			Floor	No.	Wall			Floor	No.	Wall			Floor
	Hue	Value	Croma	Value		Hue	Value	Croma	Value		Hue	Value	Croma	Value
1	5R	9	1.5	N7	13	5Y	9	1.5	N7	25	5G	9	1.5	N7
2	5R	9	1.5	N8	14	5Y	9	1.5	N8	26	5G	9	1.5	N8
3	5R	9	1.5	N9	15	5Y	9	1.5	N9	27	5G	9	1.5	N9
4	5R	9	0.5	N7	16	5Y	9	0.5	N7	28	5G	9	0.5	N7
5	5R	9	0.5	N8	17	5Y	9	0.5	N8	29	5G	9	0.5	N8
6	5R	9	0.5	N9	18	5Y	9	0.5	N9	30	5G	9	0.5	N9
7	5YR	9	1.5	N7	19	5GY	9	1.5	N7	31	5BG	9	1.5	N7
8	5YR	9	1.5	N8	20	5GY	9	1.5	N8	32	5BG	9	1.5	N8
9	5YR	9	1.5	N9	21	5GY	9	1.5	N9	33	5BG	9	1.5	N9
10	5YR	9	0.5	N7	22	5GY	9	0.5	N7	34	5BG	9	0.5	N7
11	5YR	9	0.5	N8	23	5GY	9	0.5	N8	35	5BG	9	0.5	N8
12	5YR	9	0.5	N9	24	5GY	9	0.5	N9	36	5BG	9	0.5	N9

No.	Wall			Floor	No.	Wall			Floor	No.	Wall			Floor
	Hue	Value	Croma	Value		Hue	Value	Croma	Value		Hue	Value	Croma	Value
37	5B	9	1.5	N7	49	5P	9	1.5	N7	61	10YR	8	2	N7
38	5B	9	1.5	N8	50	5P	9	1.5	N8	62	10YR	8	2	N8
39	5B	9	1.5	N9	51	5P	9	1.5	N9	63	10YR	8	2	N9
40	5B	9	0.5	N7	52	5P	9	0.5	N7	64	N8			N7
41	5B	9	0.5	N8	53	5P	9	0.5	N8	65	N8			N8
42	5B	9	0.5	N9	54	5P	9	0.5	N9	66	N8			N9
43	5PB	9	1.5	N7	55	5RP	9	1.5	N7	67	N9.5			N7
44	5PB	9	1.5	N8	56	5RP	9	1.5	N8	68	N9.5			N8
45	5PB	9	1.5	N9	57	5RP	9	1.5	N9	69	N9.5			N9
46	5PB	9	0.5	N7	58	5RP	9	0.5	N7					
47	5PB	9	0.5	N8	59	5RP	9	0.5	N8					
48	5PB	9	0.5	N9	60	5RP	9	0.5	N9					

3. RESULTS AND DISCUSSION

3.1 Semantic Differential Rating

Using factor analysis, the semantic differential rating data were separately analysed for the young and the elderly. Table 2 shows the factor loading of each scale concerning both generations. The primary and the secondary factors, 'cheerfulness' and 'comfort', which describe the atmosphere of the interior, were extracted for each generation. Factor scores for each experimental pattern are plotted on a plane consisting of 'cheerfulness' and 'comfort' concerning the young and the elderly (see Figure 1). As for the young, a strong relationship between 'cheerfulness' and the value of the floor was found. The higher the values of the floor, the higher were the factor scores for 'cheerfulness'. It seems that 'cheerfulness' has a relationship with the hues or chromas of the wall. The higher the chromas of the wall, the higher were the factor scores for 'cheerfulness'. The pattern with the white wall has a neutral score. A strong relationship between 'comfort' and the hue of the wall was also found. Experimental patterns having warm wall colours obtained higher scores for 'comfort', while those having achromatic colours received lower scores. A relationship between 'comfort' and the value of the floor was found. The lower the values of the floor, the higher were the factor scores for 'comfort'. Patterns with the white wall and white floor had lower scores. As for the elderly, a relationship between 'cheerfulness' and the hue of the wall was found. Experimental patterns having reddish wall colours had higher factor scores for 'cheerfulness'. A relationship between 'cheerfulness' and the value of the floor was found. The lower the values of the floor, the lower were the factor scores. Patterns with the white wall and white floor also had lower scores. A relationship between 'comfort' and the value of the floor was clearly found. The lower the values of the floor, the higher were the factor scores for 'comfort' experimental patterns; those having higher values for the floor had lower scores.

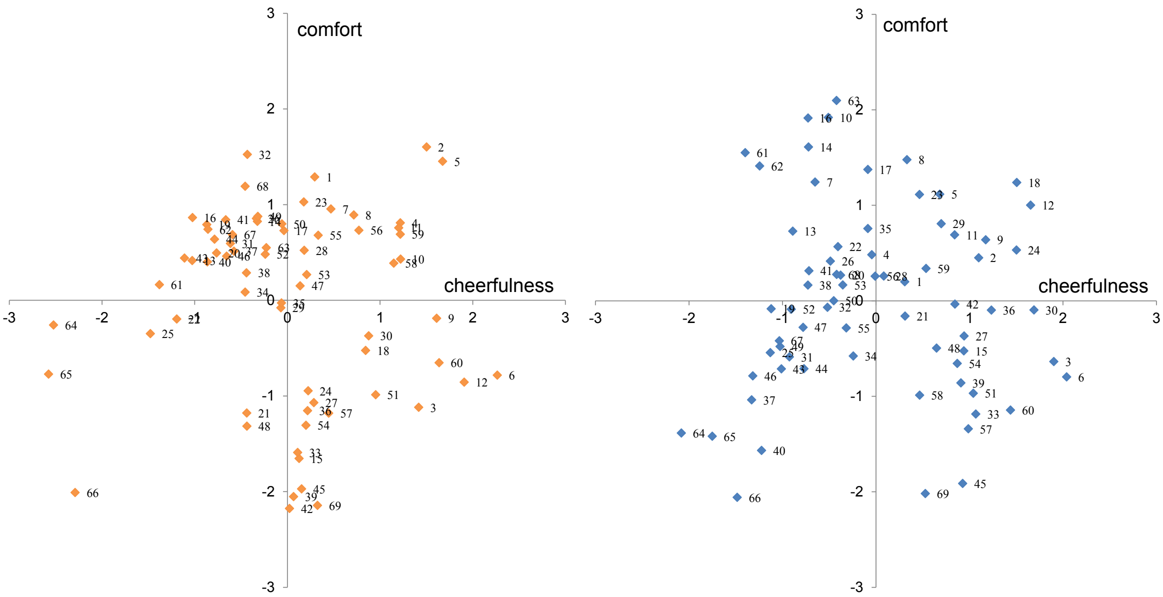
Analyses of variances were conducted using the General Linear Model procedure. Raw data for 'cheerful-gloomy' and 'comfortable-uncomfortable' scales were used as dependent variables representing 'cheerful' and 'comfort' respectively, because factor scores are imaginary values computed artificially. Experimental factors were the generation, the value of the floor, the chroma of the wall, and the hue of the wall. As for 'cheerful-gloomy', the effects of all experimental factors were statistically significant (Level of Significance 0.05). Figure 2 shows the profile plots of each experimental factor for 'cheerful-gloomy'. As for generation, the score for the elderly is higher than that for the young. As for the value of the floor, the higher the value, the higher the score was. As for the chroma of the wall, the higher the chroma, the higher the score was. As for the hue of the wall, warm colours received a higher evaluation. As for 'comfortable-uncomfortable', the effects of all experimental factors, except for chroma of wall, were statistically significant (Level of Significance 0.05). Figure 3 shows the profile plots of each experimental factor for ‘comfortable–uncomfortable’. As for generation, the score for the young is higher than that for the elderly. As for the value of the floor, the score of N9 was the lowest. As for the hue of the wall, warm colours received a higher evaluation. More specifically YR had the highest score.

3.2 Evaluation of Tolerance

The evaluation of tolerance shows a strong relationship with the factor scores for ‘comfort’. Correlation coefficients between those stated above with regard to the young and the elderly are 0.91 and 0.97 respectively.

Table 2. The factor loading of each scale.

The eldery			The young			
Semantic differential scales	Factor		Semantic differential scales	Factor		
	Cheerfulness	Comfort		Cheerfulness	Comfort	Boring
Cheerful-Gloomy	0.974	0.071	Cheerful-Gloomy	0.982	0.124	0.045
Showy-Plain	0.967	-0.104	Showy-Plain	0.968	0.031	-0.139
Light-Heavy	0.948	0.035	Bright-Dark	0.952	-0.067	0.287
Bright-Dark	0.924	-0.179	Light-Heavy	0.923	-0.048	0.293
Soft-Hard	0.918	0.124	Soft-Hard	0.881	0.367	0.068
Warm-Cold	0.877	0.168	Calm-Nervous	-0.778	0.528	-0.181
New-Old	0.873	0.030	Beautiful-Ugly	0.707	0.019	0.554
Varied-Monotonous	0.624	0.438	Warm-Cold	0.669	0.542	-0.162
Comfortable-Uncomfortable	0.026	0.980	Comfortable-Uncomfortable	-0.235	0.921	0.070
Likeable-Dislikeable	0.068	0.970	Likeable-Dislikeable	0.002	0.881	0.133
Calm-Nervous	-0.366	0.888	Relaxed-Tense	0.351	0.863	-0.810
Beautiful-Ugly	0.305	0.871	Natural-Unnatural	0.305	0.767	0.051
Varied-Monotonous	-0.038	0.859	New-Old	0.315	-0.723	0.344
Natural-Unnatural	0.078	0.790	Refined-Rude	0.278	0.165	0.668
Relaxed-Tense	0.589	0.659	Varied-Monotonous	0.246	0.552	-0.663
Contribution (%)	46.6	36.9	Contribution (%)	43.3	30.3	10.6
Accumulated contribution (%)	46.6	83.4	Accumulated contribution (%)	43.3	73.6	84.2



The elderly **The young**

Figure 1: Configurations of each experimental pattern in factor space.

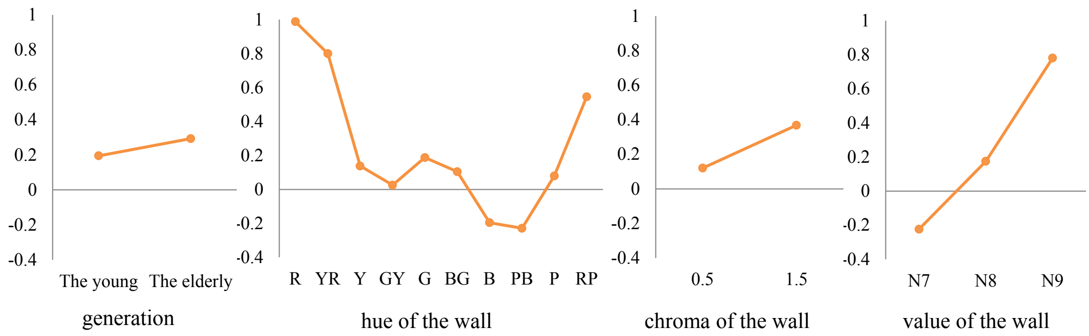


Figure 2: The profile plots of each experimental factor for 'cheerful-gloomy'.

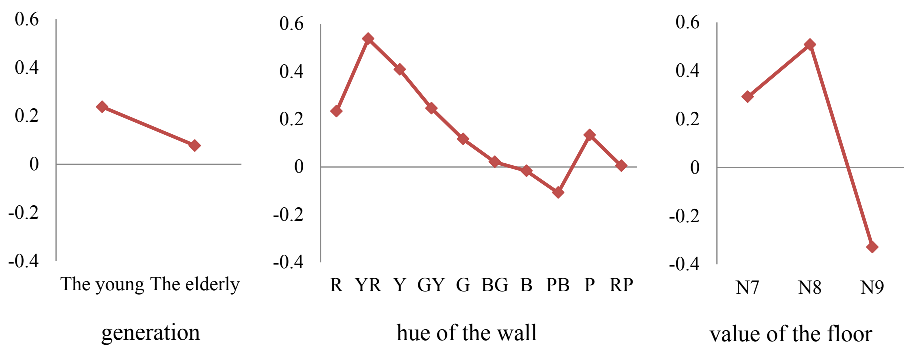


Figure 3: The profile plots of each experimental factor for 'comfortable – uncomfortable'.

4. CONCLUSIONS

As a result of the factor analysis, extracted factors were shown to be common to the two generations. The evaluations are also similar for both generations: Warm-coloured walls are comfortable while too white or too bright a space is uncomfortable and intolerable. However, with regard to the relationships between psychological factors and physical factors, evaluations differ between the two generations: The elderly needed lower valued floors for comfort. The young are tolerant towards walls coloured in variety of hues and in higher chroma.

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Effects of Coloured Lighting on the Perception of Interior Spaces

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ABSTRACT

This study compares different coloured lightings (red, green and white) in order to understand their effects on interior space perception. Participants evaluated the experiment room according to a questionnaire that was prepared for testing six main evaluative factors: pleasantness, spaciousness, aesthetics, use, comfort and lighting quality. It was found that coloured lighting (red and green) affects the perception of an interior space and space perception differs according to the colour of lighting for some of the evaluative factors. For instance, under coloured lightings the space was found more aesthetic than under white lighting. On the other hand, under white lighting the space was found more useful than under coloured lightings.

1. INTRODUCTION

Light and colour are important physical factors influencing the perception of a space. Whether natural or artificial, light affects people both physiologically and psychologically. Light can change the perception of a space in different ways. By changing the quality and quantity of light, impressions of a space can be reinforced, weakened or changed entirely. Various studies have investigated the psychological aspects of lighting and the effects of light on space perception (Flynn et al. 1979; Flynn et al. 1973; Durak et al. 2007; Manav 2007; Manav and Yener 1999; Loe, Mansfield and Rowlands 2000; Boyce and Cuttle 1990). However, there are not any studies that have been conducted investigating the effects of coloured light on space perception. Coloured lights, as light do, have an influence on psychology and physiology of people. There are various interior spaces in which coloured lighting is used such as bars, night clubs, hotels, restaurants, houses, offices, museums, cinemas and shops. Coloured lights are increasingly being used in diverse spaces; therefore, understanding the effects of coloured lighting on space perception is gaining importance.

2. METHOD

The aim of this study is to explore the effects of coloured lighting on space perception in an experimental set-up. It is hypothesized that coloured lighting has an effect on and there are differences between white and coloured lighting in the perception of an interior space.

2.1 Sample

The sample group consisted of 97 students (59 females and 38 males, mean age 21.36) from Bilkent University in Ankara, Turkey. As it was important to eliminate the effects of interpersonal differences, the experiment was conducted for the three different lighting conditions with the same sample group.

2.2 Experiment Room

The experiment was conducted in the Building Science Laboratory of the Department of Interior Architecture and Environmental Design at Bilkent University. The room has no windows and no heating units. The room measures 4.10 × 4.18 m (17.138 m^2 total area) and the ceiling height is 3.84 m. The walls and the ceiling are painted in matte white (Munsell N9) and the floor is covered with 30 × 30 cm gray (Munsell N5) terrazzo tiles. There were one chair (indicated as b) where the participants sat while evaluating the room and one torchere lamp (indicated as a) for task lighting in the room (Figure 1).

Fluorescent lamps were used for the experiment and the walls were washed, one colour at a time, with red (chromaticity coordinate x → 0.595, y → 0.335), green (chromaticity coordinate x → 0.313, y → 0.547) and white (chromaticity coordinate x → 0.328, y → 0.348) lights. In addition to these, a compact fluorescent lamp with a colour temperature value of 6500K was installed in the torchere for task lighting that was used simultaneously with all three lightings. The illuminance on the surface of the armrest of the chair where the participants filled in the questionnaire was fixed to 323 lux for all lightings.

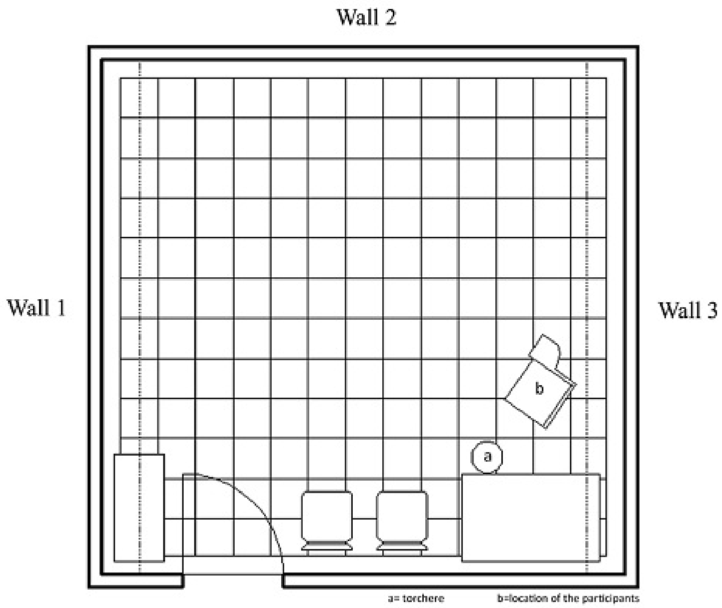

Figure 1: Plan of the experiment room.

Mean values of the wall surface luminances of the experiment room were at the proximate levels as shown in Table 1. Figure 1 shows the walls; all measurements are in cd/m^2.

Table 1. Wall surface luminances of the experiment room in cd/m^2.

	Wall 1	**Wall 2**	**Wall 3**
RED	60.7	73.2	62.1
GREEN	62.3	73.5	64.0
WHITE	62.8	74.2	64.3

2.3 Preparation of the Questionnaire

A common psychophysical method used in lighting research is semantic differential (SD) scaling. In order to prepare the questionnaire, firstly, bipolar adjectives from previous studies about lighting and colour were gathered and arranged by eliminating and adding some adjectives considering the experiment room's condition and their translation in Turkish. The adjective pairs that remained after these eliminations and additions were divided into groups according to the factors they evaluated (pleasantness, spaciousness, aesthetics, use, comfort and lighting quality) and used in the questionnaire for evaluating the perception of space under different lightings.

2.4 Procedure

The participants were first tested for their colour vision with Ishihara's tests for colour blindness. Participants who passed the Ishihara tests took part in the experiment. Only one participant was in the experiment room at a time. Each participant evaluated the space under one coloured lighting using 5-point bipolar semantic differential rating scale for each of the adjective pairs presented to them. As the same sample group experienced all three different lighting conditions, in order to eliminate the effect of order, there was at least one week in between viewing of each lighting set-up.

3. RESULTS

Statistical analysis (ANOVA) showed that there are significant differences between coloured lightings in terms of comfort, lighting quality and spaciousness (Table 2). There are significant differences between coloured lightings and white lighting in terms of aesthetics, comfort, lighting quality, spaciousness and use (Table 2).

Table 2. Results of ANOVA.

Pleasantness	Spaciousness	Aesthetics	Use	Comfort	Lighting Q.
F= 2.328 p= 0.130	F= 64.563 p= 0.000	F= 38.126 p= 0.000	F= 46.304 p= 0.000	F= 18.688 p= 0.000	F= 122.895 p= 0.000

When the mean values of all lightings were compared, the results showed that under white lighting the space was found more spacious than under coloured lightings, and under green more spacious than under red. Under coloured lightings the space was found more aesthetic than under white lighting. The space was found more useful under white lighting than under coloured lightings and under green lighting it was found more useful than under red lighting. Under red lighting the space was found less comfortable than under green and white lightings.

The adjectives in the group "lighting quality" were bright vs. dim, clear vs. hazy, light vs. dark and good lighting vs. poor lighting. The mean values showed that under white lighting the space was perceived as clearer and more luminous and that white light was perceived as brighter than the coloured lights. Moreover, mean values showed that under green lighting the space was perceived as clearer and more luminous and that green light was perceived as brighter than red light. White lighting is found better than green and green lighting is found better than red.

4. CONCLUSIONS

Findings of this study suggest that an interior space is perceived equally pleasant under white, green and red lighting. White lighting makes a space to be perceived more useful, spacious, clear and luminous. Among coloured lighting, green lighting would make the same effect. Green and white lighting are perceived equally comfortable in an interior space. Ultimately, coloured lighting (green and red) are found to be more aesthetic in a space than white lighting. The results of this study can be useful for interior architects, designers and those who use light in order to create different atmospheres in a space. It is important for designers to understand light and lighting in a space so that they may use it effectively. The results also may assist researchers who study colour, light and their effects on human psychology and perception.

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Colour Planning in Urban Furniture: Development of a Project Methodology

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ABSTRACT

This paper presents a Post-Doctoral research which investigates a new methodology for urban furniture colour planning, giving continuity to the research topics from a former project. The aim of the methodology is to establish the importance of a pertinent and structured colour application to urban furniture, which will make possible to create colour plans for urban environments, allowing urban furniture to stand out from its background, contributing for their better legibility, and transforming them in identification elements that will improve the orientation within the cities. The development and implementation of the new methodology will allow the determination, with a higher scientific approach and rigor, of the colour planning to be applied to urban furniture in each district or urban area, of a city.

1. INTRODUCTION

A former project aimed to define and emphasize the importance of Colour application to urban furniture, arguing that a pertinent application of colour to these elements may contribute for a better visualisation and, consequently, to ameliorate its use. The study also addressed the issue of the colour application to the city environment, mainly for city areas identification and how its use would increment the orientation within the city, becoming colour a signage factor.

During the process of defining colours for the urban furniture of the chosen study cases we acknowledged that the existent methodologies of support to data recording and creation of Chromatic Plans, which are generally mainly linked to architecture, were not sufficiently adequate to reach the objectives of this study, neither the expected and desired results. In order to fulfil the project needs, a new methodology was developed, becoming an important part of the PhD thesis. Therefore, we acknowledged that it should be improved, and have a further development, to become a true new and scientific methodology to create urban chromatic plans including other issues like urban furniture.

2. FUNDAMENTATION

The urban furniture concept was only institutionalized from the mid-20th century (Serra 1998). However, we may consider that, although not with this designation, it has always existed. In urban environment, people need places to seat, being that the church marches or a stone on the edge of a path. Accesses are prevented by railings and, on streets and fairs, there always have been trading booths. When the populations increased and become organized in villages and towns, the implantation of these elements started to become systematized.

The urban furniture choice exceeds aesthetics, or the simple wish to decorate the city, it must accomplish its functional requirements in order to fulfill the population needs, facilitating their lives and contributing to their comfort. So, to assure its functionality, urban furniture must protect the health and well-being of the city inhabitants; facilitate the accessibility and use to people with visual or motor difficulties; reinforce the local identity, representing a formal *family* that is coherent and values the surroundings (Águas 2003). However, while recognizing its necessity, the urban furniture functional possibilities have not been used to their fullest extent, and the choice of its colour or form only rarely obeys to a logic thought.

2.1 Inclusive Design / Design for All / Universal Design

> Inclusive Design is a way of designing products and environments so that they are usable and appealing to everyone regardless of age, ability or circumstance by working with users to remove barriers in the social, technical, political and economic processes underpinning building and design. (Fletcher, 2006 apud Pinheiro, 2012)

We must consider the impossibility to contemplate all people's needs with high disabilities. However, the objective of inclusive design must be to erase, as much as possible, the differences between disabled and able-bodied people. Effectively, all human beings must benefit from the improvement of visibility on urban furniture and everyone, disabled or not, will feel more comfortable if the bus stop, the bench or the waste bin, they are looking for, stands out from the environment without the need of an accurate search.

Despite its recent development, inclusive design issues are primarily focused on people with motor limitations and tend to forget visual disabled people. Though, we must consider that the city population is constituted by a wide variety of people, with different visual acuities and limitations and, also, by a high percentage of older people. Insofar as people grow older, their ability to see small details decreases and eyes have a crescent difficulty of adaptation to sudden changes of light or a quick change in focus. Bearing in mind the visual limited population, only a small percentage is unable to see any colour and the main part is able to distinguish luminosity differences (Lindemann et al 2004). Therefore, to have better visibility conditions, under an inclusive design perspective, urban furniture must present a good chromatic and luminosity contrast. Considering this, Per Mollerup (2005:161) states that "color can be seen from longer distances than other graphic elements" and that "in signage differentiation is the first and foremost role of color".

2.2 Chromatic planning existent methodologies

Urban plans that are concerned with colour application to cities, generally employ methodologies directly related with the cities different characteristics and are mainly focused in architecture.

On recovery or restoration of historic cities, the chromatic plans are usually based on file collections that tell the architectonic and chromatic history of the zone or city researched, and on samples of the buildings coatings extracts, which allow the determination of each building colours during their life time. Examples of this methodology application are the well-known chromatic plans of Turin and Barcelona.

The chromatic planning methodologies meant to be applied to new cities or zones, which are yet to be build, cannot use historic file collections except for the mention of the region traditional colours. Also, they only use the colours of the natural environment, and not the surveys of building existing colours.

Since 1965, Jean-Philippe Lenclos has developed a methodology called *Colour Geography*, which constitutes an inspiration source to other authors of urban chromatic plans. This methodology focuses on the search and definition of specific local colours, the environmental colour, that may include the survey of the chromatic palette both of the existent materials and local vegetation, in order to create harmonic, or similar, sets which will allow the chromatic plans preparation, considering colour as an adaptive language to a defined context.

Michael Lancaster, Tom Porter, Shingo Yoshida and Grete Smedal, among others, have applied similar methodologies to their chromatic plans projects.

3. METHODOLOGY FOR COLOUR PLANNING

The present research project is focused in Portuguese cities, with different characteristics, establishing as result colour plans that can be applied whenever there is a need to design urban furniture chromatic plans.

The new methodology applies to the study cases an extensive direct observation, with the use of mechanical devices, including photographic mapping of both urban furniture and signage, in order to evaluate their visibility and legibility, as well as their colour applications. In each urban area, and to facilitate the study, shall be defined a sample area, including the main streets and places and, also, some secondary ones, with the intention of encompassing the most representative zones, those with specific characteristics. Along the chosen area, an exhaustive record of all the environmental colours is made, including material samples not only from the buildings, but also from pavements, vegetation and any additional elements present with a relative permanence in the urban environment − *the non permanent colours* − that must be taken into account for the spatial chromatic readings, which are then classified using the Natural Colour System (NCS). Among the environmental colours we must take in account the percentage in which the sky colour will interfere on the urban area colour.

These collections, that take in account the chromatic variations along the different climatic seasons, are completed by photographs of the environment elements and panoramic views from the different blocks, using urban plans, architectural elevations and sections of the selected paths as well, which act as elements of the environment colour components. All these records are methodically indexed in forms and maps, previously designed and tested, which allows the creation of a data base guided by scientific rigor, in order to determine a chromatic palette for each quarter, or urban area and, consequently, to establish a coherent chromatic plan that may be applied to urban furniture.

This palette is tested along the seasons' changes to judge the chromatic alterations aroused from the different colours of the vegetation as well as day light variations, sky colours according to weather changes to evaluate the chromatic plan pertinence.

In order to guarantee the scientific rigor on each quarter chromatic plan determination, we consider the dominant colours, proportionally represented, choosing colours to the urban furniture which may establish an adequate chromatic and luminosity contrast with the dominant colours and, also, respect the traditions, culture, identity and history of the quarter.

The urban furniture chromatic plan, which will be different for every quarter, must stand out from the environment, contributing for a better legibility and identification of these elements and, in the same way, will become a city's area identification element which may be used in different supports and, this way, facilitate the orientation and wayfinding within the city.

4. EXPECTED RESULTS

We expect that this methodology, which establishes the importance of a pertinent and structured colour application to urban furniture, will contribute to the enlargement of the urban chromatic plans perspective, allowing them to become more holistic and comprehensive.

In addition to the inclusion of all the environmental colours, being them from architecture, vegetation, skies and all other elements that constitute urban spaces this methodology takes in account perceptive factors related with colour interactions, as well as the geographic and atmospheric conditions. In consequence, the urban chromatic plans will gain a higher scientific approach and rigor.

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White Lighting: a Theoretical and Empirical Framework

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ABSTRACT

Recently, Rea and Freyssinier were able to define a line of minimum tint in chromaticity space for sources of illumination of different correlated colour temperatures (CCTs). They noted that chromaticities along the line of minimum tint were not metamers but, rather, that they should represent, for a given CCT, chromaticities where the neural signals from the two spectral opponent channels were minimized. Recently, Wuerger and colleagues provided a framework for interpreting the four unique hues in terms of differential absorptions by the three cone photopigments. Using their theoretical framework for interpreting unique hues, it was possible to represent the empirically derived line of minimum tint for sources of illumination of different CCTs. In a follow-up experiment, Wuerger's framework was used to model the amount of tint perceived in six different sources of illumination. That study, presented here, in conjunction with the studies by Rea and Freyssinier and by Wuerger and colleagues provide empirical as well as theoretical support for an industry-sanctioned line of minimum tint in chromaticity space that could be used as a basis for characterizing sources of "white lighting" and ones of a specific tint as they might be used in architectural applications.

1. BACKGROUND

Rea and Freyssinier (2013) showed that chromaticities of illumination perceived as "white" do not always plot on the line of blackbody radiation. As shown in Figure 1, chromaticities associated with minimal tint trace a "white" line of illumination through the chromaticity diagram. These "white" sources of illumination are sometimes perceived as more similar to one another than they each are to sources of illumination of the same correlated color temperature (CCT) on the blackbody locus. However, these "white" sources are not metameric, suggesting subtle differences in their apparent hues and/or their apparent hue magnitudes.

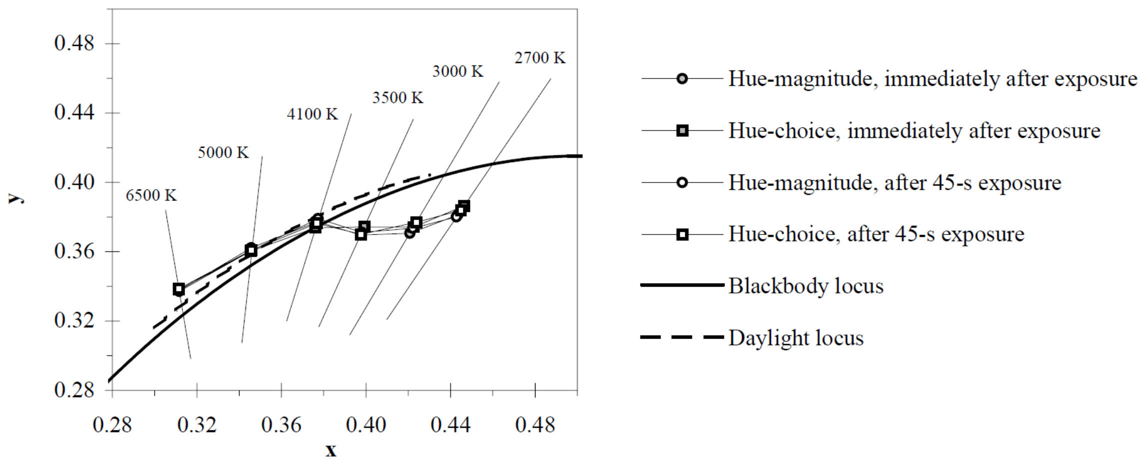

Figure 1. Estimated "white" points for different CCTs based on hue-choice and hue-magnitude estimations obtained immediately following and after 45-s exposures (after Rea and Freyssinier, 2013). Data were obtained from subjects viewing an empty viewing box illuminated to 300 lx (~72 cd/m²).

Surprisingly, no other empirical studies have been undertaken to examine perceptions of "white" illumination as might be used for architectural applications. Moreover, no theoretical analyses have been performed to understand and to predict how people perceive "white" illumination. In principle, however, the appearance of the "white" sources of illumination should be governed by spectral opponent processes in the retina and brain (Ingling 1977, Hurvich and Jameson 1957, MacLeod and Boynton 1979). More specifically, "white" illumination should be seen when the output from both the blue versus yellow and red versus green spectral opponent process are minimized (Valberg 1971). A provisional model based upon conventional color theory was developed to predict the apparent tint and the magnitude of apparent tint in sources of "white" illumination that might be used in architectural applications.

Recently Wuerger and colleagues (2005) established a method for characterizing the four unique hues (red, green, yellow and blue) in a color space based upon the S-, M- and L-cone absorption fundamentals and the two spectrally opponent channels, red versus green (r-g) and blue versus yellow (b-y). In their characterizations, unique blue and unique yellow (i.e., r-g = 0) are on the same spectral-opponent axis. In other words, unique blue and unique yellow are approximately 180° from each other in the cone absorption color space. In contrast, unique green and unique red (i.e., b-y = 0) are not 180º apart in the cone absorption space. Rather, the angular relationship between the lines for unique green and for unique red suggest very different response characteristics for the b-y channel, or channels, and indeed their relationship seems to change with light level (Deng et al. 2005). In fact, Wuerger and colleagues suggest that there is not one, but two, b-y channels with different neural response characteristics (Wuerger et al. 2005).

2 ANALYTICAL AND EXPERMENTAL APPROACHES

We began our analysis by examining whether our "white" illumination data (Figure 1) could be rationalized within the color space presented by Wuerger and colleagues. More precisely, we wanted to determine whether our empirical data were compatible with the cone absorption and spectral opponent framework provided by Wuerger and colleagues. In principle, all six of our "white" chromaticities, one for each CCT, should plot near the origin of their color space. Figure 2 shows the chromaticities of sources of minimum tint from Rea and Freyssinier (2013) in a color space like that developed by Wuerger and colleagues. The unique hue lines from Wuerger and colleagues are shown together with their associated spectral wavelengths. The coefficient values for the cone fundamental in this color space are also shown in Figure 2, providing a provisional model for characterizing the quality of the tint (hue) and the magnitude of that tint for sources of "white" illumination.

The implicit predictions of tint magnitude were tested empirically. Six sources illuminated the viewing box used previously by Rea and Freyssinier. Three pairs of CCTs, 2700 K, 3500 K and 5000 K, were employed; one source of each pair had a chromaticity on the line of blackbody radiation (designated "B") while one source of each pair had a chromaticity on the "white" line from Figure 1 (designated "W"). Subjects made estimates of tint magnitudes immediately after viewing the illuminated box and after 45 s of viewing. As can be seen in Figure 3, there is a high correlation between the predicted tint magnitudes, equal to the radial distance from the origin, and the observed hue magnitudes for both the immediate and the 45-s viewing conditions. It should also be noted in this figure that the slope relating the observed responses and the model predictions decreases with time of adaptation (immediate viewing, left, versus viewing after 45 s, right). This change in slope suggests, as would be expected, that tint becomes less pronounced with viewing time (Fairchild 2005). It is important to add, as Rea and Freyssinier (2013) previously stressed, that chromaticities associated with "white" do not change with viewing duration; rather, a wider range of chromaticities are accepted as "white" with longer viewing times.

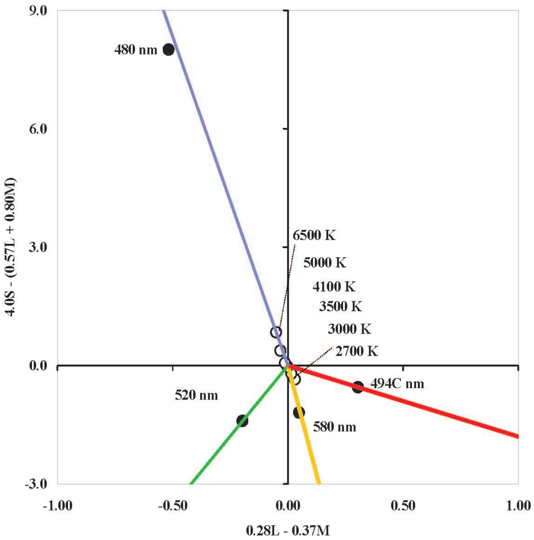

Figure 2. Location of the unique hue lines from Wuerger and colleagues as well as the corresponding spectral unique hues 480 nm, 520 nm, 580 nm, and 494C nm in DKL space (Wuerger et al. 2005) for equal luminance when the cone-fundamental scaling coefficients are those shown in each axis. Also shown are the six estimates of "white" illumination from Rea and Freyssinier (2013) plotted in Figure 1.

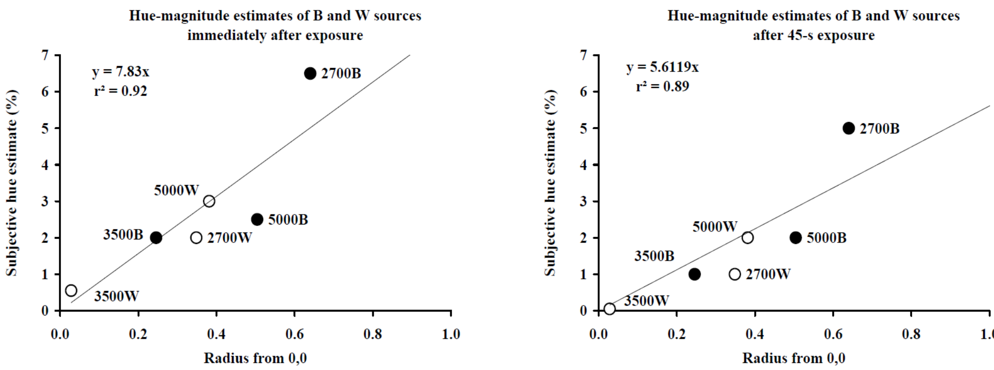

Figure 3. Correlations between the subjective hue-estimates of the six experimental sources and the radial distances from the origin of those sources derived from the secondary, spectral-opponent color space (Figure 2). Distances are scaled for equal luminance using the coefficients in Figure 2.

SUMMARY

The provisional model developed here was useful for predicting the amount of tint observed in the validation experiment. The data and theoretical framework represent only one adaptation level, so it is important to extend these findings to other adaptation levels. Nevertheless, the provisional model provides a basis for predicting the amount of tint in "white" sources of illumination that might be used in architectural applications.

ACKNOWLEDGEMENTS

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Investigation of Spectral Power Distributions of LED Light Sources to Provide Preferred Colors of Natural Objects

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ABSTRACT

This paper reports the results of psychophysical investigation of the SPDs that provide preference colors to natural objects illuminated by a LED light source system with eight-primary colors. Observers evaluated six kinds of impression for color appearances of natural objects illuminated by lights with different SPDs. The results showed that moderate high saturation in color appearance of the natural object provided observers with a preference color. However, an excessively high saturated color reproduced by an illumination reduced subjective impression scores except for vividness.

1. INTRODUCTION

An LED light source is easy to control and adjust spectral power distributions (SPDs) compared to a fluorescent lamp or an incandescent lamp by combining different colored LED devices or selecting added fluorescent materials to the LED device. Therefore, we can design the SPD of LED light source so that the LED light source provides a preferred color to a particular object. The properties of an illuminant have been characterized by the CIE Color Rendering Index (CRI) for many years. However, several studies recently have reported that observers often prefer the color appearance under the illuminant such as an LED light source with a low CRI rather than that under a broadband light with a high CRI (Hashimoto et al 2007, Rea and Freyssinier 2008, 2010). Therefore, it is necessary to establish a new color rendering index for recent new light sources.

In this study, we investigated the SPDs of LED light sources providing preferred colors to natural objects including fruits and vegetables by using a LED light source system with eight-primary colors.

2. METHOD

2.1 Light source conditions

We prepared 8 different light source conditions: one reference light source condition and seven test light source conditions. The reference light source was a fluorescent lamp (Toshiba FL20S-N-EDL-D50) at 5000K. The seven test light sources were made by the LED light source system consisting of eight primaries. Whereas the seven test light sources had the same correlated color temperature as the reference lightning, the SPDs of them were different. The illuminances of the reference light source and the seven test light sources were 200 lx. Table 1 shows lighting properties of the 8 light source conditions. Figure 1 shows SPDs of the 8 light source conditions.

2.2 Subjects

Twenty subjects (13 males and 7 females) participated in the experiments. All subjects had normal color vision confirmed by the Ishihara color vision test.

Table 1. Lighting properties of the 8 light source conditions.

Name	Sources	Illuminance (lx)	CCT (K)	Ra	FCI	CQS
#1	RGB LED	204.4	4620	31	179	54
#2	RAGB LED	194.7	4832	67	145	69
#3	RAGB LED	191.8	4915	82	126	73
#4	RAGB LED	188.8	4986	82	100	70
#5	AGB LED	185.2	4879	58	63	47
#6	GB+WW LED	191.9	4632	86	101	73
#7	RGB+WW LED	193.4	4803	85	130	77
D50	fluorescent lamp	190.9	4808	95	105	78

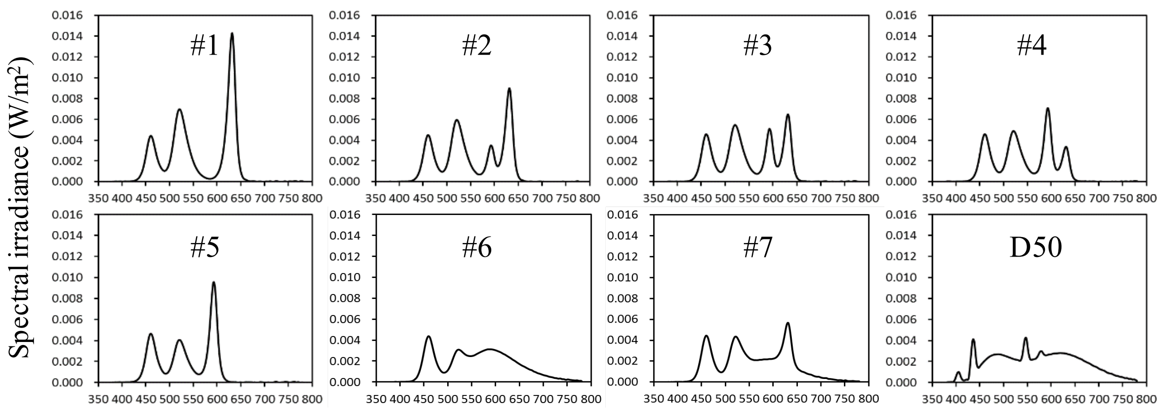

Figure 1: The SPDs of the 8 light source conditions.

2.3 Natural Objects

We used an apple, a peach, an orange, and a banana as natural objects in this experiment. Figure 2 shows the spectral reflectance factors for the natural objects. Figure 3 shows the CIE 1931xy chromaticity coordinates of these natural objects illuminated by the 8 lighting conditions.

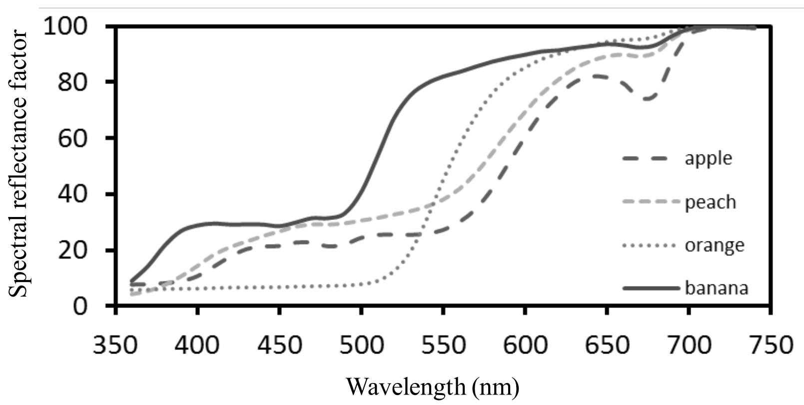

Figure 2: The spectral reflectance factors of the natural objects.

2.4 Procedure

We prepared two illumination boxes in darkroom. The fluorescent lamp (D50 in Table 1) was set up at the top of the one box, and the eight-primary LED light source system (#1 to #7 in Table 1) was at the top of the other box. In the experiment, the observers evaluated subjective impressions (i.e. deliciousness, naturalness, vividness, safety, suitableness, and appetite of consumer) of a natural object illuminated by one of the test light sources compared with that illuminated by the reference light source by a 7-point rating method.

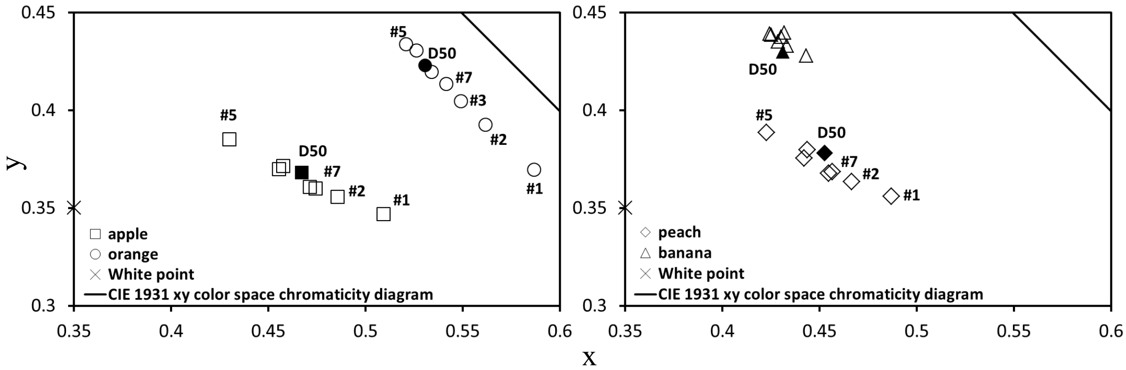

Figure 3: The CIE 1931xy chromaticity coordinates of natural objects illuminated by the eight kinds of lighting source.

3. RESULTS AND DISCUSSION

Figure 4 shows the results of average subjective impressions obtained in the experiment. We applied the two-factor (the 7 light source conditions and the 4 natural object conditions) analysis of variance to these data. Then, there were significant differences among the object conditions except for difference between the apple and the peach conditions. This suggests that the SPD of light source providing the preferred color depends on the natural object's color (e.g. red, orange, yellow, and green) or the rough spectral reflectance property.

In the light source conditions, when these red objects (i.e. an apple and a peach) were illuminated by the test light source with a high ratio of the red LED (i.e. #1), they were evaluated more delicious and vivid than those illuminated by the other test light sources. On the other hand, the test light source of #1 reduced perceived naturalness and suitableness of the red objects. The best light source condition for the red objects was either the test light source consisting of the red, green, blue, and the few amber LEDs (i.e. #2) or the broadband LED light source including the warm white LED (i.e. #7). For an orange, the test light source with an intermediate ratio of the amber LED (i.e. #3) provided high evaluations in naturalness, safety, suitableness, and the appetite of consumer.

In summary, moderate high saturation in color appearance of the natural object provides observers with a preference color. However, the excessively high saturated color reproduced by an illumination reduces the subjective impression scores except for vividness.

Lastly, we examined the correlations of the subjective impression score with color rendering indices (Table 2). The Ra had high correlations with the subjective impression scores of naturalness and suitableness. The FCI (Hashimoto et al 2007) had high correlations with the scores deliciousness and vividness. The CQS (Davis and Ohno 2007) had high correlations with the scores of safety, naturalness, suitableness, and appetite of consumer. These results suggest that it is necessary to choose a color rendering index, depending on a purpose.

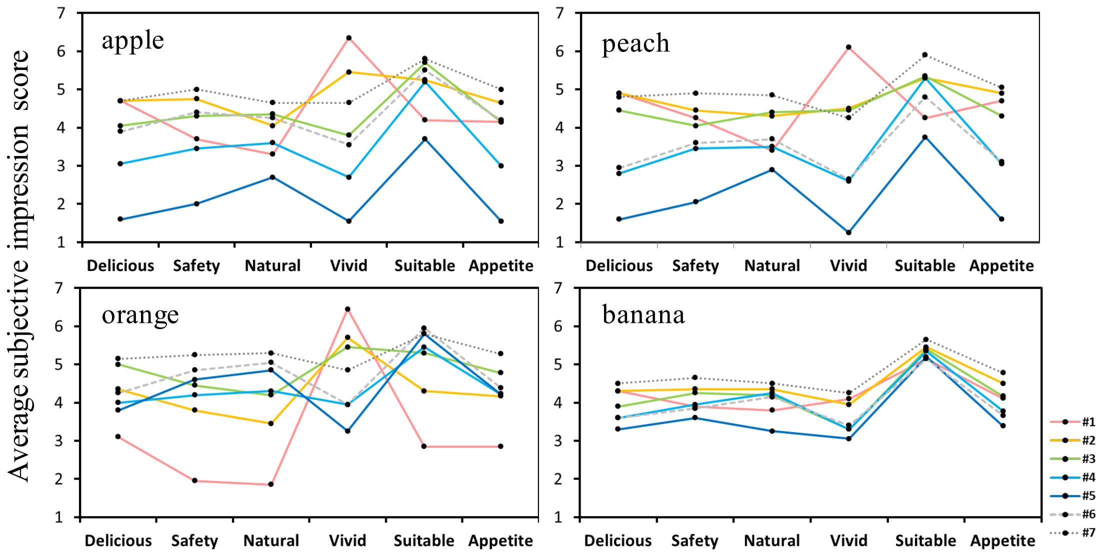

Figure 4: Results of the average subjective impression score for each natural object.

Table 2. Correlation of the subjective impression score with the color-rendering indices.

	Ra	FCI	CQS
Deliciousness	0.15	0.53	0.50
Safety	0.52	0.03	0.59
Naturalness	0.65	-0.20	0.59
Vividness	-0.34	0.79	0.14
Suitableness	0.66	-0.31	0.53
Appetite of consumer	0.30	0.38	0.57

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Colour Performance of a Mixed-LED White Light Source

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ABSTRACT

A subjective viewing experiment was performed to provide empirical evidence of the colour-rendering performance of a mixed-LED white light source by comparison with conventional (tungsten-halogen) museum lighting. It can be inferred from the results of the experiment that the observers in general were unable to make a clear distinction between the performance of the two light sources.

1. INTRODUCTION

The American Institute for Conservation organised a Lighting Workshop to precede its 2007 Annual Conference, held in Richmond, Virginia, and with support from the Getty Conservation Institute, the second author conducted an assessment survey as one of the workshop activities (Cuttle 2009). Because of the limited publicity for the original experiment, and in response to prompting from colour rendering researchers, this paper is offered as a means of making the work accessible to the wider colour community.

2. THE EXPERIMENT

Two identical display cases were constructed (Figure 1), one illuminated by a tungsten-halogen lamp (12V MR-16 3500K dichroic) and the other by a mixed set of LEDs (Philips "Luxeon" LED sources, Red, Amber, Green and Blue in colour).

"LightWorks" software was used to control the LED outputs, enabling data storage for SPDs representing optimal combinations for various colour temperatures, and for cross fading between these spectra. In this way, illuminance and colour temperature could be varied independently while maintaining optimal balance of the individual LED outputs. The chromaticity of the LED combination was matched to that of the halogen lamp, and both displays were maintained at 50 lux throughout the survey.

The display cases were set up on opposite sides of a partition in a dimly lit room at the conference centre, as shown in Figure 2. A total of 114 workshop participants completed the survey in three sessions, and for each session the following pairs of identical coloured objects were displayed in the two cases:

(i) Gretag Macbeth ColorChecker® charts

(ii) groups of coloured ceramic objects

(iii) reproductions of a Claude Monet painting.

Subjects completed a questionnaire with four questions concerning their assessments of the clarity of detail, the colour appearance of the lighting, the colour appearance of each displayed object, and their overall viewing experience.

Figure 1: The display cases during set-up with the ColorChecker® charts on view.

Figure 2: Participants assessing objects in the two cases, on opposite sides of the partition.

3. RESULTS AND DISCUSSION

This section presents a summary and analysis of the participants' responses to each of the questions posed. Display Case A was lit by the tungsten-halogen lamp, and Case B by the blended LED source. Scene references are: Scene 1 = Color Checker; Scene 2 = Ceramic Artefacts; Scene 3 = Monet reproduction.

3.1 Question 1: Clarity of Detail?

The clarity scale given in the questionnaire appeared to confuse some subjects since it appeared to offer ten options for comparing Displays A and B when, in reality, there were only five. For purposes of analysis the Clarity Scale is expressed as: 1 = A more clear; 2 = A slightly more clear; 3 = Equally clear; 4 = A slightly less clear; 5 = A less clear.

This permitted the analysis to be performed numerically, by assigning one of the above values to each observer's response for each scene. Table 1 presents the summary results for all 114 subjects. On this basis, one may expect an average score of 3.0 if the subjects as a group were unable to distinguish between the properties of the two source types.

Table 1. Summary of responses to Question 1.

	Scene 1	Scene 2	Scene 3
Maximum	5	5	5
Minimum	1	1	1
Average	3.23	3.45	3.04
Std. Dev.	1.34	1.44	1.49

These results indicate a very small preference for the mixed-LED source in Display B; but the relatively large standard deviation indicates the difficulties the observers, as a group, experienced in assigning a conclusive response. In fact, 10 observers chose to avoid giving a response for one or more of the scenes.

3.2 Question 2: Relative Colour Appearance of the Lighting?

The observers were offered the opportunity to repond to a suggested set of colour appearance categories; and some clearly identifiable subjective distinctions emerged. The lighting in

Booth A was seen to be more white, more cool, more yellow, and more green. The lighting in Booth B appeared more warm, more red, and more purple.

Observers were also asked to nominate which display (A or B) gave the more acceptable lighting colour. The results are summarized in Table 2.

Table 2. Summary of results for Question 2.

	Scene 1			Scene 2			Scene 3		
	Prefer A	Prefer B	No Resp.	Prefer A	Prefer B	No Resp.	Prefer A	Prefer B	No Resp.
Totals	53	49	12	43	50	21	55	38	21
Nett in favour of A	4			–7			17		

Noting that there was a 16% non-response rate, these results indictate a small, but somewhat inconclusive, response in favour of Display A.

3.3 Question 3: Relative Colour Appearance of the Displayed Object?

The format of this question was similar to the previous question, with the difference that responses were elicited for "more natural", "more artificial", *etc*. Some instances of inconsistencies became evident when the responses to this question were being recorded. The emerging distinctions were that the displayed object in Booth A appeared more natural, less clearly revealed, and more dim. The object in Booth B appeared more artificial, more clearly revealed, and brighter. For some observers, the appearance of distorted hues was more strongly associated with Booth B.

Observers were also asked to nominate which display (A or B) gave the more acceptable object colours. The results are summarized in Table 3.

Table 3. Summary of results for Question 3.

	Scene 1			Scene 2			Scene 3		
	Prefer A	Prefer B	No Resp.	Prefer A	Prefer B	No Resp.	Prefer A	Prefer B	No Resp.
Totals	52	50	12	49	46	19	54	41	19
Nett in favour of A	2			3			13		

Here one notes a slight drop in the non-response rate to 15% – and again a small, barely significant, preference for Display A.

3.4 Question 4: Overall Viewing Experience?

Observers were asked to respond separetely for each scene. The observer satisfaction scale has been given the following numerical values, and the results are summarized in Table 4: 1 = Very Satisfactory ... 2 ... 3... 4 = Satisfactory ... 5 ... 6 ... 7 = Very Unsatisfactory. It is evident that the better viewing experience corresponds with the lower score.

Table 4. Summary of responses to Question 4.

	Booth A				Booth B			
	Scene 1	Scene 2	Scene 3	Booth A Average	Scene 1	Scene 2	Scene 3	Booth B Average
Maximum	7	7	7		7	7	7	
Minimum	1	1	1		1	1	1	
Average	4.49	4.49	4.43	4.48	4.28	4.46	4.43	4.38
Std. Dev.	1.58	1.50	1.33		1.54	1.42	1.55	

This result shows a small (probably insignificant) preference for the mixed-LED source.

4. CONCLUSIONS

It would be fair to say that the differences of appearance between the two displays were subtle, and the analysis of results identified only small differences in averaged responses. It needs to be borne in mind that that the subjects in this experiment were museum professionals who had opted to participate in a two-day workshop on museum lighting. The subjects were fairly consistent in observing differences in colour appearance, but the results did not clearly identify one source to be preferred or perform better than the other. On the basis of this survey, there is no reason to consider the discontinuous SPD of the LED combination to be visually less acceptable than the broad spectrum of the tungsten-halogen lamp, for the viewing of coloured objects.

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Development of Dimensional Model of Lighting Affectiveness and its Application to Orchestra Lighting

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ABSTRACT

As a pursuit of theoretical basis of affective lighting, we have established a dimensional model of lighting affectiveness which is based on Korean affective words describing various lighting experience and feelings. We collected 2,194 Korean affective words from previous studies on the classification of universal human emotion and the sensibility evaluation of lightings conducted in diverse disciples including psychology, linguistics, design, architecture and so on. We chose 264 candidate words for a rating task on the appropriateness as the lighting affective word and finally selected 40 words related to the lighting affectiveness. Based on the results, we had a similarity rating on every word pairs consisted of the 40 affective words carried out to examine the relations among the words and conducted a multidimensional scaling (MDS) analysis which found out dimensions of lighting affectiveness in the Euclidian distance model. Through the analysis, we identified two dimensions of lighting affectiveness, 'Natural'-'Artificial' and 'Warm'-'Cool'. After MDS, we tried to apply the model to our newly developed floor-standing lighting, the Orchestra, which was experimentally combined with several IT-technologies. The result of this study will provide a useful methodology for the development of affective lighting in the future.

1. INTRODUCTION

In our society, the results of design such as products, indoor space, and urban environment are the critical factors in affecting the quality of human life. Accordingly, it is important to realize design which reflects well and understands the emotion. If the emotion will be realized as the technology to be applied to the real life design and products, the foundation which is based on the design can be first established in the academic and basic systematic way.

As the human emotion is handled in various fields such as literature, design, engineering, medicine and psychology etc, it should be first defined as a concept which can be used in various disciplines through interdisciplinary exchanges and studies, and also the method of measuring regarding the emotion should be developed.

Accordingly, in this study, regarding the affective lighting which has not been clearly defined in the field of lighting, we hope to contribute to come up with its theoretical foundation to propose the dimensional model of lighting affectiveness.

The results of this study may be utilized as the basic evaluation tool using the affetive words and deriving the concept. As an example of it, we would like to find out what kinds of emotional effects are reflected under the lighting scenes where the light parameters are classified into the visual factors under the various lighting environment using the case of the Orchestra, which is resemble to Korean traditional porcelain, Yijobaekja, in its shape and color (Woo and Murano 2008). Also, the Orchestra was experimentally combined with several IT-technologies like voice recognition, Bluetooth music player, smart phone application control and so on.

2. METHOD

2.1 Sampling of affective words

The linguistic expressions of emotion cannot be the direct indication of emotion such as physiological indication and facial expression. It is easy for people to control the linguistic expressions of emotion, therefore there is a lot of possibility that they will reduce or exaggerate, twist or shield the expression of emotion when they are affected by their socio-cultural situations and personalities.

In addition, if people aren't conscious of their emotional status accurately, the words for expression cannot represent the emotional status exactly. However, it is also true that the linguistic expressions are the means for human to express their emotions in various and delicate way and one of the best developed ways of expressing their emotions. That is, the major emotions which people experience in their life are defined as the words in the most cases (Russell 2003).

Based on these background, we have collected 2194 affective words that are used in 3 papers which have been frequently quoted as emotional Korean words and the paper on the language system for emotional evaluation (Son et al. 2012 ; Park and Min 2005 ; Han and Kang 2000 ; Jung and Na 2007). And then, we reduced the number of the collected words by using several psychological and linguistic methods of word analysis like semantic network, word frequency, and association strength level. As a result, we derived 264 candidate words from these words.

Using the words, we have conducted a rating task on the appropriateness as the lighting affective words and finally selected 40 affective words related to the lighting affectiveness. The 40 affective words are as follows: sweet, intense, holy, cheerful, quality, calm, vintage, pure, radiant, unique, warm, romantic, fabulous, bright, soothing, refreshing, creative, vivid, classy, cool, mystical, beautiful, pretty, gentle, elegant, soft, natural, kind, balanced, tranquil, friendly, comfortable, relaxed, happy, modern, luxurious, dazzling, energetic, intriguing, dim.

A similarity rating on every word pairs consisted of the 40 affective words was carried out to examine the relations among the words and a multi-dimensional scaling (MDS) analysis was conducted to find out dimensions of lighting affectiveness in the Euclidian distance model.

2.2 Development of dimensional model of lighting affectiveness

Through a multi-dimensional scaling (MDS) analysis, we got the dimensional model of lighting affectiveness which shows the Euclidean distance between two words. The results are shown in Figure 1.

As shown in Figure 1, the horizontal axis is affected by the cool and the warm factors while the vertical axis is affected by the artificial and the natural factors. So we call Dimension 1 as 'Cool-Warm' and Dimension 2 as 'Artificial-Natural'. The dimensional model of lighting affectiveness will be a good tool in realizing the lights in real life.

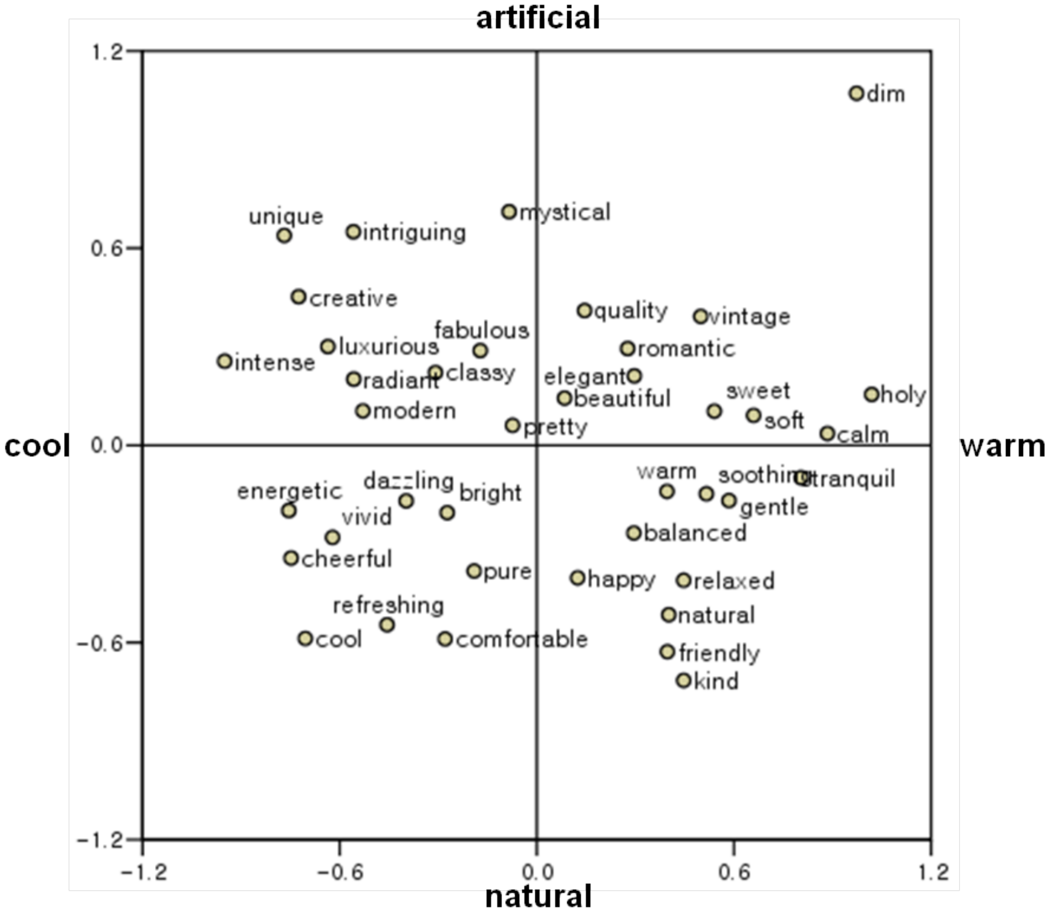

Figure 1: Dimensional model of lighting affectiveness.

3. APPLICATION

The dimensional model of lighting affectiveness can be applied to two different applications when it is combined with the qualitative elements of light[1] in the future. First, it can be applied when the emotion felt in lighting environment will be realized. Second, it can be used in analyzing the lighting scenes which is realized by the luminaires. Now, we are studying the correlation between the qualitative elements of light and lighting emotion. We think that this study would be a helpful understanding of light and emotion in the future. In this paper, we find out that the emotion felt through the luminarie called 'the Orchestra'has what positions and how to harmonize with various emotions in the dimensional model of lighting affectiveness.

Above all, we classified the visual parameters of light used in the Orchestra and then analyzed the emotional scenes in lighting environment since looking for the words to which these factors are connected in dimensional model of lighting affectiveness. The results was shown that the affective word 'refreshing' is more related to the direct and indirect parameter and correlated color temperature, several factors of the qualitative elements of light, while the affective words such as 'romantic and gentle' are more related to the direction of light. The affective word 'soft' is more related to the weak pattern and intensity of light while the word 'vintage' is related to both direct and indirect effect and the direction of light.

1 The qualitative elements of light are composed of sixteen visual parameters; Brightness, Tone, Hue, Saturation, Provenance, Modeled, Orientation, Reflection, Transparency, Translucency, Tralucency, Clearness, Uniformity, Pattern, Confine, Expansion

As shown in the light environment analysis of the Orchestra according to the dimensional model of lighting affectiveness, the affective word 'refreshing' appeared to more relate to the affective words 'cool and comfortable' which are the smallest Ecludian distance from refreshing.

4. CONCLUSIONS

As described in the introduction of this study, the dimensional model of lighting affectiveness would contribute to the construction of theoretical foundation for affective lighting which has not clearly defined yet. It is expected to be widely used as a basic tool in evaluation and concept derivation using the affective words.

It is necessary to find out what kinds of parameters of light are involved when the lighting is actually expressed using the affective words, and the related studies are now in process. As shown in the Orchestra, we hope that the affective words related to the visual parameters of light can be applied not only the lighting, environment design, architecture but also various application fields such as IT technology, UI/UX and emotional interface.

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colour education

CDES - Colour Design Edu.System: An Educational Tool for a Creative, Systematic and Interdisciplinary Colour Knowledge

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ABSTRACT

The PhD research "Colour Design Edu.System. For a systematic and creative approach to an interdisciplinary colour education in design" (2009-2012) identifies in education and *Design Thinking* the opportunity to develop a shared colour culture in step with the complexity and interdisciplinarity of today's knowledge. The context of design education has been chosen to develop and test the *CDES Toolkit*, conceived both as propaedeutic and supplemental tool and method for the colour design activity, supporting students and teachers from research to the *meta-design* phase. The toolkit is made of two sets of cards of which one was tested through *action research strategy* at three European design schools. Both as educational toolkit and online service, the *CDES* is going to be subject of new workshops and test phases, to contribute to the development of those "colour design communities" in which each type of expertise and discipline can participate creatively and "designerly" to the knowledge sharing in the huge colour scenario.

1. INTRODUCTION

The interest in colour has increased in the recent years; because it surrounds us and has a strong influence on our lives, it has an outstanding role in the market's mechanisms, and affects the research and project activities in any disciplinary field. Moreover the increasing number of national and international colour organisations, and their activities to promote the sharing of a common colour knowledge demonstrate the interest on the subject all over the world, across cultures and disciplines. But despite this will and enthusiasm in exchanging knowledge and opinions, the problem of communication among the different disciplines and types of expertise is considerable, because of the meeting of different concepts, tools and methods, languages, and cultures.

As a continuation of *The Colour Scenario*[1] analysis, and as s connection to the purpose of the web colour platform *Coloret*[2], the *Colour Design Edu.System* research[3] deals with how to support the development of a shared colour knowledge considering its aspects of interdisciplinarity and complexity, approaching them through the tools and methods of *Design*

1 *The Colour Scenario* research was conducted by Colour Lab, Design Department of Politecnico di Milano (www.labcolore.polimi.it), with the support of AICC-Italian Coil Coating Association, from May 2007 to September 2008.

2 *Coloret* is a research project by Colour Lab, Design Department of Politecnico di Milano, which benefits various partners' collaboration (i.e. enterprises and international universities), and aims for monitoring the contemporary colour scenario, favouring new dialogues between the different fields and types of expertise, supporting the construction of a real colour culture (www.coloret.polimi.it).

3 "CDES - Colour. For a systematic and creative approach to an interdisciplinary colour education in Design" Valentina Vezzani's PhD thesis (2009-2012).

Thinking. As a a systemic activity that doesn't tend to reduce variables, but rather model and re-set them for a prevision of possible solutions (Penati 2001), the *Design Thinking* allows to manage a system of unordered wires and knots, lacking of any steady structure.

To assure the development of an accessible colour knowledge for all the disciplines and 'languages' interested in it, handling it exactly as a system of unordered wires and knots, an intervention on the educational level that considers these terms of interdisciplinarity and complexity is necessary. Today there are many colour learning opportunities, but none seems to be effectively guided to an inter-, cross-, or trans-displinary approach. For this reason the *Colour Design Edu.System* mainly deals with the key theme of education oriented to creative and interdisciplinary learning, with some reference to a *lateral thinking* approach, to provide new strategic tools and methods that can support and lead young generations to create their own way of learning about and working with colour.

2. METHOD

After the investigation through *literature* and *desk research* on how colour knowledge is shared today, the idea of a model for teaching colour has been defined starting from design environments. In fact, Design is one of the best case and opportunity for interdisciplinarity: it can provide methods, or better, it can be the method to access the 'meta-point' among different viewpoints (Morin 2007), and designers are mediators between various cultures, skills and 'languages'.

The contemporary colour education provides students notions from numerous disciplinary fields; for this reason themes as *interdisciplinary learning*, *creative education*, *creative epistemology* and *creative society* have been analysed together with the techniques of *problem solving*, *brainstorming*, *learning-by-doing*, to select approaches and tools useful for complex learning processes and dialogues, for instance, the *card sorting*[4]. From this the *CDES Toolkit*, made of two decks, *Cards* and *Index*, is a systematic tool and method to organise the research and *meta-design* phases in the huge and interdisciplinary colour knowledge. The *Cards* were tested through *action research strategy* at three European design schools, different for culture of colour and design: the École Nationale Supérieure des Arts Visuels 'La Cambre' in Brussels (Belgium) with students of the compulsory course "Couleur" by Prof. Felix D'Haeseleer; the School of Design of University of Leeds (UK) with students of the elective course "Colour: art and science" by Prof. Stephen Westland; the School of Design of Politecnico di Milano (Italy) with students of the elective course "Colour & Experimentation" by Prof. Mario Bisson.

3. RESULTS AND DISCUSSION

The testing phase brought to define the *Cards* in their contents, structure and graphic solution, then also to design the *Index* and its use. The graphic choices have been fundamental to connect the *Cards* to the *Index*; the characteristic of being a systematic tool is also revealed by this 'communication' between and across the two decks. The configuration of both *Cards* and *Index* has been defined also considering the next research developments, that is the *CDES* as an online service.

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4 The *card sorting* is a user-centred design methodology used to guide the design of an information structure. It is used especially when the amount of data and information to be organised in a system is big and complex.

On one side the *Cards* deck are designed to manage the colour component during the research/analysis and *meta-design* phases of a design process. The *Cards*' categories are: 1. Basic Questions; 2. Design Fields; 3. Research Fields; 4. Theme; 5. Production & Materials; 6. Colour Issues (this last group of cards is systematically linked to the *Index*' "colour issue" group). The *Index* is complementary to the *Cards*, in fact, through brief descriptions, references and practical exercises, it would provide those notions that the *Cards* just question or suggest to learners. The idea of a classic colour handbook was given up to define, on the contrary, the concept of another system of cards structured according to five sections: 1. Support (explaination of the system of cards and methods to use it; description of the design process and the role of colour as a design component); 2. Index Introduction (how to use the *Index*, with and without the *Cards*; the future development on the Net on a special online colour platform); 3. Index Cards; 4. Glossary; 5. Bibliography.

Considering both the experimentations with students and the needs of today's learning environments, the *CDES Toolkit* has to be considered as an integration and teaching aid to those didactic activities, such as theoretical lectures, short practical exercises, short workshop experiences. In fact, today the concept of "courses as seeds" is taken more into account; it deals with an educational model that aims to create a culture of informed participation in the context of university courses and yet extends beyond the temporal boundaries of semester-based classes. Courses are conceptualised as seeds, rather than as finished products, and students are knowledge workers who play an active role in defining what they will learn (dePaula et al. 2001). It is in this context that the *CDES Toolkit* has the aim to educate learners to colour at a basic, practical, then also advanced level, encouraging them to the autonomous and deeper research for a personal, systematic, interdisciplinary, then also open and active culture of colour.

4. CONCLUSIONS

Because many different types of expertise, disciplines and cultures can readily access and use different and articulated aspects of colour, even the most specific notions, a systematised knowledge must be provided. To systematise means to provide an elastic structure of macro-themes (as main containers of information), nodes (specific topics), and connections that can be selected and re-organised on different levels, on the basis of one's objectives, interests, and context. According to this idea, the *CDES Toolkit* has been conceived as a system of cards that support the activities of research (as a personal investigation and knowledge enrichment), dialogue (supporting the exchange with other disciplines, finding a common 'language' to understand each other), and design (by visually organising information and steps, and above all, coordinating the activities).

The *CDES* has been conceived by considering also the Net as the main "place" where general knowledge currently develops and evolves, thanks to the action of the growing *digital communities* and contagious *social creativity* (Fisher 2004); in fact, the *CDES* is going to become an online learning service (possibly on the already existing *Coloret* platform) based on the direct participation of numerous types of expertise, disciplines and cultures interested in colour and its knowledge evolution. Creative, design and digital communities will be able to establish an interdisciplinary and systematic approach to colour knowledge, considering the needs of society, especially, as well as those of the market and industry.

Sharing is a new way of knowledge production which creative expertise grooves on and this is what happens mainly in the wider creative community of the Net (Ciuccarelli and Valsecchi 2007). By the statement that everybody can assume the role of designer, contributing to the project of a real colour culture, it can be said more to give force to the objective of supporting the joining of people and the creation of design communities for colour knowledge.

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The Virtual Colour Laboratory: The Development of an Interactive Web Application for Colour Education

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ABSTRACT

This paper presents the development of the popular science project *The Virtual Colour Laboratory (VCL)*, and the problems connected to translating spatial colour phenomena to a digital spatial context, from the viewpoint of practice based architectural research. The original idea was to create an application where users could explore colour phenomena while walking around in a photorealistic 3D-environment. Eventually it became apparent that the problems connected to visualisation of colour appearance and spatial experience could not be solved without simplifying the concept. So instead of modelling in 3D, the application was based on 2D-images, derived from thorough studies of colour phenomena in real life situations. VCL, in its current form, is an interactive web based application for visual presentation and demonstration of existing research results on spatial colour phenomena. It currently contains eight different stations, presenting and demonstrating either a spatial colour phenomenon or a principle for simultaneous contrast. We now want to expand the application to demonstrate more colour phenomena. In this development we invite other researchers to contribute with new stations.

1. INTRODUCTION

This paper presents the development of the popular science project *The Virtual Colour Laboratory (VCL)* (Stahre et al. 2009), and the problems connected to translating spatial colour phenomena to a digital spatial context that were encountered during the process of developing the VCL-application. The project, which is a work in progress, is carried out at the Department of Architecture at Chalmers University of Technology, Gothenburg with the intent to contribute to a more widespread understanding of the perception of colours, from the viewpoint of practice based architectural research. It aims to present research results, to develop the forms for such presentations and to identify the needs for complementary research. It originates in the various research projects on spatial colour appearance that during the last two decades have been conducted at Chalmers and the Royal Institute of Technology in Stockholm. The project has resulted in an application for visually conveying existing research results on spatial colour phenomena. It is meant mainly as a tool for educational purposes. In its current form, the VCL exists as an interactive web based application for visual presentation and demonstration of existing research results on spatial colour phenomena. It enables you to actively investigate how colours appear in different situations and provides you with information on relevant literature and links for further studies.

1.1 The original VCL-application

The original project idea was that users should explore and learn more about indoor and outdoor colour phenomena in an interactive 3D-environment, opened and used via the web. A spatial 3D-model was created, in which the user was guided through a northern European landscape, on a road leading up to the colour laboratory-building. Along the walk were a number of stations, each presenting a specific colour phenomenon. These demonstrated for example characteristic aspects of colours in nature; the impact of distance perception on colours; and colour's interaction with the surrounding landscape. Inside the laboratory several rooms demonstrated the effects of different choices of colour, light, pattern and material. In the corridor linking the rooms, surfaces were used to show two-dimensional colour phenomena and optical illusions connected to perspective. The core of the building contained a library with relevant links and references. For the colour phenomenon currently displayed, the graphical user interface showed written information and a link to the Colour Guide, a pdf-file containing further information. At certain stations the user could make interactive choices. For this the application switched between a number of pre-defined models, which limited the choices for the user.

2. PROBLEMS WITH VISUALIZING COLOUR PHENOMENA IN A 3D-MODEL

The visualization of real settings in a 3D-model is difficult due to the different conditions in a virtual setting compared to reality. The problems are connected both to the specific prerequisites for reproducing colour appearance and to more general issues regarding the design of a virtual world in terms of realism and spatial experience. These issues affected the possibilities to correctly demonstrate colour phenomena in the VCL-application. However well-made it is, a virtual setting can never offer the sense of real presence in a spatial context. For example, our movements are different in a virtual model (depending also on which type of system we are using) compared to reality. In the VCL-model it was hard to focus on relevant aspects of what was visualized as our attention is not drawn by the same means. A virtual setting consists mainly of sight impressions which thus restrict active investigation. To make a user observe a specific detail or a certain phenomenon can therefore be difficult. This problem is also connected to the different experience of scale in VR compared to reality. The objects in the model were perceived by the research team as smaller and further away than in reality. This was clearly shown with the exterior façade in the VCL outdoor model. The changing colour of a façade according to distance was one central phenomenon to be demonstrated in the model. In reality, our attention is drawn to that which contrasts to the background. Thus a solitary building by the edge of a forest would be observed, even if its part in our field of vision is very small. However, in the VCL-outdoor model buildings were hardly noticed at a distance, even less their colours (see Figure 1). Even after having largely increased the size of the front façade of the virtual laboratory to 50 m x 20 m, at 600 meters distance the façade was only a few pixels wide. Only at 150-100 meters distance was it large enough to display any changes in colour appearance. Another problem was, that in the export to interactive 3D, the models lost much of their graphical information as well as gained visually different proportions: although they looked sufficiently natural in the program used for modeling (Virtual Map), a significant loss of light and details became visible in the export via 3Ds max® to the interactive 3D-model. As a result, much of what in reality is experienced as harmonic became dull and uninteresting in the final presentation model. The interior model, with its straight lines, was less affected than the outdoor model, with its organic shapes.

Figure 1: The laboratory building in the outdoor model was hard to notice when approaching it, and experienced as being further away than the actual distance.

3. THE VCL-APPLICATION - BASIC DESIGN IN ITS CURRENT SHAPE

In order to solve the visualization problems, a simplification of the visual concept for VCL was necessary. Thus, instead of modelling in 3D, we decided to base the demonstration of colour phenomena on 2D-images only. By this simplification, the ideas for the interactive demonstrations were also made clearer, as was the layout for the graphical user interface. In its current shape the application so far contains eight stations, each presenting and demonstrating either a spatial colour phenomenon or a principle for simultaneous contrast (Figures 2-3).

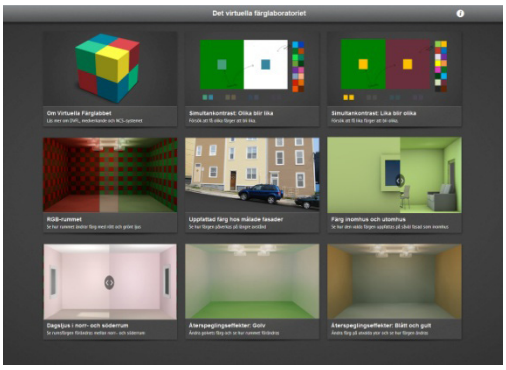

Figure 2: The VCL-application contains an introduction (top left) and currently eight different stations demonstrating 2D- and 3D-colour phenomena, with exercises and adjacent information.

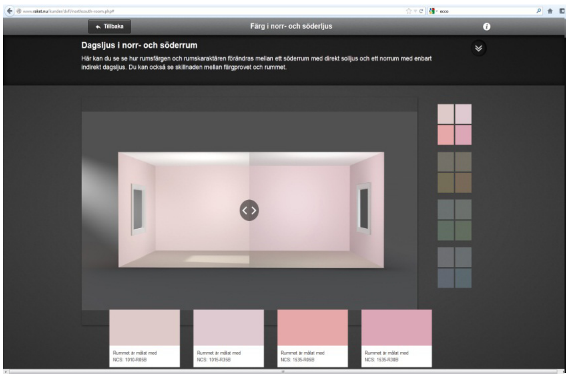

Figure 3a. Example of one of the stations, demonstrating how daylight affects colours in north- compared to south facing rooms. The exercise, where you can choose colours for each room, is combined with a short introduction at the top end of the page.

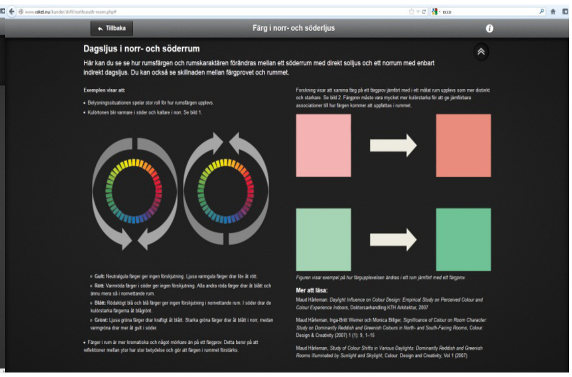

Figure 3b. A fly-out page with additional information for each station can be found when clicking the icon at the top right corner.

The concept is simplified as to the fact that the stations are now free-standing and not part of a visual all-encompassing structure (i.e. the former virtual world). In two stations on simultaneous contrast the user can either experiment with getting various colour pairs with different colours to look the same or the same colours to look different, by changing their background colours. There are also stations demonstrating perceived colours 1) on facades; 2) on exterior surfaces compared to interior; and 3) in north- compared to south-facing rooms. Two stations deal with interreflections within a space. Here the user can either 1) change the colour on the floor and see how the other room surfaces are affected by this, or 2) change colour on different room surfaces and see how this will affect the room as a whole. One station deals with RGB, demonstrating how, by changing the colour of the illumination from neutral to either red or green, the coloured pattern of the wall surfaces will appear differently. The VCL-application is web based. The stations are based on images constructed in 3Ds max; Cinema 4D and Adobe Photoshop, and are the result of thorough studies of colour phenomena in real life situations. Adobe Photoshop has been used in order to correct the colour appearance on the rendered textures. The current language in the application is Swedish, but the finished product will also contain an English version.

4. DISCUSSION

The presentation of colour is a crucial factor for the understanding and interpretation of a virtual setting. When it comes to the reproduction of colour appearance it is possible to calculate highly realistic scenes where each pixel has physically correct colorimetric data, and scenes can be created that are almost impossible to distinguish from reality. However, there has been significantly less investigation into how to apply this data in order for the colour appearance to correctly correspond to reality, according to how we perceive our surrounding world. When creating visually realistic simulations, it is therefore not enough to base the computations on physical measurements of colour and light in the real world. Instead, we need to include our perception of reality in the computations. Hence, in the development of the VCL, colour realism could not be accurately reproduced for technical reasons. The problem of visualizing colour phenomena in the VCL-models therefore became a problem of correctly compensating for the different conditions in the virtual setting compared to reality. In the VCL it was enough to simulate correctness, since the colour appearance of reality was known (in order for this to work however, the colour appearance of reality must be known). This required comparisons between real environments and digital models. Finally, we want to expand the VCL web application to include more colour phenomena. In this development we invite other researchers to contribute with new stations.

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Knowledge Development in Colour Education Based on Practical-oriented Projects

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ABSTRACT

The objective of this paper is to show how to enhance the interest of students to learn colour in the fields of Computer Vision and Computer Graphics. As illustration we will consider the example of the master program CIMET (Color in Informatics and Media Technologies). We will see how some subjective concepts can be taught to scientific students thanks to practical-oriented projects and a systematic use of concrete and illustrative examples. We will also see how some fundamental skills, such as interaction between light and matters, interaction between light and visual appearance, can be taught to students thanks to the use of interactive materials and practice-oriented examples.

1. INTRODUCTION

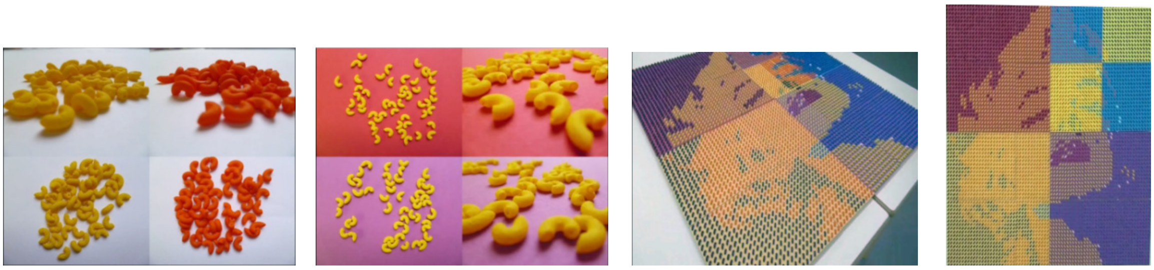
The objective of the master program CIMET is to educate students in advanced methodologies and models in computationnal colour science (CIMET 2013) with two goals: assimilating theoretical concepts, such as colour management, colour reproduction or colour science on one hand, and experimenting through practical projects on the other hand (Trémeau 2012). In this master we have experimented that a majority of students prefers: (1) seeing many illustrations, demonstrations and relevant animations during lectures than seeing equations and theoretical explanations; (2) testing concepts with interfaces, demos, practical test during the laboratory sessions than attending exercise sessions. We have also noticed that an understanding of the fundamentals of colour cannot advance without the underpinning of basic principles and methods. On the other hand, an understanding of subjective concepts (e.g. colour emotion) cannot be correctly apprehended and understood without the use of illustrative examples. To stimulate student interest, to foster their open-mind, to develop their intellectual curiosity, to encourage student's initiatives, several practice-oriented projects are proposed each year on challenging issues. The idea is to push students to learn by themselves, to explore new scientific fields by themselves, to develop their self-learning abilities, to see by themselves how some effects occur and to find by themselves the corresponding explanations.

We will see through few examples how some subjective concepts can be taught to scientific students thanks to practical-oriented projects. We will also see how some fundamental skills, such as interaction between light and matters, interaction between light and visual appearance, can be taught to students thanks to the use of interactive materials. Among the examples that we will present, we will see how demonstrations based on colour illusions are essential to convince students to learn, to experiment, what they experience by themselves. We will also see how practical projects based on applicative problems are crucial to train students to front themselves to challenging industrial problems (e.g. the assessment of colour emotion on Nokia cell phones). The result of these projects has been really impressive in terms of amount of work done by students and in terms of knowledge they acquired. Furthermore, some of the student's methods were published that shows the relevance of the work. All these examples prove that a knowledge development strategy based on practical-oriented projects can be implemented to improve the knowledge acquired by students in a colour education programme. Based on human-driven, i.e. requiring human-to-systems dynamic interactions, knowledge-driven and task-driven processes, this strategy could be extended to several colour education programs.

2. EXAMPLES OF PRACTICAL-ORIENTED PROJECTS

2.1 Colour illusion project

In 2012, CIMET students worked, under the supervision of Eric Dinet and Alain Trémeau, on a "colour illusions" project. The objective of this project was to develop self-learning abilities of students, to push them to experiment by themselves how some visual illusion effects occur, such as simultaneous contrast, colour constancy, colour memory, watercolor illusion or metamerism, and to push them to find the main explanations of these effects. The project requirements for the students were to propose a demonstration (either an animation done by simulation/computation/digital editing or a real scene filmed by a camera) to illustrate a visual illusion effect linked to a change of illumination, of point of view, etc. Project supervisors were very satisfied by most of the demonstrations and the explanations proposed. Furthermore, some of them were quite original. Consequently, we encouraged several students to submit their demonstration to the 12th AIC Congress. Among them, Ailin Chen proposed a very original demonstration (Chen 2013). Her demonstration (Figure 1) aims to illustrate the phenomenon of colour induction such as simultaneous contrast and colour assimilation through a piece of artwork.



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

Figure 1: Flowchart (a) colour gomito pasta in front of colour papier canson, (c) and (d) colour induction effect (Chen 2013). Credit: Ailin Chen.

Thanks to this project, students better assimilated basic principles and methods, as light and matter interactions, and subjective concepts, as colour appearance, and learned more by themselves than during lecture sessions.

2.2 Colour website design project

In 2012, CIMET students worked, under the supervision of Amit Ray, on a "colour website design" project. The objective of this project was to design a website for a town public library that has membership of people of various spectra. The project requirements for the students were to respect several constraints: colour harmonies, colour properties & tonal variation, relative colour combination, colour and cultural relevance, compositional elements (space, emphasis, etc.), non-verbal communication. They had to carefully choose suitable 'fonts' and their 'size', to not use different font styles in the same page, size may vary. They had also to take into account that the library is trying to increase its membership by offering new theme, facilities to open window to the world, and that it proposes to include some new innovative attractive areas for larger readership and intellectual growth. Most of proposals and explanations given by students demonstrated that they assimilated basic principles and concepts, as harmonious colour, complimentary colours, analogous colours, warm & cool colours, and subjective concepts, as colour appearance, colour emotion, mood of colour, taught in several CIMET courses.

Among these students, N. Hrabovskyy chose the specific tint of reds (Figure 2) for a couple of reasons. Firstly, because so low hue contrast does not draw attention away for searching book or reading. Secondly, to associate website colours with real library. Since in classical libraries there is a lot of wooden furniture, he tried to use colour close to brownish. Besides brown creates serious and intellectual mood along with comfort (like sitting in armchair when reading), combined with reddish tint it also stimulates brain activity. Grey colour is a bit boring (so it will not distract) and also symbolises reliability. With grey logo and grey library name in the header he also tried to depict carved-liked appearance to make it feel more solid, meaning that knowledge obtained in library is solid. He used colour differences to create tiny depth effect in between menu and sub-menus.

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

Figure 2: (a) Main page of the website, (b) Colour palette, (c) Example of sub-menu, (d) Colours of the text and of the background are adjustable. Credit: Nazary Hrabovskyy.

2.3 Project on colour calibration of an eyepiece microscope

In 2011/2012, CIMET students worked, under the supervision of M. Hauta-Kasari and A. Trémeau on an "industrial" project. The objective of this project, proposed by Olympus Company, was to design a multi-stage colour correction framework to display on a monitor colours as they are perceived through the eye-piece of a microscope.The first step of this project was to study what are the parameters which affect the image appearance of a colour sample: surface properties of the sample (e.g. size, lightness, transmittance, reflectance), microscope (e.g. optics, light source, lighting conditions, viewing conditions), camera (e.g. lightness sensitivity, transfer function, gain and offset), monitor (e.g. size and lightness of the displayed sample, lightness of the background and of the surround, sensitivity and transfer function), observer (e.g. colour perception through a binocular device, colour perception in front of a monitor, sensitivity to lightness changes).

The topic of this project was more challenging than the two other ones described above, as students had:

- to manage by themselves a research activity,
- to learn to work in group (at least 4 students per group) and at distance (by skype or by email, as in semester 2 half of each group studied at Granada, Spain meanwhile the others half studied at Saint-Etienne, France, next in semester 3 all groups

were once again split in two groups, one studied at Gjovik, Norway, meanwhile the other one studied at Joensuu, Finland),

- to learn to communicate and exchange with Olympus research team and project supervisors by skype or emails.

Several groups of students did a very good job and proposed very interesting ideas. Considering that their ideas could contribute to the state-of-the-art, some of them decided to submit their framework to the 12th AIC Congress (Martinez-Garcia 2013) (Bokaris 2013). Thanks to this project, students better assimilated basic principles and methods (e.g. light and matter interactions, colour calibration and correction) and subjective concepts (e.g. colour appearance) taught in several CIMET courses.

4. CONCLUSIONS

In the master CIMET, each year students are enrolled in practical-oriented research activities on stimulating problems (e.g. optical illusions) or challenging issues (e.g. colour emotion on cell phone), either directly through research projects or internships or indirectly through pedagogical projects, to foster their open-mind, to develop their intellectual curiosity and also to encourage student's initiatives. The idea is first to motivate students to learn by themselves and to develop their self-learning abilities, secondly to push them to see by themselves how some effects occur and to find the corresponding explanations, lastly to incite them to explore new scientific fields by themselves or to contribute to open fields by experimenting/implementing news ideas.

In complement to these practical-oriented projects, the pedagogical policy of the CIMET teaching staff is to use, in a systematic way, not only concrete and illustrative examples but also interactive tools, animations or videos. The intent is not only to better stimulate students interest for fundamental concepts and models taught in the CIMET program but also, beyond this master program, to contribute to bridge the gap faced by scientists or non-scientists (e.g. designers) when teaching theoretical concepts in colour education.

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The Influence of Colour on Learning in University Libraries

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ABSTRACT

In this study, six environmental colours (pure red, pure blue, pure yellow, light red, light blue and light yellow) were manipulated in a simulated study environment to determine their effects on adult students' learning performance, emotions and physiology. It was hypothesized that learning, physiological and emotional states would be affected by different colours in individual study spaces within university libraries. A total of 24 undergraduate and postgraduate students participated in this study. The dependent variables were reading performance, emotional responses, and changes in heart rate. The results showed that, although participants felt more relax, calm and pleasant in the light colour conditions, reading scores were significantly higher in the pure colour conditions. Heart rates were significantly affected by hue; they increased in the red and yellow conditions. In addition, the results suggested that, regardless of whiteness, the hue had a significant impact on participants' emotions; blue had increased relaxation and calmness feelings of participants. Implications of these findings and suggestions for further research are discussed.

1. INTRODUCTION

This study focuses on the role of colour in the learning spaces of university libraries, particularly in individual study areas, and its impact on learning activity within them. The university library can be considered as the heart of an educational institution, as well as a place where new information technologies can be integrated, and social and educational modes of learning and research supported (Edwards, 2009). This important transformation of university libraries to become learning centres was due to shifts in modes of learning, and to learners becoming more diverse in age, ability and background. Some people prefer formal learning that is systematic and guided by instruction such as listening to lectures, while others prefer informal learning that results from interactions among individuals without teachers such as networked, mobile devices and group discussion (Oblinger, 2006). Recently, university libraries have included both formal and informal learning; formal learning occurs through workshops and lectures and informal learning through group study and more independent individual study (Edwards, 2009).

Colour can be considered as an important element of the physical environment as it has a significant effect on students by influencing their emotions, performance and heart rate (Küller, Mikellides, & Janssens, 2009). Colour, as it affects the emotional state and potentially the heart rate of the learners, is one aspect of the physical environment that may impact on learning. For this study, it was predicted that learning performance in university libraries would be affected by different colours in the library environment, and that heart rate and the emotion of learners would vary as a function of the colour of the library environment.

2. METHOD

The purpose of this study was to examine the impact of six colours (particularly the dimensions of hue and whiteness) on learning performance by affecting students' emotion and their heart rate while in the individual learning spaces of university libraries.

2.1 Participants

Twenty four participants (11 males, 45.8%; and 13 females, 54.2%) were recruited from undergraduate and postgraduate students of Curtin University in Australia. The participants' ages ranged between 20 and 38 years. Participants were not forewarned concerning the exact colours to which they would be exposed. This eliminates participant expectancy bias concerning the colours tested. None of the participants had defective vision as verified with Ishihara Colour Blindness Test (ICBT). Participants were also asked to complete a Learning Channel Preference Questionnaire (O'Brien, 1989) which revealed that all participants were visual learners.

2.2 Colour Samples

Colour samples were taken from the NCS Colour Atlas. The colours to be used in this experiment were three elementary hues, pure red (S 1080-R), pure yellow (S 0580-Y) and pure blue (S 1565-B) and also one colour sample from each hue with a higher level of whiteness, light red (S 0540-R), light yellow (S 0540-Y) and light blue (S 0540-B) and a neutral colour white (S 0300-N). Previous colour studies regarding learning spaces proposed that blue and yellow are suitable colours for educational environments. Other studies have mentioned that warm colours, such as red, are appropriate for highly active learning areas because they can stimulate communication among students and increase interaction (Kaya & Crosby, 2005). However, these studies did not identify which of the numerous yellows, blues and reds are appropriate. Therefore, the researcher attempted to examine possible colours and how these will impact on learning performance.

2.3 Instruments

To assess the emotional state of participants, nine bipolar colour-emotion scales were used in the experiment. Osgood et al. (1957) divided these into three factors according to their meanings. These scales were: evaluative (dark/light, pleasant/unpleasant, fresh/stale), potency (heavy/light, calm/exciting, dull/sharp), and activity (tense/relaxed, warm/cool, interesting/boring). In order to measure the physiological changes of participants the Fingertip Pulse Oximeter was used to record heart rate when the participants were exposed to different colours. In addition, different reading tasks were used to assess the learning performance.

2.4 Room Design

Two rooms have been set up in the school of Built Environment within Curtin University for the experiments. The first was a neutral waiting room with light grey walls and ceiling and dark grey floor. This served as an adaptation room. The second room was the test room (3.68m length × 2.88m wide × 3m high) with no windows and with walls and ceiling painted white and the floor grey. Neutral colours reduce any effects of the room on the colours to be used in the experiment. The experimental room was divided by a partition to establish an individual study area (1.80m long × 1.30m wide × 3m high). Colours were manipulated by hanging Corflute panels 180cm×180cm×2mm thick, which were painted (pure red, pure yellow, pure blue, light red, light yellow or light blue). Each coloured panel was hung on the wall so that it extended 1.70 m above the top of the desk. The room was furnished with a white student desk and one grey chair. The student desk was centred along the wall, and faced the coloured panel. In addition, the desk of the experimenter was located behind the participant on the left side in order to control the time and to measure the heart rate (HR) of the participant during the experimental session. Ambient temperatures of rooms 1 and room 2 were recorded on several occasions on different days; the temperatures of both rooms were a constant 25˚C. The rooms were located internally in the basement of a multi-level building therefore their temperature and humidity vary little throughout the year. The test room was illuminated with four florescent tubes (40 W), having 3000˚ colour temperature (CT) and 75 colour-rendering index (CRI).

2.5 Experimental Procedure

Each participant was asked to stay in the waiting room for at least five minutes to adapt to room conditions and to have their HR measured before the experiment. Participants were then tested individually in the test room and seated at the desk facing the selected coloured panel. The participants were asked firstly to focus on the coloured panel for five minutes. At the end of the five minutes, they rated their emotions on a questionnaire. At the end their heart rates were taken again. To assess their learning performance, they were given a reading task, asked to study the text and answer the test's questions for ten minutes. Finally, they were interviewed to obtain more depth of qualitative data. This process was conducted six times and each time the participant was exposed to a different colour condition. There was one day free between one session and the next as a wash-out period, to reduce carry over effects from one colour to the others.

3. RESULTS AND DISCUSSION

The data were analysed using the Statistical Package for the Social Sciences (SPSS Version 20). The results revealed that, the main effect for whiteness was significant ($F[1,138] = 5.41$, $p = .022$) for reading performance. Reading scores were significantly higher in the pure colour conditions compared to the light colour conditions (Figure 1). This finding may be because pure colours are more arousing than light colours. Therefore, if the reading tasks are difficult, the pure colour conditions may increase arousal levels thereby enhancing learning performance. As for changes in heart rate, the main effect for hue was significant ($F[1,138] = 11.93$, $p < .001$). The graph suggests that, regardless of whiteness, heart rate tended to increase in the red and yellow conditions and to decrease in the blue condition (Figure 2). This finding supports the notion that warm colours are more arousing than cool colours because they are bright. In terms of emotions, although the light colours were rated to be calm, relax and less sharp, the reading performance was better in the pure colour conditions. The blue was perceived to be more pleasant, calming, relaxing, fresher, cooler and more interesting; therefore, the participants felt less active and energetic to study. They reported that the blue increased the feelings of relaxation because it reminds them of the calming aspects of nature such as the water and sky, and that might have redirected their focus away from the reading task. The yellow was perceived to be light 'sunny' and arousing which helped participants to concentrate on the task.

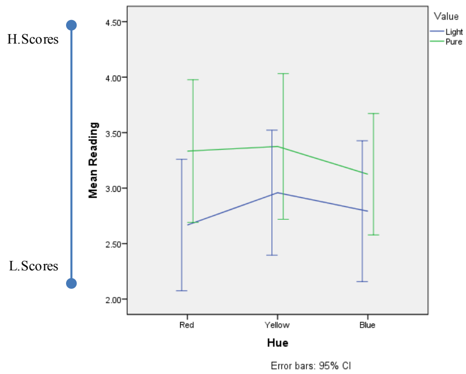

Fig.1: Reading scores.

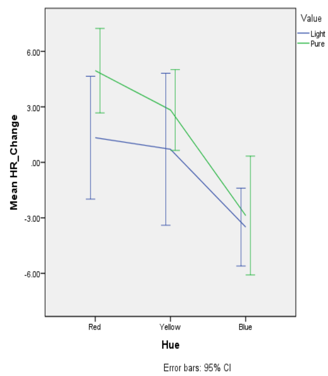

Fig.2: Heart rates.

4. CONCLUSIONS

The study found that emotions and heart rate had been affected by different colours, as was the participants' reading performance. The hue and whiteness actually had a significant impact on students' emotions. The light colours were rated more positively than the pure colours because they were perceived calming and relaxing, blue and yellow put the participants into a more positive state. In addition, the results suggest that the whiteness had a significant impact on learning performance; participants' reading performance was significantly better in the pure colour condition. As well, the heart rate was significantly affected by hues; it increased in the red and yellow conditions and decreased in the blue condition. This means that the reading task needs stimulating colours to make students more active and alert and that will enhance their focus and concentration.

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Colors of Schools in the Learning Intensive Society

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ABSTRACT

In the next years, the teaching methods will have to undergo radical changes as a result of the information society consolidation. The citizens having access to advanced information and communication technologies will grow up more and more. This situation will deeply change the ways to use, create and learn information, knowledge and skills.

It means also that technologies or techniques having a long history must change for reducing the time and cost of information diffusion putting learners in direct contact with teachers. In parallel our physical spaces will blend material, informational and communicative structures with functionality, same as the work will change becoming knowledge-intensive. Productive activities will be concentrated in some geographical regions and become globally distributed. This is to be intended as what we experiment in today life, being not so far from what many of us have predicted some years ago.

In this new world the schools designers have many problems on how imagine the school of the future. How to give to schools the better adequacy for the new way of teaching and learning? Which colors will represent the new learning spaces? In this field we are experiencing some solutions both in interior of schools and to the exterior.

1. INTRODUCTION

The society ruled by information, such as the one in which we are deeply immersed, has changed considerably if compared to the previous one born and developed in the industrialization era. To mark the times of the subject production is no longer the rate of production of goods, but the ability to learn new things and adapt to the continuous change of the basic conditions. The knowledge required in this type of society is no longer acquirable through the traditional means of transmission of knowledge, now too "physical" (Tuomi 2005). We can understand following the dispute over an EC document which foreshadows a scenario concerning the learning-intensive society on year 2020. Miller et alia (Miller 2008) applied a methodology aimed to identify the future learning spaces (LS) into a future learning-intensive society (LIS). The scenario is: how society might function in 2020 with new type of learning? The scenario is based on an assumption that the now-wavering mass-production and mass-consumption of current societies are no longer prevailing (Markkula, Sinko, 2009), or as they put it: "-- the crucial moment in industrial society when the entrepreneur or engineer or designer comes up with an idea that can then be implemented by taking advantage of economies of scale is no longer central. The aims and organization of wealth creation no longer take on the form of a pyramid or hierarchy, with the genius who generates new ideas and the technocrat manager who implements them occupying the top floor, while down below at end of the chain of command is the "front-line" worker. --. Everyone is the inventor and implementer of his or her own designs, the unique, personalized set of artifacts, services, and experiences. As a result, in the Learning-Intensive Society there is a profound difference when compared to industrial society in the relationship of knowledge to production or, in more general terms, the activities that (re)create daily life".

Unstable clouds condense the knowledge we need to know in order to survive and produce into the new type of society. They are clouds of basic news that contain an overabundance of information often without direct connection between them. The societies that have accepted or suffered the change have no other way out than adapting to the new way of knowledge transmitting. Who doesn't adapt is placed on the outskirts of the world, left out and doomed to isolation. Global communication and massive use of ICT, erasing the traditional physical and political boundaries, has prompted the teaching experts to imagine a new approach to the education of the younger generation, but also those already in the workforce. The lifelong learning activity has become necessary just because of the ever changing ways to produce (EC 2000, 2003). The need for continuous updating brings back to school even one who thought he had finally finished with his training period. The schools, in turn, have to reconfigure themselves, becoming spaces open to change and flexible, capable to adjust themselves to the new learning requirements. Within the expected changes, in addition to the quality of spaces and their functionality, the color theme enters in a non-marginal way (in the new guidelines of the Italian Ministry of Education are reported as negative factors: "dull colors or random"). Designers can no longer take into account only the functional, spatial or technological aspects, but must face with the environmental quality, where the color and light are able to provide a incomparable contribution to learning.

2. SCHOOL ADEQUACY

How to give to schools the better adequacy for the new way of teaching and learning? The way in which we can take action revolves around some necessary distinctions, distinctions that for reasons of space are here necessarily expressed in brief.

Since the cut down of the physical and political boundaries of the States, which occurred through knowledge transmission processes produced through a network of common knowledge different from the previous era, the process of belonging and socio-cultural adaptation of large sectors the world's population has radically changed. While desperately trying to recover the sense of the State, nations have proved to be obsolete structures and unable to allow a large-scale identity. The identities have again become phenomenon of proximity and so the concept of local strengthened. In parallel with the need to operate globally the need to acquire a global background is born. The business, in turn, tends first to develop itself globally, while the sociability and the meaning of life are explicated mainly at local level, as social micro-cell, of immediate vicinity. The clash between these two aspects of contemporary imply the need to reset, as well as production spaces and those of socialization, even the teaching places.

The school should become the place where transpose the new innovative drive, it should be a place of rapid change and continuous adaptation to new conditions. The school should overlap different environmental functions: that of information, relationships, quality of architectural spaces, materials and technologies, colors and lighting. If the school isn't able to answer at least to these requirements we know that there will be no chance to follow the basic teaching needs required by the contemporariness. In particular, the architectural quality is inclusive of the construction aspects and therefore based on spatial distribution, materials, technologies, colors and light control. The architectural quality is a strategic element to ensure the chance to obtain adequate relationships, convey, transfer and stimulate the growth and development of the information needed to place (or re-place) anybody anywhere in this new world.

In the Italian context, in an attempt to overcome the old prescriptive approach to the definition of school spaces, the MIUR (Ministry of Education, University and Research) has issued new guidelines for the construction of new school buildings titled: “Technical standards framework containing directories for the minimum and maximum functionality on town planning, on building works, also referring to the technologies for energy efficiency and energy saving and production of renewable energy, and teaching necessary to ensure appropriate and homogeneous project standards throughout the country”. Dramatically, as detected by the title but clarified in the text, the adjustment to the reality appears very minor, attempting to unify a nation that for long history and geography cannot have the same parameters, homogenizing cultural processes far away from each other and never unified. In the guidelines they put great emphasis on to the ideology of energy saving, on renewable energy sources including also those which can severely damage the environment, to unidentified technological building processes that don’t apply at all the quality and type of teaching. The very few references to color seem to be considered, as always, a hiccup, a troublesome burden that quietly can be bypassed by the lighting, on which are sketched some hints. At the same time, however, the part intended for sport is the longest, reflecting the fact that a nation of ignorant people that consider the sport as a religion is better manageable of a cultured, independent and instructed population.

3. COLOURS FOR NEW LEARNING SPACES

Which colors will represent the new learning spaces? The information society uses high saturated and often contrasting colors, aiming at strike the attention of those attending the privileged places of the contemporary representation. The new squares and places where information is distributed are basically very colorful. It would therefore seem a logical consequence that the spaces of the knowledge transmission will be adapted to the contemporariness. How to do it mainly affects local cultures and how they intend to get into the “glocal” world. The experiments carried out by the IUAV Research Unit “Colour and Light in Architecture” which I am responsible show that in colorful spaces and even in the saturated ones learning is more easy than in spaces painted on soft colors and without character. The absence of evident hues, tones and saturation depresses those who have to spend a big part of their lives in these spaces. In such environments, the level of creativity and intellectual vitality we detected to be very low. It’s got to be noted that the color differentiation of the teaching spaces should be based on: age, geographical context, social-historical and cultural context, the type of instruction (classical, scientific, technological), degree (preschools , elementary, middle, high school, college, LLL, etc..), the tools and resources used (overhead projector, projection, multimedia, computer laboratory, etc.)., posture and / or movement (sitting, standing, acting on machines or instruments, walking, running, singing, etc..) and so on. The list of differences could be quite long, but enough to understand that to operate within the possible color choices in the learning spaces requires knowledge and experiments that have had, to date, only a few respondents (eg. Manke, Steiner, Pugno, Malaguzzi et alii), limited to specific contexts we cannot generalize. Since then, the teaching context is very little static, for the reasons related to the need for adaptation required by the contemporary world, any solution that we would find contains high levels of rapid obsolescence.

4. CONCLUSIONS

To the researcher who intends to search design solutions including the color theme and congruent with the impulses of the contemporary teaching and learning spaces a world of very complex questions opens up. Even just analyzing the state of things of the various entities to delimit the field of investigation the risk is to make a big work unable to give many useful solutions. Within the Research Unit we analyzed, only from the point of view of color, about 30 schools built in the last century in Europe and 50 Italian schools. The result is a view not fully useful in obtaining information necessary to produce some guidelines to be transferred to the theme of color project in schools. The first results, which were already confirmable without great analysis, report the fact that where the population is located geographically where the light intensity isn't very high and the daytime is short they like colors more saturated than in bright places. Consequently, the "thermal" function of color often determines with great prevalence the choices in learning environments. Another obstacle concerns the chromatic culture of the places. The color, in fact, is one of the fundamental aspects of many of the cultures with long historical tradition. Here the offhand typical of people without history and traditions find many obstacles and the chromatic interpretation differs from place to place. This suggests that the culture of the places interprets the contemporary time choosing the colors according to a process that is accomplished seamlessly. The color in the teaching environment becomes an opportunity to continue the traditions adapting to the changing conditions of the surroundings, without being too contaminated by external processes, "change everything to change anything".

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symposium: colour harmony

Aesthetic Quality of Colour Combinations

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ABSTRACT

Colour harmony seems to involve some higher cognitive processes, which can fuse sensorial characteristics, expressive attributes, and abstract meanings (for instance mathematic relations). We studied how colour combinations set up in accordance with two different theories are evaluated by using a multisensory semantic differential. Results show that aesthetic evaluations in terms of pleasantness are enriched by a number of synaesthetic qualities which can finely differentiate various colour combinations.

1. INTRODUCTION

Colour perception occurs inside a general framework of more or less accentuated synaesthesia. Since a long time researchers have studied what is common to perceptions derived from different sense organs, and some fundamental common features have been found. No wonder if all perceptions show aesthetical properties that can be evaluated on scales of beauty. Harmony seems to involve some higher cognitive processes, which can fuse sensorial characteristics, expressive attributes, and abstract meanings (for instance mathematic relations). We studied which psychological reactions people show when observing some particular colour combinations, set up according to the theoretical hypothesis "correspondence/inversion" proposed by Spillmann (1985) and "colour distance" proposed by Moon & Spencer (1944).

2. EXPERIMENTS

To test the suitability of the multisensory semantic differential we proposed to discriminate the aesthetic values of colour combinations, two experiments were performed, differing in the colour combinations studied and in the groups of participants, being the evaluation methodology the same (da Pos, 1995, 2004).

2.1. Experiment 1

1) *Material:* three pairs of bicolour combinations were prepared, in which three highly chromatic colours were combined with less chromatic colours to produce either correspondent or vague inverted bi-colour combinations, following the terminology by Spillmann (1985). According to the author, the correspondent combinations are generally pleasant, while the vague inverted bi-combinations most often appear ugly. The combinations are listed in Table 1.

Table 1 Colour combinations used in experiment 1(a,b) and 2 (c,d).

a 10 080 R - 00 30 B90G corresp	15 65 G - 20 50 R60B vague inv	20 65 B - 30 40 B20G vague inv
b 10 080 R - 10 60 B90G corresp	15 65 G - 60 40 R60B corresp	20 65 B - 10 40 B20G corresp
c 10 080 R - 20 40 R30B vag.inv.	10 80 Y - 20 40 B60G vag.inv.	10 80 R - 20 50 B90G vag.inv.
d 10 080 R - 30 60 B90G corresp	15 65 G - 30 60 B60G corresp	10 80 R - 30 20 B90G vag. inv.

Each colour combination had the shape of a 2×3 chessboard (Figure 1), with squares of 5 cm, mounted on a white cardboard (18 × 22 cm) and observed under a simulated D65 light source.

Figure 1. Example of a colour combination card and the position of its colours in a NCS triangle.

2) Method. Evaluation of aesthetic quality of the colour combinations were made by a multisensory semantic differential, characterised by 9 bipolar scales. Three were the well known factorial scales by Osgood et al. (1957) in verbal form (active – passive; pleasant – unpleasant; weak – strong). The other six are described in Table 2.

Table 2. Multisensory scales used in the experiments.

visual	- an orange and a turquoise 10×15 cm rectangle (0090 Y50R - 2060 B50G)
tactile	- hot and cold water (about 40° - 10°);
tactile	- two pieces of sandpaper (N 60 and N. 1000; 10 × 15 cm);
haptic	- an empty and a stone filled 1.5 l bottle (about 40 g - 2 kg),
auditory	- a loud and a faint sound (60 dB difference) in earphones;
auditory	- a high and a low-pitched sound (5120 Hz$_{75dB}$ - 32 HZ$_{110dB}$) in earphones;

25 adults with normal colour vision participated in the experiment. The colour combinations were presented at a distance of about 1 m in random order under a D65 simulation, and the participant had to evaluate them by crossing one of eight squares in a Likert-like scale printed in a stripe of paper.

3) Results. Two kinds of statistical analysis were performed, an analysis of variance to look for significant differences in the evaluations of the six colour combinations as a function of the kind of combination (correspondent vs. vague inverted; close vs. distant colours in NCS space), and a factorial analysis to study the basic components of the evaluative process. Considering those combinations which are balanced as regard to the kind of combinations and to the distance between its colours, an ANOVA showed that evaluations of the correspondent combinations are significantly different from the vague inverted ones ($F5,120 = 26,49$, $p < 0.0000$), while these latter do not differ each other. In particular, there are significant interactions between scales and combinations ($F8,192 = 8.844$, $p < 0.0000$), illustrated in Figure 2.

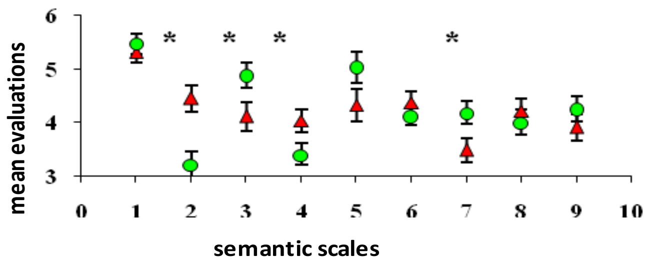

Figure 2. Mean evaluations as a function of correspondent (green disks) and vague inverted (red triangles) combinations.

This means that semantic evaluations in the nine scales are globally different in the two kinds of combinations; on the other side they do not differ in the combinations differing for their colour distance. Another interesting result deals with the interaction semantic scales – colour combinations: distance between colours is relevant only when correspondent combinations are considered (Figure 3 b).

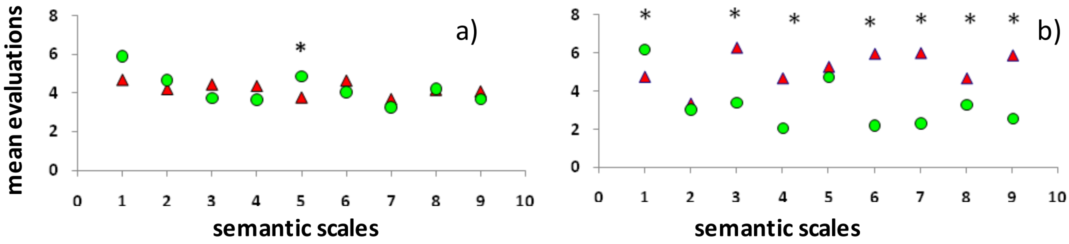

Figure 3. Mean evaluations as a function of far (green disks) and close (red triangles) colours in the vague inverted (a) and in the correspondent (b) combinations.

2.2. Experiment 2

The colour combinations used in this experiment are described in Table 1 (c,d). The procedure was the same as in the previous experiment; a different group of 25 persons with normal colour vision took part to this experiment.

Results. Considering those combinations which are balanced as regard to the kind of combinations and to the distance between its colours, an ANOVA showed that evaluations of the *correspondent* combinations are significantly different from the vague inverted ones ($F_{1,24} = 11.027$, $p = 0.003$) and also distance between colours significantly affect semantic evaluations ($F_{1,24} = 8.926$, $p = 0.006$).

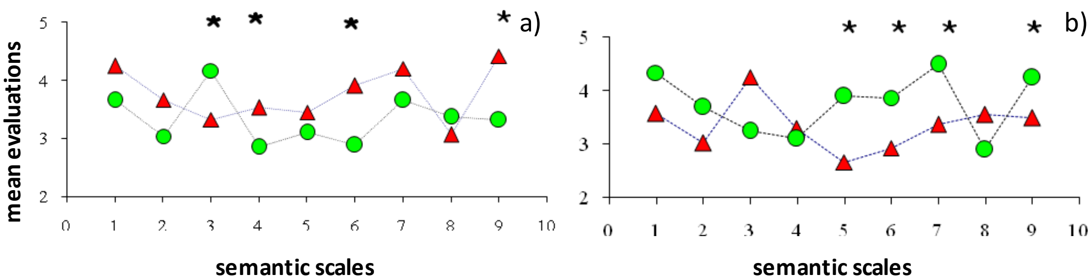

Figure 4. Mean evaluations as a function of the correspondent (green discs) and vague inverted (red triangles) combinations in a); and as a function of the close (green discs) and the far (red triangle) colours in b).

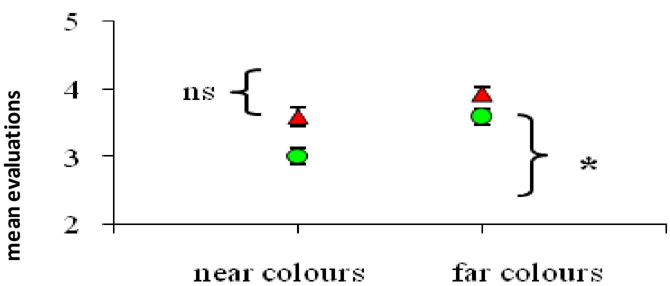

Figure 5. Mean evaluations as a function of the correspondent (green discs) and vague inverted (red triangles) combinations.

Figure 4 a) shows that scale 4 (pleasantness) significantly discriminates correspondent from vague inverted combinations according the predictions by Spillmann (1985), but does not discriminates the colour combinations on the basis of their colour distance (Figure 3 b), against the hypothesis by Moon & Spencer (1944).

Figure 5 shows that only correspondent combinations are differently evaluated as a function of colour distance, while vague inverted combinations are not affected by distance in agreement with results of the previous experiment.

Factorial analysis performed on both experiments reveals the basic criteria used by participants in performing their evaluations. We present in Table 3 the solution with 4 rotated (Varimax) factors explaining 58% of the variance. The solution with 4 factors seems quite good as the two Osgood's basic factors *evaluation* (pleasantness) and *activity* are here separated. In this case we also find that pleasantness appears together with high/low pitch. Scale 1 (orange/turquoise) appears as usual together with scale 5 (warm/cold) confirming the importance and universality of this synaesthetic quality of heat assigned to colours [6]. The remaining scales (3- weak/strong; 6- light/heavy; 7- smooth/rough; 9- piano/forte) seem to give the factor a property which spreads from a delicate and soft character to powerful and hard. These characterizations enrich the potency factor with multisensory features.

Table 3. The three factors from factorial analysis.

Factors:	1	2	3	4
1 orange/turquoise			**.811**	
2 active/passive				**.924**
3 weak/strong	**.688**			
4 pleasant/unpleasant		**.863**		
5 warm/cold			**.762**	
6 light/heavy	**.640**			
7 smooth/rough	**.614**			
8 high/low pitched		**.636**		
9 piano/forte	**.801**			

In conclusion the methodology here adopted seems very suitable for evaluating various aspects and qualities of our experience, independently from the sensorial nature of the object which is being evaluated.

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colour naming

Colour Naming: a Multilingual and Multicultural Study

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ABSTRACT

It is generally accepted that there are cross-linguistic universal tendencies in the naming of colours. This is due in large part to the findings of Berlin and Kay. Recently, however, these universalist findings have been challenged, on both methodological and substantive grounds. Nisbett's research on cultural cognition offers another interesting theory and provides a theoretical framework for our cross-cultural study. Through observation of how people from diverse cultures view images, Nisbett has defined two different cognitive styles: holistic and analytic. He combines cultural and cognitive perspectives that enrich the understanding of cultural influence in web usability research, thus creating a new approach in this field. Research in the field of online communication has previously focused on the consistency of the cognitive styles of people within the same cultural context. In this paper we report results of an experiment in which participants (N=67), representing 15 different languages as mother tongues, name the colours of the same photograph. An eye-tracking device was used in the experiment to record eye fixation and saccades. This information with the colour namings was analysed using the self-organizing map algorithm.

1. INTRODUCTION

Web accessibility and usability are communication issues that expand on art, language, cognition, and emotion. Colours may give instinctive emotional responses that shape the user experience. Berlin and Kay (1969) found universal patterns in colour naming data collected from several languages. These findings were later challenged on both methodological and substantive grounds. From these starting points The World Color Survey (2002) has continued the research by collecting and statistically testing comprehensive colour naming data from 110 unwritten languages from non-industrialized societies.

Research on online communication has focused on the consistency of the cognitive styles of people within the same cultural context. Nisbett (2001, 2002) with Masuda and Nisbett (2001) provide a theoretical framework for the cross-cultural study defining a holistic and analytic cognitive style by revealing perceptual differences between East Asians and Westerners. Nisbett combines cultural and cognitive perspectives that enrich the understanding of cultural influence in web usability. The holistic and analytic styles of viewing echo phenomenologist Merleau-Ponty's (2004) concepts of *living perception* and *reflective attitude*.

Cognitive style is a preferred approach to organise information, and eye movements can provide a window into a person's thinking patterns (Dong & Lee, 2008; Namatame & al., 2006). The anthropological and psychological studies of general cognitive processes suggest that cognitive styles are connected to culture (Dong & Lee, 2008; Nisbett & al., 2001). The purpose of our study was to test these hypotheses and to use the results for proposing approaches for enhancing the accessibility of web page design.

2. METHOD

We made an experiment along another larger design experiment to see how participants (N=67) representing 15 different languages as mother tongues would A) indicate colours in a previously unseen photograph during an instructed information seeking task, and B) name the five most important colours of the same photograph. In our study, we seek to establish: 1) if holistic and analytic people show different viewing patterns, 2) if there is any correlation with eye-tracking data and the naming order of colours.

Holistic and analytic reasoning can be summarized as follows: Holistic thought involves 1) orientation to the context or field as a whole, including attention to the relationships between a focal object and the field; 2) a preference for explaining/predicting events on the basis of such relationships; 3) an approach that relies on experience-based knowledge rather than abstract logic and the dialectical; 4) an emphasis on change, recognition of contradiction, and the need for multiple perspectives. Analytic thought includes 1) a detachment of the object from its context; 2) a tendency to focus on the attributes of the object in order to assign it to categories; 3) a preference for using rules about categories to explain and predict an object's behavior; 4) inferences that rest in part on the decontextualization of structure from content, use of formal logic, and avoidance of contradiction. (Nisbett & al., 2001).

A Tobii eye-tracking device was used in the experiment to record eye fixation and saccades. This information with the colour namings was analysed using the self-organizing map algorithm (SOM; Kohonen 2001). The participants (N=67) were from Asia, Europe, and Latin America between the ages of 24 and 55, with 33 males and 34 females using total of 15 languages as mother tongues, and living permanently or temporarily in Finland. The test photograph (Figure 1) was a bitmap image designed to fit on the Tobii screen and it was shown by Firefox web browser.

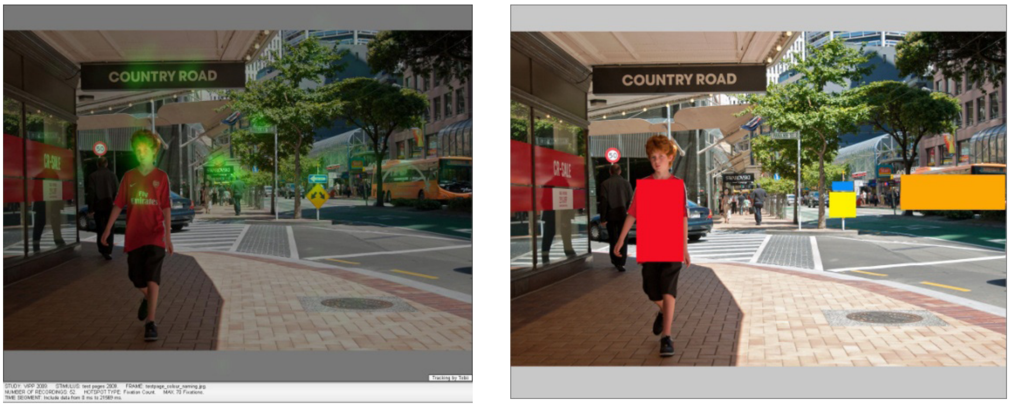

Figure 1: On the left, the test photograph with combined hot spots of 67 participants added after tests. Hot spots indicate strong attention, e.g. human face and shop sign. On the right, combination of the five most important colours by test persons with the area where selection was made: Red, yellow, blue, orange and black.

Participants were instructed to select at least five colours from the photograph according to their personal taste (Figure 1, right side). Language support for Russian and Asian languages such as Japanese, Chinese, Tamil, and Hindi was included. An input by clicking a mouse on a selected area resulted in a form of window where participants could type the name of the colour according to their own liking. After five colours participants were encouraged to name more colours if they wished.

3. RESULTS AND DISCUSSION

The test persons' colour choices were plotted into NCS colour space by converting the RGB data to visually defined colour regions in the NCS Atlas (colour data available at http://mlato.uiah.fi/cgi-bin/VIPP/admin/VIPPadmin). The defined colour regions were: black, white, red, orange, yellow, yellow-green, green, blue-green, blue, violet, purple, red, brown, pink and grey. The colours that were named most often were chosen for comparison of eye fixation data and colour naming data. These colours were red, yellow, blue, orange and black. Figure 1 shows how 1) the combined hot spots of 67 test persons (left) do not correlate at all with the colour naming (right), and 2) how selections and different colour terms of 15 languages cluster according to colour areas on the test photograph. Secondly, we combined all data to see possible holistic or analytic cognitive styles. The self-organizing map (Figure 2) combines information from both eye-tracking and colour naming data for direct comparison.

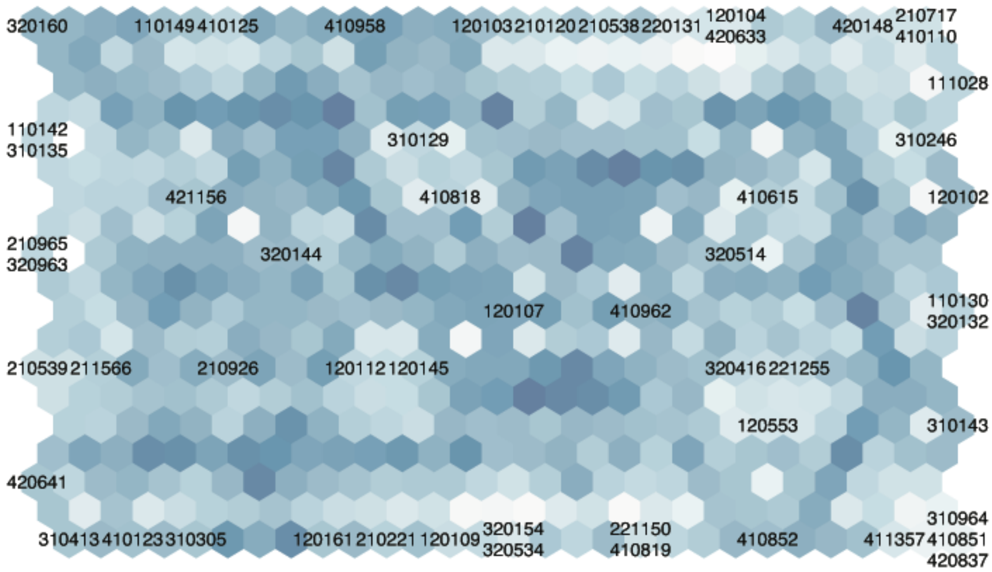

Figure 2: An SOM with 55 participants (6 digit user ID: role 1-4, gender 1-2, language 01-15, ID 01-67, e.g. 310129 = media professional, female, Finnish, 29).

The results showed discrepancies between sampled colours and named colours. For example a colour sample with a 'brown' appearance was identified as 'orange'. We suspect that this is due to other factors than wide divergences in colour categorization. In this experiment test persons were asked to name colours in an image of a natural spatial scene. As our data show, attention is drawn strongly to objects that bear information or emotional content: the boy's face, the signs and texts (Figure 1). These objects constitute a primary level of visual information, and they are overlaid with other visual levels, which are accessible through a more analytical approach. For example, the colours of objects are modified and defined spatially by light and shadow as well as reflected colours and highlights. Merleau-Ponty (2004) identifies two modes of attention: In *living perception* the 'real' colours of objects are apprehended despite the modification of their qualitative appearance, whereas in the *reflective attitude* the colours are perceived as if out of their spatial context. The experiment shows that participants often identified the 'real' colour, although the sample showed it as modified by the light. Our method does not recognize the difference between the apprehended 'object colour' and the modified colour.

4. CONCLUSIONS

In this work, we have devised an approach to comparing eye-tracking results with colour naming. We recognize the need to make clearer separations between cognitive styles and modes of attention in the future experiments. Also an analysis of the discrepancies between named colour and perceived colour might reveal differences in cognitive styles. Literature and web design practice indicate that holistic and analytic differences exist. In our initial experiments, we did not find clear evidence of these two major cognitive styles, although American, Azerbaijani (Russian speaker), British, Chinese, Finnish (both hearing and Deaf participants), German, Indian (Tamil and Hindi speakers), Iranian, Japanese, Korean, Portuguese, Turkish and Venezuelan people were recruited for the experiment. However, we understand the need to continue research about the plausible cognitive differences and their existence among holistically-minded people and analytically-minded people, in order to enhance the accessibility and usability of the web-based communication.

ACKNOWLEDGEMENTS

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Colournamer – a Synthetic Observer for Colour Communication

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ABSTRACT

Colour specification is not only the domain of technologists but is also an important process for anyone who needs to communicate about colour in the multilingual Internet environment. We have developed an online application *Colournamer,* a synthetic observer 'trained' by the participants' responses, to facilitate colour communication between different cultures. At present it supports English, Greek, Spanish and German.

1. INTRODUCTION

Various methodologies for developing colour-naming models from experimental data have been proposed. In most cases, however, these models are constrained to a small number of colour names and assume a 'universal' colour categorisation (Benavente *et al*, 2008; Lin *et al*, 2001). In such models the use of each colour name is restricted to a unique colour category, which means that when colour names are translated into other languages the colour categories remain the same. This has the advantage that it requires partitioning the colour space only once and then simply translating the selected words to each language. Universal colour naming models must assume that the chosen colour name represents the same colour category on a global scale, with a firm commitment by all the involved cultures. This assumption is inaccurate, and results in a colour space that is only partially mapped by colour language (Berlin and Kay, 1991; Gage, 1993).

Our *Colournamer* application adopts an alternative methodology based on an online colour-naming model that is distributed worldwide (Fig. 1). It is composed of multiple 'culture dependent' lexical sub-models, each of which is based on the same numerical 'culture independent' colour model (Mylonas *et al*, 2010). This global but relativistic framework, where each colour name is bound to a colour category in a particular cultural context, supports more subtle colour identification. This is in accord with recent scientific findings that show the influence of language on categorical perception. What we have developed, in effect, is a synthetic observer that is able to predict a colour name with the highest probability of agreement with the judgements of thousands of participants in our ongoing colour naming experiment. This enables the system to return the most likely colour sample when a user enters a colour name, and conversely also to respond with the most likely name in a given language when a user chooses a colour sample.

2. EXPERIMENTAL METHOD

A custom online colour naming experiment at http://colournaming.com was designed to collect broad sets of multi-lingual colour names with their corresponding colour ranges in sRGB and Munsell specifications. The 600 test stimuli were selected from the Munsell Renotation Data, and colours were specified in the sRGB colour space. Samples outside the sRGB gamut were excluded. In each experimental session an observer names 20 samples, selected at random from the 600 test colours (Mylonas & MacDonald 2010).

Over the past four years (2009-13), the server has gathered responses from over 3,000 participants. This has produced a dataset of over 60,000 colour names in eleven languages: English, Greek, Spanish, German, Catalan, Italian, simplified Chinese, traditional Chinese, Korean, French and Danish. Associated metadata include the language, cultural background and possible colour deficiency of each observer, and the hardware/software configuration and viewing conditions prevailing in the experimental session. To validate our methodology, we compared the centroids of the 11 English basic colour terms (BCTs) against the 27 most frequent chromatic colour words in the results of the web-based experiment of Moroney (2003) with satisfactory agreement. A colour-naming model was developed, with maximum *a posteriori* (MAP) parameter estimation (Mylonas *et al*, 2010).

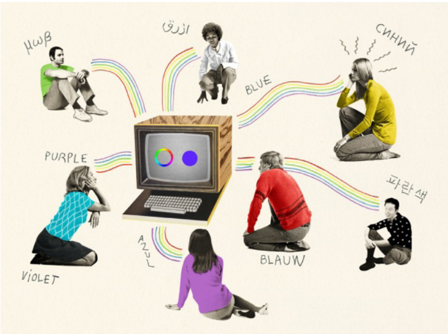

Figure 1: Illustration of Colournamer framework, by Valero Doval.

Figure 2: Screenshot of the Colournamer application showing the most probable English names corresponding to a selected colour.

3. DEVELOPMENT OF COLOURNAMER

The data for the four most popular languages of the experiment – English, Greek, Spanish and German – were analysed after removing the responses of observers with possible colour deficiency. From 5428 total responses in English we identified 1166 unique colour names, and from 4274 responses in Greek we identified 984 unique colour names. For Spanish and German the total responses were 2960 with 928 unique colour names and 4280 with 1161 unique colour names respectively. Using our MAP algorithm we classified the colour coordinates of all test stimuli to determine which colour names would retain their identity across languages. This could apply when a user chooses a colour name to return the most likely sample, or conversely when a user selects a colour sample to return the same colour name. We identified 30 predominant colour names in English, 27 in Greek, 24 in Spanish and 29 in German, as shown in Fig. 3.

Colournamer is a synthetic observer using participants' responses and a 'democratic' probabilistic algorithm to assign a colour name automatically. Through a simple graphic user interface (Fig. 2) it enables a user to enter a name to return the most likely colour sample, and conversely to choose a colour sample to respond with a word cloud of the most likely names. The font size of each colour name is related to its probability, while the colour names are plotted using their coordinates in the a^*-b^* plane. The web app was developed with Python and the visualisation with canvas of HTML-5. Recently, we have used the new web audio APIs of HTML-5, so visitors with an up-to-date browser will be able to listen to a recorded voice naming the selected colour samples. Users are also invited to validate the predictions of the application to improve its performance.

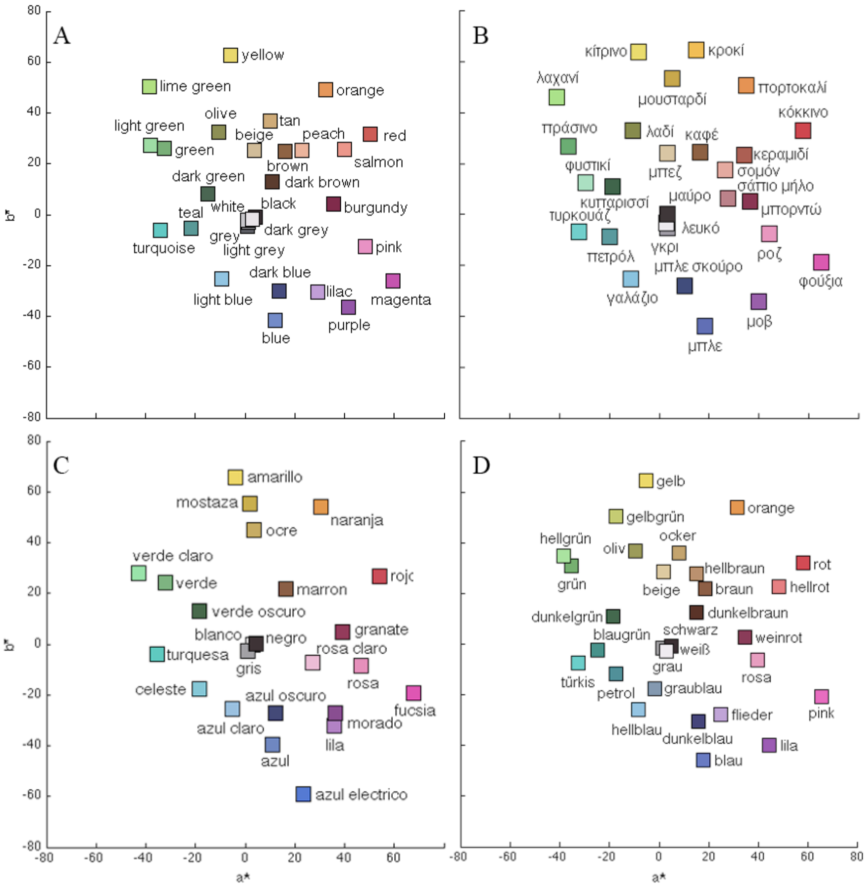

Figure 3: Centroids of predominant colour names in the CIELAB a-b* plane for: (A) English; (B) Greek; (C) Spanish; and (D) German datasets.*

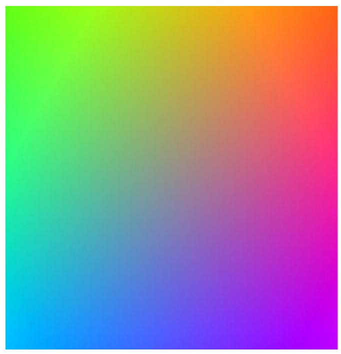

Figure 4: Synthetic image Van de Weijer et al, 2009.

Using the same probabilistic model and the same four training sets we classified the 320 samples of Munsell's hue-value surface and segmented a synthetic image (Fig. 4). In the results in Fig. 5 we can see interesting similarities and differences. The synthetic image was segmented into 19 English, 18 Greek, 16 Spanish and 20 German colour categories. English and Greek observers used the colour names 'lime green' and 'lahani' (λαχανί) to describe a region between green, turquoise and yellow, while for the same area Spanish and Germans used the modifiers of green 'verde claro' and 'hellgrun' (light green). Greek observers used the basic term (Androulaki *et al*., 2006) 'galazio' (γαλάζιο) to describe a large area between blue and turquoise which was not shared with the other tested languages. In German an equivalent area was described as 'hellblau' (light blue) with a hue angle different from 'blau' (blue). This is interesting because we usually associate 'light' as a modifier of lightness only. The same trend was observed for English too, but covering a smaller area. A large area between blue and green was named as 'turquoise' in English, 'τυρκουάζ' in Greek, 'turquesa' in Spanish and 'türkis' in German, and it appears to be a strong candidate for status as a twelfth basic colour term.

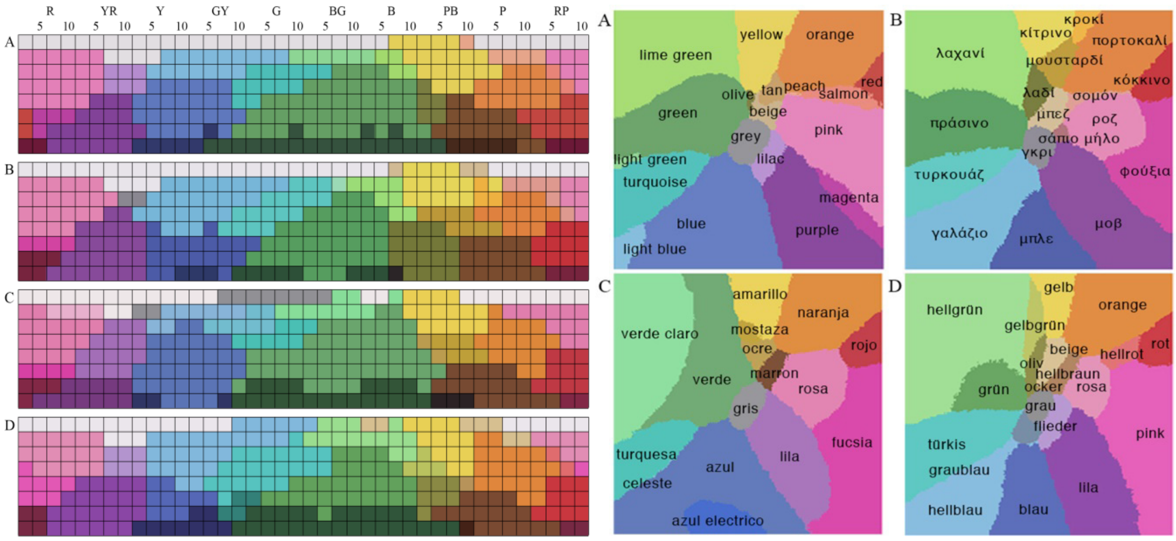

Figure 5: Classification of (left) Munsell 320-colour array of value vs hue and (right) synthetic image by observer-based colour names in: (A) English; (B) Greek; (C) Spanish; (D) German. Each category is represented by the colour of its centroid (see Fig. 3).

In conclusion, we have demonstrated that a flexible colour naming architecture adapted to the communication needs in each language/culture has significant advantages over universal models, because it is able to represent more consistently the native colour concepts of its users. It offers a route to culture-dependent interpretation of colour names.

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Colourful Language: Say What You See

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ABSTRACT

Say What You See is a research project that uses photography to create a visual record of descriptive colour terms in English. It forms part of a larger investigation in to the relationship between colour and language produced for my MA Graphic Design Major Project.

It presents photographs of objects that lend their names to descriptive colour terms to create a visual connection between the words we use and the colours we see. The objects are documented through simply presented still life photographs. The images aim to encourage reflection on our habitual use of colour terms, consideration for the relationship between colour and object and potentially a wider and more varied colour vocabulary.

1. INTRODUCTION

Since we developed the use of language, we have borrowed words from things in the world around us to describe the colours that we see. Even what we now think of as abstract colour terms like ‘black’, originally referred to something else like ‘night’.

Compared to the millions of hues our eyes can detect, our colour vocabulary is startlingly limited. Despite appearing to be well defined and understood, our basic colour terms are open to a surprising amount of interpretation and can be painfully imprecise, failing to truly capture the world we see. English has evolved to include thousands of terms for colours, and yet only a tiny percentage of these exist as abstract terms. Most are re-appropriated from tangible things like lemons and lavender, as an attempt to articulate even a fraction of the colours we experience.

It is believed that the word for pink originally came from flowers known as pinks (from the genus Dianthus) due to their frilled petal’s relation to the 14th century verb ‘to pink’, still used today in the term ‘pinking sheers’ (Anon, 2012a). Our language has evolved dramatically since then and, as with so many words, the ties to its origin have virtually been lost. Far removed from its beginnings, the word ‘pink’ is now widely understood as referring to the rosy band of hues ranging from salmon to magenta.

Of the eleven basic colour terms that we have in English as defined by Berlin & Kay (1969), only orange is still regarded as descriptive, attributed to the hue of a ripe orange. Originally derived from Sanskrit, the word first appeared in English, in the 14th century, after the Persian and Arabic form, nãranj, was adopted by European languages (Anon, 2012b).

While our vocabulary of colour terms has clearly evolved as our language has developed, has our understanding of descriptive colour terms changed as this body of words has grown? How often do we consider the origin of the words we use and reflect on the original colour of an object that now enriches out colour vocabulary and allows us to articulate what we see in the world with a greater degree of precision or expression?

2. METHODOLOGY

This project finds its origins in the nature of our colour vocabulary. I had begun to study the types of words that are used to label colours, as background research for my wider investigation into colour naming. Colour terms can be categorised in a number of ways. Abstract colour terms only refer to the colour, while descriptive colour terms primarily refer to an object but also refer to a colour. Colour Terms can also be defined as monolexemic, comprised of one lexeme or word, for example green, or compound, made from two words or more and usually employ the use of adjectives, for example light blue.

Using a wide variety of sources, I amassed a considerable body of colour terms. Through this process it became apparent that a significant proportion of colour terms in English are in fact descriptive, and their etymology could be traced back to a tangible and often mundane object. As colour terms are used in a wide variety of contexts, from everyday speech to descriptions of commercial goods, I was interested in how their use in the vernacular related to the colour of the original object from which the term was derived.

I compiled a list solely of descriptive colour terms, collecting terms that represented both a range of hues, including spectral and non-spectral, and a range of objects incorporating foodstuffs, minerals and flora. Having exhausted all of the sources of colour names collected as part of my wider investigation, it was clear that an editing process would be required to create a feasible body of words to document.

I began by editing the list to only include descriptive colour names that were monolexemic, so that the colours could be identified using only one word. I also narrowed the criteria for the list to colour terms that could be easily identified. Although this criterion was prone to a degree of subjectivity, it largely involved the removal of the most obscure colour terms, for example cinnabar and porphyry, which are not in widespread use. I edited the list further by removing terms that may not be perceived to clearly communicate both the object and the colour term. For example, an image of lavender would be clearly identified as 'lavender', whereas an ivory figurine may be primarily seen as a figurine rather than 'ivory'.

There can be considerable natural variation in colour among items that are not mass manufactured. However, the aim of the project was not to try to produce a perfectly accurate reproduction of the object, but provoke consideration for relationship between object, language and colour. Rather than trying to acquire the most colour correct example of an object/descriptive colour term, typical examples of the chosen objects were sort as these were most likely to be encountered in a real life context.

A series of tests were conducted to ascertain the most appropriate lighting conditions, camera settings and background to photograph the objects. All of the photographs were taken against a white background, in natural daylight, using consistent camera settings and at approximately the same distance. No colour correction was applied to the images, however the images were cropped to give a uniform appearance for presentation and some minor airbrushing was employed to remove dust or imperfections in the background of the frame.

3. OUTPUT & DISCUSSION

As with other aspects of my wider investigation into the relationship between colour and language this project generated a significant body of visual material so was originally presented in the form of a book. The photographs were displayed very simply, with one per page, and minimal graphical intervention in the design of the layout. After several iterations the images were sequenced by hue, to create a visual narrative throughout the book and present the images in an aesthetically pleasing manner. No written identification for the objects was provided alongside the images. As the title suggested, the purpose of the project was to say what you see, to identify both the colour term and the object. For reference a complete list of the colour terms/objects was included at the back of the book. Examples of the images can be seen in figures 1-4, below, and all of the images can be viewed in the original presentation format online, at this address: http://www.issuu.com/eleanorbydesign/docs/say_what_you_see.


Figures 1-2: Images of amethyst and aubergine descriptive colour terms.


Figures 3-4: Images of fuchsia and lemon descriptive colour terms.

Although all of the objects were photographed with the express aim of providing a clear indication of what the object was, it became evident that viewers found some objects more straightforward to identify than others. In most cases this was due to a lack of personal knowledge, such as the inability to identify the herb sage, or the semi-precious stone aquamarine.

However, rather than being a failure of the editing process or photography, the addition of a degree of uncertainty surrounding some images has created an opportunity for reflection among viewers. It encourages the consideration of their own colour vocabulary and use of colour terms, while confronting them with depictions of objects they may have never observed the colour of.

4. CONCLUSIONS

As a piece of visual research, this project has received a positive response, it presents colour in an aesthetically pleasing manner while commenting on the relationship between colour and language. It has created intrigue where images could not be immediately identified and flashes of recognition between colour terms and their etymological origins.

On an aesthetic level the project has also proved to be successful, it has been used as a sample to demonstrate the range of colours for an HP Indigo printer and the quality of colour reproduction for Mohawk Everyday paper.

This project does not aim to present a true reproduction of the colours of objects. Rather it is a visual reminder of where some of our words for colours come from, their inherently descriptive nature and their undeniable connection to the often-mundane objects in the world around us.

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A Model of Colour Naming in Normals and Anomalous Trichromats

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ABSTRACT

This paper presents a simulation of colour naming. The model incorporates early retino-cortical processes – pre-retinal filters, photoreceptors, chromatic adaptation, post-receptoral opponent processing and a neural classifier. This enables an assessment of the optimal classification performance that may be achieved in the absence of non-visual factors such as culture, language and experience. We demonstrate how the model performs the task of asigning names to Munsell colours when simulating normal trichromatic vision in the under different illuminants, and also dichromatic vision. The model produces estimates of colour classification performance potentially achievable by colour normals and also by individuals with specific forms of defective colour vision.

INTRODUCTION

The majority of us have no difficulty in naming the colours of objects under different conditions. Even under the complex conditions found in natural environments this ability remains robust (Amano & Foster, 2010). Berlin and Kay (1999) hypothesised the existence of eleven basic colour terms: white, black, red, green, yellow blue, brown, pink, purple orange and grey. Subsequently Boynton and Olsen (1987), investigated colour categorisation psychophysically in the OSA colour space. They confirmed the eleven basic terms and found that they were used more frequently than non-basic terms, and had a lower response time. Further work by Sturges and Whitfield (1995) confirmed these results in the Munsell colour space. However, there is also evidence that the eleven terms are not universal (Roberson, Davies, & Davidoff, 2000) and Davidoff (2001) argues that colour categories are created by linguistic systems. Individuals with colour vision deficiencies can also name colours accurately (Bonnardel, 2006). In this paper we develop a simulation of colour naming, in order to explore what can be achieved by a physiologically motivated model without effects of culture and language. It incorporates stages corresponding to the early processes of human colour vision combined with a neural classifier.

2. METHOD

2.1 Model

The model comprises the four stages which are illustrated in Figure 1. The spectral sensitivities of the cone photoreceptors were those derived by the CIE (MacLeod et al., 2006). Anomalous colour vision was simulated by shifting a specific sensitivity curve along the wavelength axis; dichromatic vision by replacing a specific photoreceptor spectral sensitivity with another. The photoreceptor signals are subjected to a simple form of retinal gain control based on a von Kries process (Gegenfurtner, Sharpe, & Boycott, 2001).

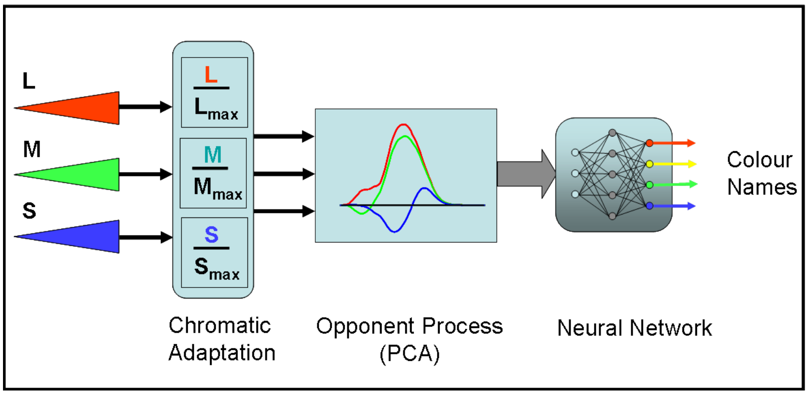


Figure 1. Components of the Colour Naming Model.

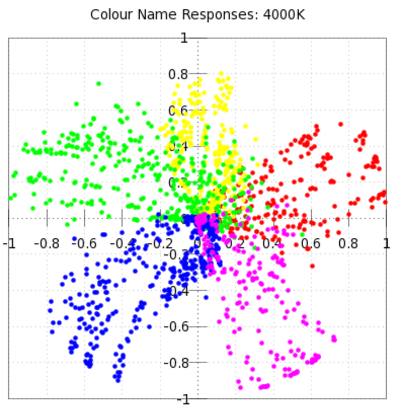
The opponent channel weights are derived by computing the principal components from the covariance matrix of the LMS signals (Buchsbaum & Gottschalk, 1983), (Moorhead, 1985). Subsequent to the opponent process stage is a neural net classifier implementing a back-propagation learning rule (Rumelhart, Hinton, & Williams, 1986). The outputs from the network corresponded to individual hue names (see next section).

2.2 Colour Samples and Network Training

The model simulated an observer viewing a colour patch on a uniform neutral background and being required to produce a colour name for the colour patch. The colour patches were selected from the Munsell set and were used to the model to produce hue names. The L, M and S inputs to the model were computed for each of the Munsell colour samples and with each of seven different blackbody illuminants with colour temperatures ranging from 3000K to 6500K in steps of 500K. For any single illuminant it was assumed that the observer was in a steady adaptation state. The opponent channels were derived from the Munsell colours under that single illuminant. All illuminants were adjusted to produce the same photopic luminance from a perfect white diffusing surface (200 cd·m^{-2}). These calculations resulted in 1269 X 7 separate colour samples. Half of these were selected evenly from the full set to train the network. For each sample the corresponding Munsell hue was extracted. Value and chroma designations were ignored. This resulted in ten hue names – five principal colours: red (R), yellow (Y), green (G), blue (B) and purple (P) and five intermediate colour names: yellow-red (YR), green-yellow (GY), blue-green (BG), purple-blue (PB) and red-purple (RP). On the presentation of a colour surface to the model the corresponding output unit of the ten possible outputs was set to unity and the remaining nine units were set to zero. Training was carried out for a fixed number of cycles.

3. RESULTS AND DISCUSSION

Qualitatively we can examine how the model classifies each of the different Munsell colours. This is shown in Figure 2 as a polar plot.



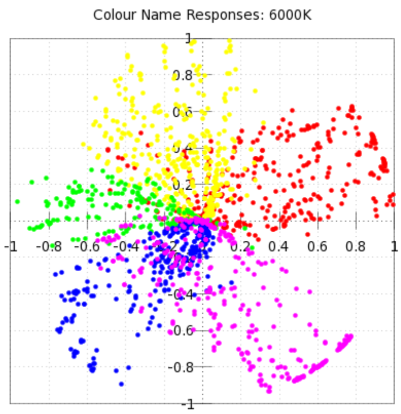


Figure 2. Colour coded polar plot of classifier outputs for two illuminants.

Only five of the ten outputs corresponding to R, Y, G, B and PB are plotted for clarity. The colour provides a representation of the hue being encoded. It is apparent that each output unit signals a limited range of the Munsell set. Gaps in the representation corresponding to the intervening alternate units demonstrate that the full sequences of Munsell Hues are represented by the network. Many of the units do not achieve the maximum possible trained value (unity), but still produce the correct colour name. In a human observer, this would correspond to a reduced confidence as to exactly what name to use. A quantitative estimate of performance by a normal trichromat is provided by the confusion matrix illustrated in Figure 3 (left). The horizontal direction represents the ten input hue categories. The vertical direction represents the ten output units. Perfect (100%) classification of all colours would produce values lying only along the diagonal. In this example the model achieved an overall performance of 71%. The majority of the colour name misclassifications lie adjacent to the diagonal indicating that errors are made with adjacent hue names. For example a Munsell RY may be labelled as a Munsell R.

98	9	1	3	44	0	0	0	38	688
6	0	0	0	3	57	40	107	675	38
0	0	0	0	0	32	149	655	58	0
0	0	0	0	0	84	428	48	3	0
0	0	0	5	62	427	55	12	9	0
6	11	15	107	484	36	0	0	3	7
4	2	58	300	68	0	0	0	0	0
5	81	591	252	11	0	0	0	0	1
47	500	160	65	6	0	0	0	0	5
668	129	33	30	12	0	0	0	0	83

57	14	7	10	89	29	3	3	26	461
0	0	0	0	0	137	201	237	557	61
0	0	0	0	0	7	182	422	75	1
0	0	0	0	0	37	188	109	27	0
0	0	0	0	2	423	98	51	101	55
130	59	32	90	478	3	0	0	0	145
96	176	238	348	29	0	0	0	0	8
10	139	404	130	2	0	0	0	0	1
33	211	109	63	1	0	0	0	0	4
508	133	68	121	89	0	0	0	0	86

Figure 3. Confusion matrix for a normal trichromat (left) and a deuteranope (right).

Similar computations were undertaken for different degrees of defective colour vision by changing the wavelength separation of the L and M receptors as described above. Figure 3b illustrates confusion matrix for a deuteranope. The corresponding classification performance is 55%. Performance for a protanope was 53%. Clearly the model can develop an ability to classify colours, and this ability is still present to a lesser degree in dichromats. The level of performance reported here can be improved upon by additional training. It is however affected by the number of illuminants. Performance is best with a single illuminant.

4. CONCLUSIONS

A simple model of colour naming has been developed. It provides a baseline performance estimate of the classification performance that can be achieved by human colour vision, independently of any additional factors such as culture and language. The model allows the effects of different parameters to be investigated as well as how performance is affected by different forms of colour vision deficiency. It was trained using a synthetic data set with all colours appearing with equal probability. Further work is required to understand how unequal priors influence the model performance.

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colour and music

Collision: Studio Practice, Score Analysis and Interpretation through Painting and Digital Media

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ABSTRACT

Historically much of the activity in the area of visual music has been focused on the creation of visual compositions stimulated by musical performance. I suggest that the intuitive act of painting to live and or recorded music is flawed in its interpretation of the musical intentions of a composers score. For the purpose of this investigation the studio practice concentrates on the shared systems and language of composition, what Zilcer identifies as the 'application of formal compositional elements of music to painting'.[1] In part, the project will draws on the expertise of British composer Michael Berkeley and conductor Peter Manning.[2] The premise for the research is to identify the presence of process and system in each of the practitioner's work. Also through collaboration with a composer and conductor the project offers a further opportunity to consider the effects of music found in contemporary painting practice. The initial findings of the research are used to establish an intellectual framework where neither the audible or visual elements of the disciplines take precedence over each other.

1. INTRODUCTION

This paper details the analyses of Berkeley's four musical scores: *Coronach*, *Inner Space*, 'Elegy' and *Gethsemani Fragment*. The scores are interpreted into a series of preparatory paintings, which culminated in a digital-media projection piece, in the form of repeat-pattern wallpaper entitled, *Collision*. The process of analysis is pre-determined by a series of research questions which are outlined in the introduction to Chapter Four, '*Collision:* The Translation and Interpretation of the Structural Elements of Berkeley's Musical Compositions through the Painting and Digital Media'. *Coronach*, *Inner Space* (for Solo Flute), 'Elegy' (from the slow movement of the Oboe Concerto) and *Gethsemani Fragment* form the primary reference material for *Collision.* In its entirety, *Collision* comprises nine paintings, a series of thirty-six postcard paintings and a forty-four minute digital-media projection piece. The nine paintings and thirty-six postcards are executed in oil and may be considered as preparatory studies for the digital-media wallpaper in colour, form and pattern.

I employ four different geometric motifs in the translation. The geometric information is retrieved from the score in numeric form. Each motif is then numerically pro-portioned to represent a specific musical feature of the score. This information is taken from either the melodic (horizontal) or harmonic (vertical) components of the score and the geometric motifs are re-configured into regular repeat pattern formations, similar to those used to create patterns in textiles and wallpaper design. Initially, I explored this translation through conventional oil painting techniques, but ultimately I realised it with digital media, in conjunction with Berkeley's music in either a live or recorded format. The musical analysis and visual interpretation of the scores were carried out using a series of five research questions.

1 Judith Zilcer, 'Music for the Eyes: Abstract Painting and Light Art' in *Visual Music: Synaesthesia in Art and Music 1900,* eds. by Olivia Mattis, Jermey Strick, Ari Wiseman and Judith Zilcer (New York: Thames and Hudson, 2005), p. 34.

2 Director of the Manning Camerata, (Concert Master at the Royal Opera House Covent Garden).

2. SCORE ANALYSIS AND VISUAL INTERPRETATION

I analysed and interpreted the formal compositional elements of Berkeley's scores, creating visual formats suitable for painting and digital media using the following parameters:

1. Harmonic analysis of the score structure.
2. Analysis of score proportion versus metronomic proportions.
3. Identification of visual and audible mirroring and repetition of musical motifs.
4. Identification of the gestural aspects of the compositions, for example, accent intervals, pitch, rhythm and rhythmic contour.
5. A comparison of the visual proportions of Feldman's (1926-1987)[3] scores in relation to time signature, as a comparative assessment of Berkeley's score structures and proportions.

The questions (or methods of musical analysis) are designed to extract specific musical information from the four Berkeley scores. Results of this musical analysis are used to reconfigure information from the score into four visual motifs using geometric forms that included: circles, straight lines, numbers sequences, grid structures, rectangles and grids in rectangles. In order to re-proportion the same numeric values present in the Berkeley scores, I assigned particular geometric forms (or visual motifs) to specific musical elements present in the four acoustic compositions. The choice of geometric forms was inspired by the work of the experimental filmmakers from 1919-1942. For example, in the analysis and interpretation of *Coronach,* Circular structures are used to represent the rhythmic structure of the cello line and circular forms are deployed across the digital picture plane in repeat pattern formations.

In the representation of *Inner Space,* vertical linear structures are employed in repeat patterns to represent the melodic contours of this monophonic work. In addition, I represented the rhythmic value of each note by changes in the width of the vertical lines, for example progressively thicker lines to indicate greater rhythmic values. Therefore, my interpretation of *Inner Space* is two-fold: in the assessment of musical contour and in the representation of rhythmic structure. In the analysis of the score for the 'Elegy' (the slow movement from the oboe concerto), I took the visual representation from the harmonic structure of the four-part harmony in the music. I presented the results of this analysis as a number sequence, (again, placed into a repeat pattern formation). In the final acoustic work for string orchestra *Gethsemani Fragment,* measurements of the bar dimensions are taken from each of the thirty-eight musical systems. These are observable changes in time signature throughout the composition and these are combined with the bar dimensions to create grid structures within rectangles. I used this musical information to create four visual motifs each of which are central to the construction of visual compositions in digital-media.

3. DIGITAL MEDIA WALLPAPER AND THE BERKELEY ELECTRONIC SOUND LINKS

The digital-media wallpaper is composed of eight visual components, of which four are in response to Berkeley's acoustic compositions and four in response to the electronic sound-links. Berkeley's electronic sound-links are inspired by my digital interpretation of Berkeley's acoustic works. The composition in digital-media employs the graphic design software *Illustrator.* During our discussions and preparations, Berkeley and I were uncertain about

3 Morton Feldman associated with the New York School of experimental composers which included John Cage, Christian Wolff and Earl Brown

what the collaboration would be and how it would turn out, therefore it took considerable time to come to fruition. The structure of the digital media wallpaper includes the following audio-visual components: Link to *Coronach, Coronach,* link to *Inner Space, Inner Space*, link to 'Elegy', 'Elegy', link to *Gethsemani Fragment* and *Gethsemani Fragment.*

4. VISUAL CONTEXT: SYSTEMS ART

Works from the Gallery Oldham permanent collection of 20th century painting inform the visual context. The act of selecting work from the Oldham collection enabled me to position the work I envisaged making, in relation to other works of notable British Systems and geometric artists. I selected three abstract images, two paintings and one print:

- Jeffrey Steel, (b.1931), *Scala*, 1965, oil on canvas,
- Peter Sedgley, (b.1930), *Phase 2*, 1965, gouache on card, laid on hardboard,
- Bridget Riley, (b. 1931), *Splice*, 1975, screen print on paper.

Steel and Sedgley belonged to an informal group of British artists known as the Systems Group (1969-1976). Riley was not a member of the Systems Group although her work is without question informed by the processes common to that of systemic art, namely her use of colour, geometry and tessellating pattern.

I investigated the members of the systems Group further and came across an exhibition at the Samuel Osborne Gallery, London, from 2007. The exhibition explored the work of British Constructivists and included several works by the Systems Group. Dr. Fowler[4] wrote the essay for the catalogue, which expertly traces the history of this movement in Britain. The exhibition was called, *Towards a Rational Aesthetic: Constructive Art in Post-War Britain*[5]. Soon after this, I made contact with Dr. Fowler and discovered that in 2005, Southampton City Art Gallery presented a survey exhibition of geometric abstraction in Britain from 1900 to the present day. The exhibition *Elements of Abstraction: Space, Line and Interval in Modern British Art*[6], was presented by Dr. Fowler in association with Professor Brandon Taylor[7]. The exhibition was so successful that the curatorial team were alerted to the demand for information on the subject. The Southampton show was the first exhibition of its kind since 1972. In 2008, in response to this growing interest, Southampton City Art Gallery presented a further exhibition and catalogue of systemic art entitled, *A Rational Aesthetic, The Systems Group and Associated Artists*[8]. In 1972, the then Arts Council produced a catalogue to accompany the second United Kingdom exhibition of the Systems Group entitled *Systems.* A second Arts Council publication was produced in 1978, for an exhibition of Constructive and Systems art entitled *Constructive Context*.

5. COLOUR

The use of colour in the paintings was taken from two sources. I made colour reference to four works from three of the Systems Group artists, including works by Michael Kidner (1917-2009), Jean Spencer (1924-1998) and Peter Sedgley (b.1930). In addition, I took references from two of the three works selected from the Oldham collection of British non-

4 Art Historian and Curator
5 Fowler, A. and S. Osborne, G. Samuel. *Towards a Rational Aesthetic: Constructive Art in Post-War Britain.* London: Osborne Samuel Ltd, 2007
6 Taylor, B. and A. Fowler. *Elements of Abstraction Line and Interval in Modern British Art.* Southampton City Art Gallery, 2005
7 Professor Brandon Taylor, Senior Research Fellow in Faculty Media, Arts and Society. Southampton Solent University,
8 Fowler, A. J. Steel. and T. Craven. *A Rational Aesthetic, The Systems Group and Associated Artists.* Southampton City Art Gallery, 2008

figurative painting, including works by Sedgley and Riley. The colour referenced from the two Oldham paintings and the four works from secondary sources was achieved by colour matching. The process of colour matching is not an exact science and I consider this aspect of my practice intuitive, rather than based on any pre-planned system. The matched colours were then used to create a series of nine oils on paper, which formed the preliminary studies for *Collision*.

6. SUMMARY

The nine paintings in the *Collision* series act as preliminary studies for the digital wallpaper. In many ways, the graphic qualities achieved through *Illustrator,* enabled me to make more exact translations of the number sequences (musical intervals), patterns, visual contours and reoccurring visual motifs present in the Berkeley score than can be realised through painting. It is possible using this process, more so than using hand drafting techniques for painting, to proportion information from the score to the digital picture plane with a greater degree of accuracy. Therefore the transfer of information from the Berkeley scores to a visual format in this research project has been possible and can be seen in the component parts of the wallpaper as each sequence unfolds through time. From my recent experience of working with Berkeley and in my involvement with visual music over the past six years, his visual placement of musical information on the score is not dissimilar to that of the process of handling the formal elements of design.

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Hidden Colours Recovered by Light and Sound

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ABSTRACT

Colour is defined by the amount of light that an object reflects over a range of wavelengths in the visible light spectrum. When an object is blocked by a highly scatteing medium, the colour of the hidden object may not be distinguishable by human eyes or cameras. We introduce a technique, known as the acoustically modulated laser speckle technique, to recover colours hidden behind an opaque scattering slab (5 mm thick with a transmittance of 0.24%). The technique exploits the interaction between light and sound to increase the sensitivity of colour detection of the hidden object, and can classify 25 colours with 72% accuracy. This technique has the potential to be translated into clinical applications such as measuring the oxygneation of the brain hidden behind the skull.

1. INTRODUCTION

The colour of an object is determined by the amount of light it absorbs and reflects in the visible light sepctrum. A red object reflects more light in the red colour range (~ 630 - 700 nm) and absorbs more light of other colours, leading to the perception of "red". When an coloured object is blocked by a barrier, its colour becomes obscured. Depending on the amount of optical scattering in the barrier, the colour of the hidden object may or may not be distinguishable. For example, a coloured object hidden behind a frosted glass, which has a relatively low optical scattering, may yet reveal its colour. On the other hand, a coloured object immersed in a glass of milk, which has a rather high optical scattering, may not. However, if the milk is diluted so that its optical scattering is lowered, the coloured object may become visible again to some degree. Figure 1 illustrates the effect of scattering on the detection of the hidden colour. In this scenario, a laser beam illuminates the surface of an opaque scattering slab. While the majority of the light detected by the camera comes from the light scattered by the opaque slab alone (green arrows), a small proportion of detected light (red thin arrows) has reached the coloured object, backscattered and detected by the camera. Since only a very small amount of detected light carries information about the colour of the object, the camera may be able to detect the presence of a colour but may not have the sensitivity to distinguish between similar colours.

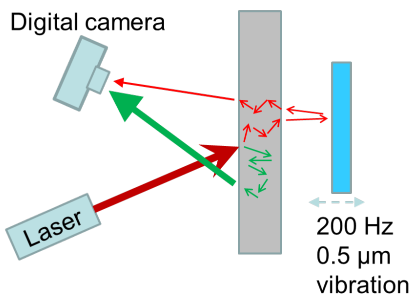

Figure 1: Detecting colours hidden behind a highly scattering medium.

We have developed a novel technique, known as the acoustically modulated laser speckle technique, to increase the sensitivity of detecting colour hidden behind a highly scattering medium. It involves inducing a small vibration (sound waves) on the colour object and detects the light patterns on the slab's surface. The technical details of the technique have been described elsewhere in a recent publication (Leung and Jiang 2013).

2. METHOD

2.1 Coloured Objects

Twenty five colours have been created by combining different proportions of the two base colours magenta and cyan as shown in Figure 2, together with their colour IDs. The colours have been printed on a white paper. The reflectance spectra of five of the colours, i.e., white (0% magenta and 0% Cyan), m25c0 (25% magenta and 0% Cyan), m50c0, m75c0 and magenta, are also shown in Figure 2.

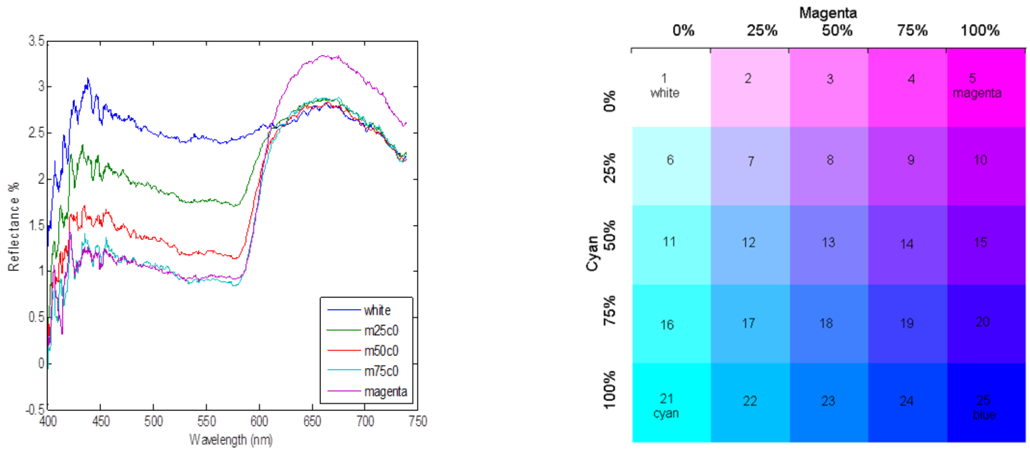

Figure 2: The 25 colours, their compositions (percentages of magenta and cyan), colour IDs and five of the spectra.

2.2 The Expereimental Setup

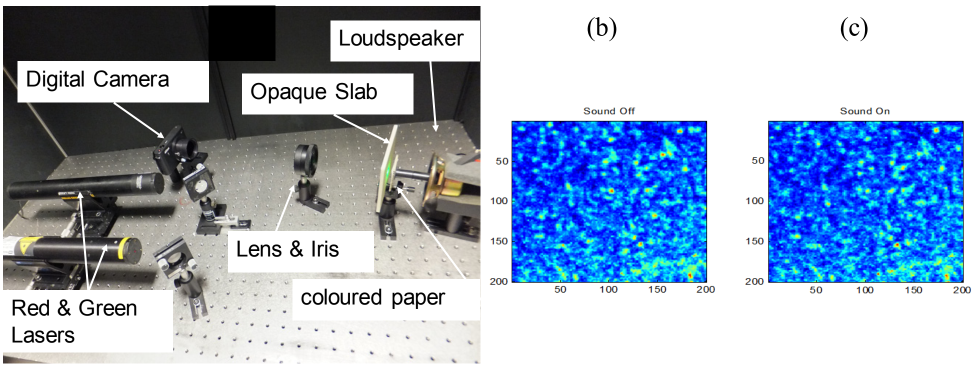

Figure 3: (a) Experimental Setup; (b) Speckle Contrast reduced by 4% when sound ON.

Figure 3 depicts the experimental setup which includes two lasers (red: 633 nm and green: 543 nm), a consumer grade digital camera (Nikon J1), focusing optics, mirrors, a loudspeaker, an opaque scattering slab and a coloured paper. The opaque scattering slab was made of epoxy resin with a thickness of 5 mm, a reduced scattering coefficient (@633 nm) of 1.8 mm^{-1} and a transmittance of 0.24%. The coloured paper was placed behind the slab with a 5 mm air gap in between. It was attached to the centre of the loudspeaker's diaphragm emitting sound at 200Hz, producing a vibration less than 0.5 µm. The detachable lens of the digital camera was taken off; exposing the CMOS sensor in the air. With the red laser as the light source, each of the 25 colored papers was placed behind the slab one after another. For each color measurement, two sets of 5 images were taken when the loudspeaker was on and off respectively. The measurement of 25 colors was repeated three times to assess variability. The whole process was then repeated again with a green laser as the light source.

2.3 Speckle Contrast

The acoustically modulated laser speckle technique is based on the laser speckle pattern formed by the interferences of coherent light (Goodman 1975). Figure 3(b) shows the speckle pattern on the slab's surface when the sound was off. When the sound was on, the light that backscattered from the colored object (thin red arrows in Figure 1) varies in amplitude causing a time-varying speckle pattern. When a digital camera with a long exposure time (relative to the speed of the vibration) was used to capture this time-varying speckle pattern, the resulting image becomes blurry, which can be quantified by calculating the speckle contrast $C = \sigma/\langle I \rangle$, where σ and $\langle I \rangle$ are the standard deviation and mean intensity of all the pixels in the region of interest. The faster the moving particles, the more blurry the image becomes and the smaller the *C*. Figure 3(c) depicts the speckle pattern when the sound was on. Although not apparent to naked eyes, *C* is reduced by 4%. The speckle contrast difference is defined as: $\Delta C = C_{off} - C_{on}$ and it can be shown that ΔC is related to the reflectance of the hidden object and therefore its colour.

3. RESULTS AND DISCUSSION

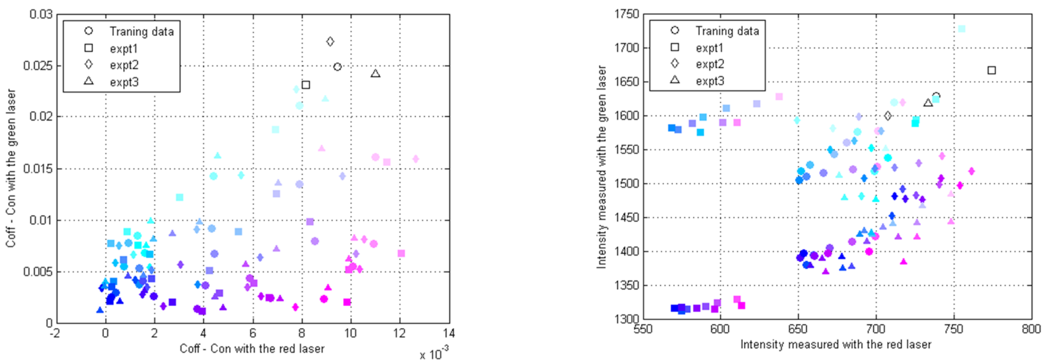

Figure 4: Results of (a) Speckle Contrast Difference (ΔC) and (b) Intensity.

Figure 4 shows the results for two measurements: (a) speckle contrast difference, ΔC and (b) intensity (conventional optical technique), using the red and green lasers. The colours of the data points correspond to the colours of the hidden objects themselves. The symbol circles are the averaged data points of the 3 independent experiments (exp1, 2 and 3). For ΔC, most of the colour clusters (formed by the 3 independent measurements) are well separated from one another, making them easier to be distinguished. For intensity, however, most of the colour clusters overlap with one another.

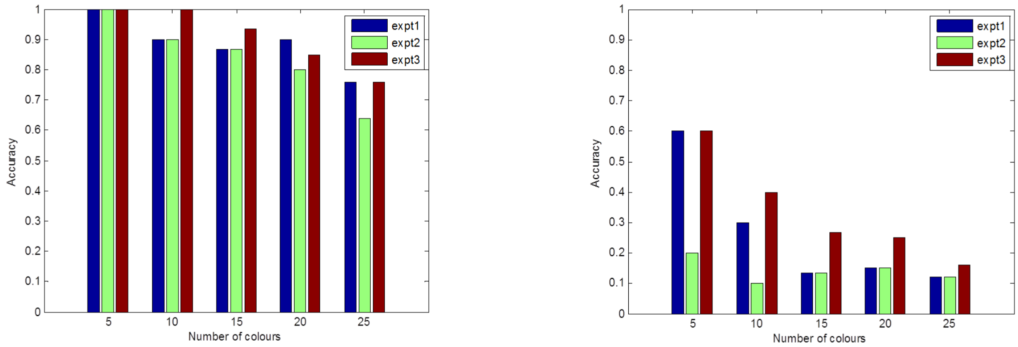

*Figure 5: Classification accuracy: (a) Speckle Contrast Difference, Δ*C *and (b) Intensity.*

The 3 independent measurements of ΔC and intensity were then classified using the nearest neighbour classification algorithm (Duda, Hart and Stork 1995) and the averaged data points as the training dataset. The accuracy is shown in Figure 5. In general, the more the number of colours (Nc) to be classified, the lower the accuracy. (Note for Nc=n: Colour IDs=1-n, where n = 5, 10, 15, 20 and 25) In comparison to the intensity results, the ΔC apporach has a higher accuracy and lower variaibility. For Nc=25, the ΔC apporach has an accuracy of 72% compared to 13% for the intensity approach.

4. CONCLUSIONS

We have shown the acoustically modulated laser speckle technique offers a higher accuracy in classifying hidden colours than the direct intensity measurement. The new technique can potentially be adapted to biomedical applications such as measureing the colour of blood and therefore its oxygen content in the brain hidden behind ths skull.

ACKNOWLEDGEMENTS

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The Colour of Music: Trans-domain Mapping of Sound

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ABSTRACT

Multimodality is integrated into the majority of our multimedia experiences, most commonly with intent. However, some experience an unintentional and subjective perceptual response to a stimulus in another sensory domain due to the neurological phenomena synaesthesia. This paper discusses the application of music-colour synaesthetic mappings in live instrumental and choral performance. A succinct discourse on literature related to synaesthesia scientifically and creatively is presented, followed by an overview of the design and development of the system. Exemplification of the mapping strategies is offered through an illustration of one potential output. Finally, the paper concludes with a brief summary alongside on-going developments.

1. INTRODUCTION

With advancements in neurological and psychological research, increasingly better insights into how we function, sense and feel are being revealed. From our early interests in the mapping between physical movements and musical events (Ng 2004), we have been exploring a range of trans-domain mapping strategies for several different application contexts, particularly multimodal feedback to enhance communication and widen accessibility. Most recently, mapping musical conducting gesture into vibrotactile and auditory feedback (Armitage *et al.* 2012), and visualisation and sonification of bowing gesture for technology-enhanced learning (Ng 2011).

Focussing on the translation of sonic to visual events, this paper presents synaesthesia inspired mapping models in the context of a live musical performance. This paper is structured as follows: Section 2 presents a background literature survey incorporating an overview of the neuropsychology behind synaesthesia together with an outline of its effect. Section 3 presents the design and development of the individual system modules with a potential resultant visual output, and Section 4 concludes with a summary and current findings.

2. RELATED RESEARCH

Synaesthesia is a neurological phenomenon whereby stimulation of one sensory modality results in an extra sensory perceptual response in another. Common manifestations of this sensation include the perception of colour for music, phonemes, numerals and letters, and ‘tactile shapes’ for taste. In the context of this project, the music-colour synaesthetic relationship is explored. There has been a range of research to study and quantify both the neurological and perceptual response of synaesthetes. When measuring a subject’s response to musical tones, Neufeld *et al.* (2012), measured increased activity in a region of the brain involved in multimodal integration for music-colour synaesthetes. Paulesu *et al.* (1995) derive similar results when analysing brain activity in music-colour synaesthetes.

Music-colour association has a rich history within both the sciences and arts. An early scientific association of the two domains is detailed by Newton (1704). Historically, visual and auditory artists have mutually served as each other’s inspiration. A direct transposition of this is characterised in the impressionist movement, particularly the work of Debussy. Additionally, musical timbre is frequently described as the ‘colour’ of music. Research into the music-colour synaesthetes perception of stimulatory audio has produced varied responses, reflecting the subjectivity of the phenomenon. Colour synaesthesia is generally individual. Despite this, there are several features that exhibit more comment trends (Hubbard 1996; Marks 1974). These include: (i) pitch and brightness; (ii) loudness to size; (iii) colour and frequency. Many composers and artists, including Messiaen, Ligeti and Sibelius report synaesthetic responses that influence their work. This body of research, alongside other pre-existing literature, provides the basic principles behind the mapping strategies developed in this project.

3. DESIGN AND DEVELOPMENT

This section outlines the design and development of the system with a particular focus on audio-visual mapping strategies and models. First, a system overview is presented, followed by an outline of the project’s design. This section concludes with a short description of a sample visualisation output of, Debussy’s, *Syrinx* that will be performed by Northern Sinfonia at The Sage Gateshead, Newcastle on 9th July 2013.

3.1 System Overview

The system in its entirety is highly modular to facilitate multiple application contexts. For this paper, it is presented from the perspective of live instrumental and choral performances; consequentially, the system requires four primary components. First, an analysis of the musical score is required. Then, in order to identify position within the pre-analysed score, an intuitive method of real-time “following” is required. In turn, the sonic-visual mapping algorithm uses this data to create the corresponding graphical visualisation. Software is then required to render the visuals for projection.

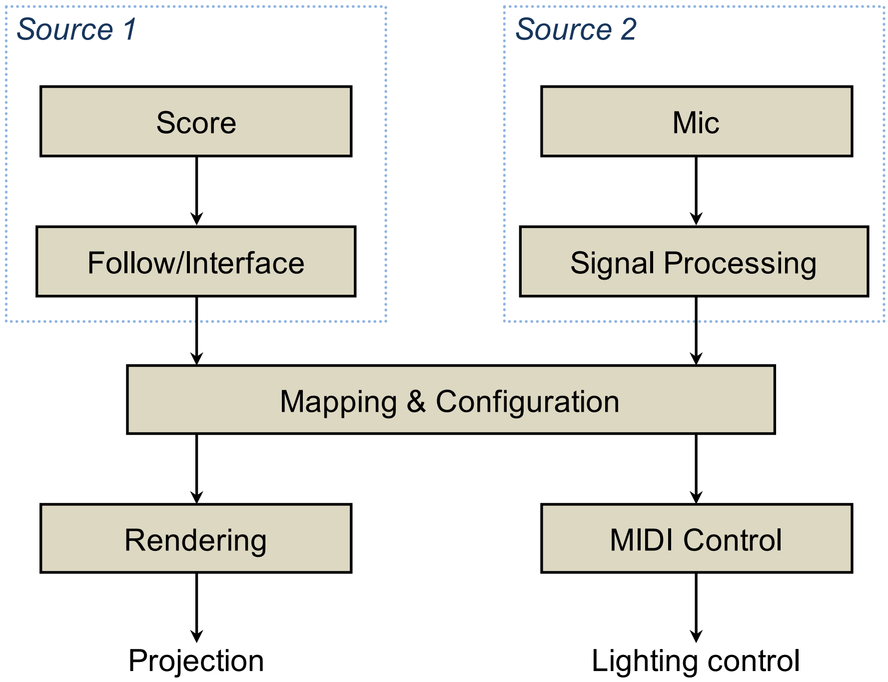

Figure 1: Overall system architecture.

3.2 Design

The system design, in this context, is focussed on its application in a varied concert programme; the overall system architecture is presented in Figure 1. Prior to performance, due to the musical complexity of large-scale orchestral works, the score is analytically reduced into a more manageable format using MIDI representation. This stage also allows manual selection to highlight particular events and structures; most critically, indicating the tonal centre of the work, but also highlighting melodic gestures and motivic movement. Other events and cues can be incorporated, including triggers for the lighting control.

In order to capture the temporal progression of a complex and diverse concert (e.g. solo, choral and ensemble works), a flexible method of performance following is required. For this reason, methods of interactive (Source 1), and automated (Source 2) control are implemented. Source 1 requires a user to track the performance using a MIDI interface output through MIDI channel 1. Whilst Source 2 analyses the live audio as it is produced, identifying fundamental frequencies, sent via MIDI channel 2. The clear advantage of this approach is its adaptability, enabling the sources to be used both independently, and concurrently with synchronisation.

According to the aforementioned literature in Section 2, mapping strategies have been designed in order to facilitate the translation of sonic to visual events. Developed in Processing (processing.org), the structure of the mapping algorithm is dynamic, with both generic/general associations, and specific mapping using a selected composer's individual synaesthesia mapping, e.g. Messiaen, Ligeti, and Sibelius. The generic mapping is designed to simulate general synaesthetic response to sound based upon findings from psychological research (Hubbard 1996).

3.3 Example Output

When considering the material for mapping there are five primary musical parameters: Pitch, duration, loudness and timbre. An example visualisation of a frame from Debussy's *Syrinx* is given in Figure 2. As it is a solo work, each defined colour object corresponds to an individual note. This mapping employs Newton's frequency-colour associations; in this example the tonal centre B♭, is signified in the strong purple-blue hues. Objects are created in a spherical trajectory, with length representing note duration, and fading out every three measures. Randomisation and easing have been applied to reflect the freedom of Debussy's melodic line, rumoured to have originally been written meter-less.

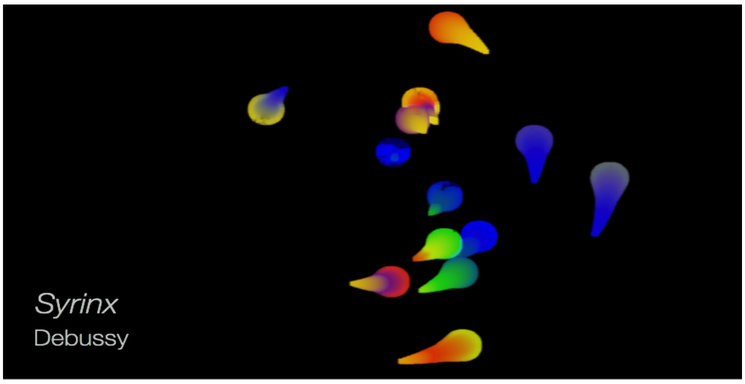

Figure 2: Visualisation of Debussy's 'Syrinx' bars 1 to 2.

4. CONCLUSIONS

Synaesthetic sound-colour associations present a framework to translate between music and visual art. This paper first presented contextualisation of the project together with the overall system aim, after which, a brief literary analysis was presented. The design and development of a prototype to visualise music was considered utilising synaesthesia-informed mapping strategies, including those based on Newton and Messiaen, together with graphical design based on psychological findings of music-colour synaesthesia. Furthermore, we are currently developing an additional multimodal extension to this concept in the form of a haptic chair.

ACKNOWLEDGEMENTS

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Why is Classical Music Yellow: A Colour and Sound Association Study

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ABSTRACT

The aim of this paper is to expand the knowledge on the subject of colour and sound association. This research investigates the correlation between colours and music, and the mental processes that people from different cultures and occupational backgrounds apply when making these connections. A subjective test was developed in order to examine whether there is an agreement between non-synaesthetic people in their individual colour-music associations. Twenty different music genres were offered to the participants, from Jazz and Blues to Classical and Byzantine, and a palette of 36 colours. A similar test was performed using 20 movie and TV series soundtracks. The results of both tests suggest that some genres generate high level of colour agreement amongst the participants. The soundtracks' test demonstrated an even higher level of agreement due to the connection people were able to make with the movies' genre, look and environment setting. This paper will present and discuss the findings of both tests.

1. INTRODUCTION

Sounds and colours have been correlated to each other from the early years of human civilisation. Even though nowadays we have advanced technological tools to achieve sound and colour combinations in any desirable way, the same questions remain unanswered: Can sounds be correlated to colours? What is the best way to present the combination of sounds and colours to achieve effective communication?

In Colour-Hearing synaesthesia people experience involuntarily and consistently the sense of colours when they hear sounds, no matter whether their feelings or thoughts vary (Harrison and Baron-Cohen 1994). These synaesthetes do not need to think or imagine how to associate sounds with colours. However, there is no agreement in colour and sound association among synaesthetes. But what about non-synaesthetic people? Do they correlate sounds to colours in a similar way? (Hubbard 1996). What process do people follow in order to accomplish this kind of association? Visual memory, for example, is a common way of linking sounds with colours when the sound source can be recognised and visually recalled (e.g. the sound of sea waves with the colour blue). However, an agreement in colour association for sounds that are not connected to a particular visual cue has not been reached.

Cutietta and Haggerty (1987) demonstrated that specific colours are associated with particular music kinds by a high number of people from different ages. This colour music agreement begins at the age of nine, but is stronger for adults. Their test proved that colour and music association is very common in people due to the rich emotional responses that music generates. The current research attempts to answer some of these questions and explain how people from variable backgrounds, connect specific music genres to particular colours, based on their emotions, visual memory and imagination.

2. METHOD

Although there are many studies involving synaesthetes there is not a lot of research on how non-synaesthetes associate colours to sound or music. Ward *et al* (2006) in their study found clear differences between sound-colour synaesthetes and non-synaesthetes. The main differences were: consistency of colour associations, specificity of colour selection and the automaticity of the colour associations. However, both groups use the same cognitive mechanism which maps auditory to visual; this involves mapping between the pitch and the lightness.

2.1 Music Genres Study

For the first study a subjective test was created using a computer-based environment through which subjects were able to hear 20 music samples and select a colour from a palette. The mean duration of the audio samples was approximately 3.4 seconds. Although previous studies have mostly used a limited colour palette of basic hues, in this study the palette, created using the NCS system (Hård, Sivik & Tonnquist 1996), comprised of eleven hues, and a lighter and darker version of each hue as well as the achromatic white, black and grey (Figure 1). The participants were prompted to select a colour that they associated with the music track that was playing. A list of the different music genres is presented in Table 1. The test was conducted using the same computer monitor in a dimly lit room. Thirty-two non-synaesthetic subjects with normal hearing and sight perception participated in this test (12 females and 20 males). Their age ranged from 17 to 50. Their nationalities were also varied to achieve a better diversity of cultures.

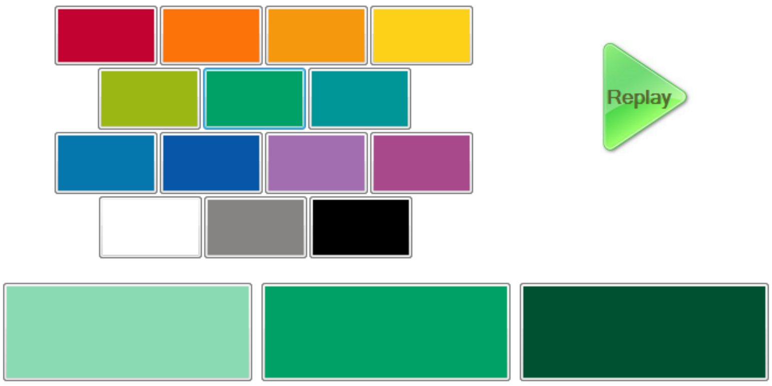

Figure 1: Screenshot of the computer-based application demonstrating how the dark and lighter versions of a hue appear below when a colour has been chosen.

Table 1: Shows the music genres that were used in this study.

No	Genre	No	Genre
1	Samba	11	Traditional Indian
2	Rock Ballad	12	Jazz
3	Bluegrass	13	Latin America
4	Blues	14	Metal
5	Traditional Chinese	15	R n' B
6	Classical	16	Reggae
7	Disco	17	Rock n' Roll
8	Funk	18	Rock
9	Gypsy	19	Trance
10	Traditional Greek	20	Byzantine Chant

2.2 Soundtracks Study

A second subjective test was conducted using 20 well-known film and TV series soundtracks to see if there was an agreement between people who recognised the origin of the soundtrack. It was expected that the film genre, style, the colour grading, the primary filming location and the clothing would play an important role in the subjects' colour choices. The test for this study was designed to be distributed online so as to reach a greater number of participants from different countries. The same 36 colour palette was used as in the first study and participants were asked to pick one colour for each soundtrack. These sound files were 10-15 seconds long in order to keep the duration of the survey within acceptable limits. Participants were prompted to use headphones and conduct the survey in a dimly lit room. This survey was completed by 200 people, 102 male and 98 female.

3. RESULTS AND DISCUSSION

The findings suggest that people make use of their feelings, memory and imagination in order to accomplish colour-music associations. Specific music genres, such as *Classical* and *Byzantine*, generated significant colour agreement, whereas *Gypsy* and *Indian* for example reached great colour variation.

In the first study (Music Genres) the highest percentage of colour agreement was reached for *Classical* music where 28% of the subjects selected Yellow Middle (Figure 2). Black (22%) and White (19%) were the predominant choices for *Byzantine* music, whereas *Gypsy* was the genre that covered every colour with no particular inclination. Almost all of the traditional music genres presented no colour uniformity and high variations: *Greek Traditional*, *Indian*, *Latin America*, and *Samba.* The exception was *Chinese*, which presented inclination towards Green and White. Other colour associations were: *Funk* with Orange, *Blues* with Yellow and Orange, *Disco* with Red and Purple, *Jazz* with Violet and Purple, *Metal* with Grey and Black, and *Metal Ballad* with Blue and Violet. Generally, ballads and slow pieces were associated mostly with cool colours, while more upbeat songs with warm ones.

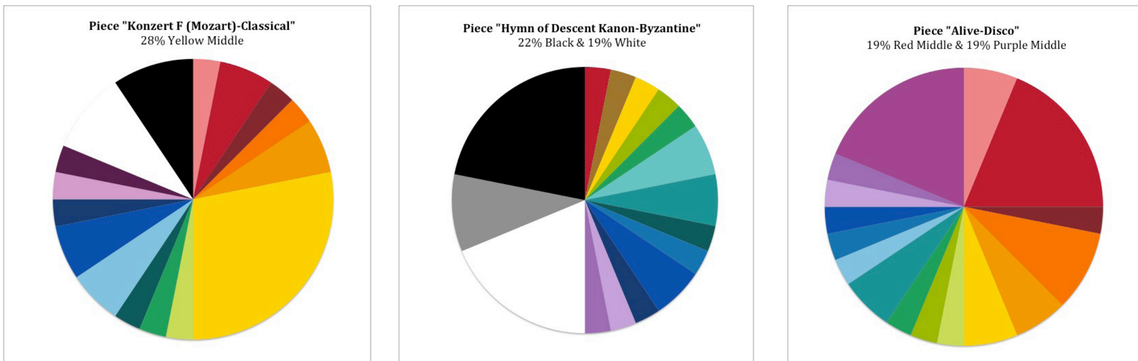

Figure 2: The colour association percentages for Classical, Byzantine and Disco music.

Most of subjects commented that they imagined colours and pictures through their attempt to achieve the correlation. Some specific examples of correlation that subjects claimed to apply were: Black or Yellow for disliked or annoying pieces, Black for boring ones, Purple, Red or Pink for favoured or pleasant ones, Pink for passionate ones, Orange for amusing ones, Green for calming ones and White for preferred music genres.

In the second study (Soundtracks) since the majority of the audio clips were themes taken from famous films, most of the respondents were able to recognise them. There were obvious colour-associations differences between the participants who recognised the clip and were able to name it and those who did not recognise it or could not name it correctly. It was interesting to see which elements of the film/TV series were the most memorable to people and therefore easily connect them to a colour or a combination of colours. These ranged from the genre, the title/logo, the clothing of the main character to the filming location. For example the colour associations for the soundtrack of Psycho were 42% red, 20% black and 11% grey, whereas the theme of Indiana Jones gathered a range of warm, sandy and earthy colours. For the theme from Star Wars the leading colours were 31% black and 22% yellow due to their presence in the logo.

4. CONCLUSIONS

Non-synaesthetic people tend to use similar processes to associate colours to music. These processes are linked to inspiration, imagination, emotions and memory, and can generate pictures, scenes or abstract colour forms into people's minds. Most people are familiar with colour and music association, even if they have never consciously thought about it. This investigation in the field of colour-music association revealed that every music piece generates consciously or unconsciously a colour atmosphere in people's perception.

People's conscious correlation between colours and music could unlock pathways to imagination and inspiration, and broaden their perception of the visible and auditory world. Further understanding of this field could lead to valuable knowledge of the complex cognitive and psychological processes. The results of this work could be applied to an audio-visual performance, an animation or film, or a graphical interface to achieve an aesthetically pleasing and balanced blend between music and colours.

ACKNOWLEDGEMENTS

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BIOGRAPHY

John McCann received a B.A. degree in Biology from Harvard University in 1964. He worked in, and later managed, the Vision Research Laboratory at Polaroid from 1961 to 1996. He currently consults and continues to do research on color. He has studied human color vision, digital image processing, large format instant photography and the reproduction of fine art. His 130 publications have studied Retinex theory, color from rod/Lcone interactions at low light levels, appearance and intraocular scatter, and HDR imaging.

He is a Fellow of the Society of Imaging Science and Technology (IS&T) and the Optical Society of America (OSA). He received the SID Certificate of Commendation and is the IS&T/OSA 2002 Edwin H. Land Medalist, and IS&T 2005 Honorary Member. He is past President of IS&T and the Artists Foundation, Boston. He served as Secretary of the Inter-Society Color Council, the USA Member body of AIC. In 2012 with Alessandro Rizzi, he published *The Art and Science of HDR Imaging*, a Wiley / I&ST book.

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