Examination of Method for Decreasing Unpleasantness Caused by Strong Brightness of Smart-phone Displays in Dark Adaptation

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ABSTRACT

The aim of this research is to suggest a method for decreasing the unpleasantness by the strong brightness on a display which the user of a smart-phone has under dark adaptation. In this research, a questionnaire survey was conducted about the unpleasantness which subjects feel to the dazzle of a smart-phone display to 21 smart-phone users. Then, a visual experiment using iPod touch (same form to iPhone) manufactured by Apple Inc. was conducted that 30 subjects evaluated the impression and the unpleasantness caused by the brightness of the smart-phone display with different brightness and background colours. The replies obtained in the questionnaire survey and the experimental results were analyzed. It authorized whether a significant difference would be between each evaluation result, and investigated correlation with luminance level and illuminance. Through the analysis of the experimental results, the followings were found out;

The 3 kinds of impressions to the brightness in each conditions, which are ‘dazzle’, ‘fatigue’ and ‘irritation’, have high correlation to luminance level and illuminance.

The favourite luminance level to use a smart-phone display was found out. In addition, at the time of dark adaptation, it was found out that brightness lower than the brightness given by the self-adjustment function of a smart-phone display reduces the unpleasantness. Moreover, the unpleasantness can be reduced by changing a background colour to black, even if the brightness was given by the self-adjustment function.

1. INTRODUCTION

Nowadays, smart-phones and tablet PCs are used very much in our daily life, and the opportunity to work by seeing their displays has been increased. Many of such display media have a self-luminous display. The display media is used under various lighting conditions. Therefore, in order to adjust users’ visual sensitivity under the various lighting conditions, the regulation function of the display can adjust luminance according to the luminance of surrounding environment, and users can see images and characters on brightness by the display automatic self-adjusted luminance. However, it is not clear whether the brightness self-adjusted is suitable for smart-phone users or not.

The aim of this study is to suggest a method for decreasing users’ visual stress such as unpleasantness. The unpleasantness which the user of a smart-phone has under dark adaptation is given by the strong brightness on a smart-phone display. In order to know about the details of the impressions relating to visual stress such as unpleasantness and dazzle when smart-phone users use their smart-phones, a questionnaire was conducted to university students. A visual experiment for evaluating 6 impressions of ‘dazzle’, ‘readability’, ‘unnaturalness’, ‘fatigue’, ‘irritation’ and ‘unpleasantness’, which were chosen using the results of the questionnaire, was also conducted. In addition, the subjects were asked to choose the most favourite luminance level samples used in the visual experiment.

2. METHOD

A questionnaire survey was conducted to 21 smart-phone users, and a visual evaluation experiment was also conducted. Then, a visual experiment was conducted that 30 subjects evaluated the impression and the unpleasantness caused by the brightness of the smart-phone display with different brightness and background colours. The results obtained were statistically analyzed using correlation analysis and analysis of variance.

2.1 Questionnaire Survey

In order to know about problem such as dazzle and displeasure when smart-phone users use their smart-phones, a questionnaire was conducted to 21 university students. The questions were use situation, problem under use, and next action when users have the problem. As one the results obtained in the questionnaire, visual problems under use are shown as below:

Replies for a question about visual problems under use (n=21)

13 replies: I feel dazzling for my smart-phone display lightness when dark such as midnight

6 replies: I can't read the screen of my smart-phone in the outdoors.

2 replies: My eyes get tired when I use my smart-phone for a long time.

2.2 Sample Preparation for Visual Experiment

An iPod touch manufactured by Apple Inc., which has the same form and similar function to iPhone, was used in this visual experiment. The details of the iPod touch is as followings; white colour, IPS retina screen, 1136x640(px), 800:1 contrast ratio, and 500cd/m^2 maximum luminance.

The display sample on the iPod touch was an e-mail which were written in Japanese. Black and white characters were used for the white and black background colours, respectively. The background colours are white and black. All of the content was the same e-mail. The display samples on white and black background were shown in Figure 1.

Figure 1: Samples used in this visual experiment: White and black background.

We used 6 luminance level samples (w0, w25, w50, w75, w100) in this research, which have different luminance on white/black background. The luminance levels of white background samples are w0, w25, w50, w75, w100, and the luminance levels of black background sample is b35. The luminance level of b35 is the luminance level given by self-adjustment function in the dark experimental room used in this study.

In addition, w50 and b50 luminance level samples were used at the first of the visual evaluation. b50 was used only for practice of subjects. The relationship between luminance levels of iPod touch and illuminance values onto subjects is shown in Table 1. The illuminance values were measured 5 times for each sample by an illuminance meter T-10 manufactured by Minolta Inc., and the measured values were averaged excluding unexpected values.

Table 1. Lighting levels of iPod touch of illuminance values onto subjects.

Luminance level	w0	w25	w50	w75	w100	b35	b50
Illuminance (lx)	0.19	2.17	5.53	10.64	23.79	0.38	0.68

2.3 Subject and Evaluation Item

The subjects are university students who are 18 to 24 years old. The number of the subjects was 30 (15 male and 15 female). The evaluation items are 'dazzle', 'readability', 'unnaturalness', 'fatigue', 'irritation', and 'unpleasantness' which were selected using the results of the questionnaire. The visual experiment was conducted using Semantic Differential Method (5 points evaluation, 1 to 5 score). The subjects were asked to evaluate 7 samples including 2 practice samples with the 5 levels. After the visual experiment, they were also asked to select the most suitable display sample.

2.4 Experimental Procedure

The subjects separately carried out the visual experiment at different date and time. The subjects entered into a dark experimental room, and they took 5 minutes for getting the dark adaptation with a iPod touch in their hands. After getting the dark adaptation in a dark room, the visual evaluation was started. The subjects were asked to evaluate each sample in 30 seconds, to reduce the influence of light adaptation. The subjects took a rest for 2 minutes after the evaluation of one sample. The samples were w0, w25, w50, w75, w100, b35 and b50 which had been prepared in advance. At the first, the subjects were asked to evaluate w50 and b50 as practice. After the practice, the evaluation for each 6 samples (w0, w25, w50, w75, w100 and b35) were randomly given and evaluated for 'dazzle', 'readability', 'unnaturalness', 'fatigue', 'irritation', and 'unpleasantness' impressions. After the evaluation for all samples, the subjects were asked to choose the most favorite sample used in dark condition.

3. RESULTS AND DISCUSSION

The visual results for 6 kinds of impressions, which are 'dazzle', 'readability', 'unnaturalness', 'fatigue', 'irritation', and 'unpleasantness', were totaled and calculated their average values respectively. Then, the correlation of each impression to luminance level and illuminance were analyzed. The values of luminance levels were directly used the level numbers of iPod touch. Table 2 shows the correlation coefficients of the 6 impressions to luminance level and illuminance.

Table 2. Correlation of the 6 impressions to luminance level and illuminance.

	Dazzle	Readability	Unnaturalness	Fatigue	Irritation	Unpleasantness
Luminance level	0.77	0.07	0.18	0.67	0.67	0.39
Illuminance	0.69	0.14	0.23	0.62	0.62	0.41

The 6 impressions have some correlation among themselves. Table 3 shows the correlation coefficients between 'unpleasantness' and other 5 impressions. This may mean that 'unpleasantness' is synthetically evaluated using other impressions.

Table 3. Correlation between 'unpleasantness' and other 5 impressions.

	Dazzle	Readability	Unnaturalness	Fatigue	Irritation
Correlation coefficient	0.54	0.48	0.66	0.68	0.70

The 6 impressions discussed in this study are relating to visual stress. Total of subjects' evaluation values for each sample through SD method was used as total visual stress index. Table 4 shows the total visual stress index. The lowest visual stress was w0, and the second lowest one was b35. The highest visual stress sample was w100.

Table 4. Total visual stress index of the 6 impressions.

Luminance level	w0	w25	w50	w75	w100	b35
Visual stress index	410	453	598	620	725	431

Table 5 shows favourite luminance level chosen by subjects. 15 subjects, a half of the subjects, chose w25. 10 subjects chose b35, and 4 subjects chose w0. W75 and w100 were not chosen.

Table 5. Favorite luminance level chosen by subjects: Frequency and percentages (n=30).

Luminance level	w0	w25	w50	w75	w100	b35
frequency	4	15	1	0	0	10
%	13.3	50.0	3.3	0.0	0.0	33.3

Comparing with the results of visual stress analysis, we found favourite samples used in dark condition are about the same to the low visual stress samples. However, the most favourite sample w25 was the third lowest visual stress sample, not the lowest visual stress sample. This means that the lowest luminance level is not the most favourite level and users choose the most favourite level with using some other factors.

4. CONCLUSIONS

It authorized whether a significant difference would be between each evaluation result, and investigated correlation with luminance. Through the analysis of the experimental results, the followings were found out;

1. The 3 kinds of impressions to the brightness in each conditions, which are 'dazzle', 'fatigue' and 'irritation', have correlation to luminance level and illuminance. The correlations between visual evaluation and illuminance levels are 0.77, 0.67 and 0.67, respectively, and those between visual evaluation and luminance level are 0.69, 0.62 and 0.62, respectively. The 'unpleasantness' evaluation result has correlation 0.39 and 0.41 to luminance level and illuminance.
2. The favourite luminance level to use a smart-phone display was found out. In addition, at the time of dark adaptation, it was found out that brightness lower than the brightness

given by the self-adjustment function of a smart-phone display reduces the unpleasantness. Moreover, the unpleasantness can be reduced by changing a background colour to black, even if the brightness was given by the self-adjustment function.

3. The lowest luminance level is not the most favourite level. Users may choose the most favourite level using some other factors. Too low luminance level may be not so good for users' favour. The details and the factors should be investigated more.

The summary of this study suggests us the following ways to reduce the problems such as unpleasantness under dark lighting condition; One is to use w25 that having low luminance white background however not so dark. Another is to change from white background colour to black background and use white characters.

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A Spectral-based Color Vision Deficiency Model Compatible with Dichromat and Anomalous Trichromat

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ABSTRACT

This paper proposes a spectral-based color vision deficiency model with compatibility both for dichromats and anomalous trichromats. The spectral projection model based on Matrix-***R*** extracts the lost spectrum as a difference in the *fundamentals* between the normal and the color deficient. The lost spectrum is re-used for image daltonization by an optimal spectral shift algorithm to maximize the spectral visibility or minimize the visual gap from the normal. The model dramatically improved the scene visibility. The proposed model is designed based on the ***original key ideas*** of

1) Extraction of *fundamental* C^*_{LMS} (spectrum visible to the normal) from sRGB camera images by a pseudo-inverse projection without spectral image.
2) Foundation of projection matrix-R_{DEF} onto dichromatic and anomalous trichromatic spectral spaces by combining the cone spectral tables of DeMarco & Pokorny & Smith.
3) Extraction of *fundamental* C^*_{DEF} (spectrum visible to the dichromat or anomalous trichromat) by operating the matrix-R_{DEF} on the *fundamental* C^*_{LMS}.
4) Introduction of complete OCS (Opponent-Color Space) to keep the perfect achromatic grayness in the opponent-color stage.
5) Estimation of lost spectra ΔC^*_{DEF} as the difference between visible spectra C^*_{LMS} to the normal and C^*_{DEF} to the dichromat or anomalous trichromat.
6) Scene visibility correction (daltonization) by reviving the lost spectrum ΔC^*_{DEF} with the optimal spectral shift into the visible waveband.

1. INTRODUCTION

Typical Color Vision Deficiency (CVD) is classified to dichromacy and anomalous trichromacy. Dichromacy is caused by the absence of one of the L, M, or S photopigments. While, anomalous trichromacy is explained by a spectral shift in the cones caused by arrangement of exon DNA in X-chromosome. The first CVD simulator is modeled to find the corresponding color pairs between the normals and the dichromats (Brettel et al, 1997). The troublesome corresponding pair procedure is simplified by a systematic color transform model (Capilla et al, 2004) and advanced to 2-step model including opponent-color stage (Pardo and Sharma, 2011). The color-blind simulators based on Brettel are widely accepted, but any of them didn't step into the spectral analysis. The author proposed a spectral-based dichromatic vision model (Kotera, 2011, 2012) based on Matrix-***R*** theory. The model clarified for the first time what spectra are visible or invisible to the dichromats and which parts are lost from the fundamentals in normal vision. The lost spectra analysis first interpreted the reason behind the *red-green opponent-color* blindness. The anomalous trichromatic vision is modeled by a simple spectral shift (Yang, 2008) or (Machado et al, 2009) but without dealing spectral losses. This paper proposes a versatile model compatible with both of dichromacy and anomalous trichromacy. The paper demonstrates the spectral daltonization algorithm for correcting the color blindness, which is designed to maximize the visibility for the confusing colors and minimize the visual spectral gap from the normals based on the mathematical evaluation criterion.

2. SPECTRAL PROJECTION ONTO COLOR DEFICIENT SPACE

2.1 Visible, Invisible and Lost Spectra based on Extended Matrix-*R* Theory

Based on *Matrix-**R*** theory (Cohen, 2001), *a* spectral input $\boldsymbol{C}$ is decomposed into the *fundamental* $\boldsymbol{C}^*_{LMS}$ and the *metameric black* $\boldsymbol{B}$ through the projection matrix $\boldsymbol{R}_{LMS}$ as

$$\boldsymbol{C} = \boldsymbol{C}^*_{LMS} + \boldsymbol{B},\ \boldsymbol{C}^*_{LMS} = \boldsymbol{R}_{LMS}\boldsymbol{C},\ \ \boldsymbol{B} = (\boldsymbol{I} - \boldsymbol{R}_{LMS})\boldsymbol{C}$$

$$\boldsymbol{R}_{LMS} = \boldsymbol{A}_{LMS}(\boldsymbol{A}^t_{LMS}\boldsymbol{A}_{LMS})^{-1}\boldsymbol{A}^t_{LMS}\ for\ \ \boldsymbol{A}_{LMS} = [l(\lambda)\ m(\lambda)\ s(\lambda)]\ :\ cone\ sensitivity$$

The fundamental $\boldsymbol{C}^*_{LMS}$ denotes the visible spectra to normal vision, while $\boldsymbol{B}$ is by-passed and lost as an invisible spectrum with zero tristimulus value. While, the spectra visible to the color deficient are much more lost through the matrix $\boldsymbol{R}_{DEF}$ corresponding to each type of color deficient (Figure 1: sample for Protanopia).

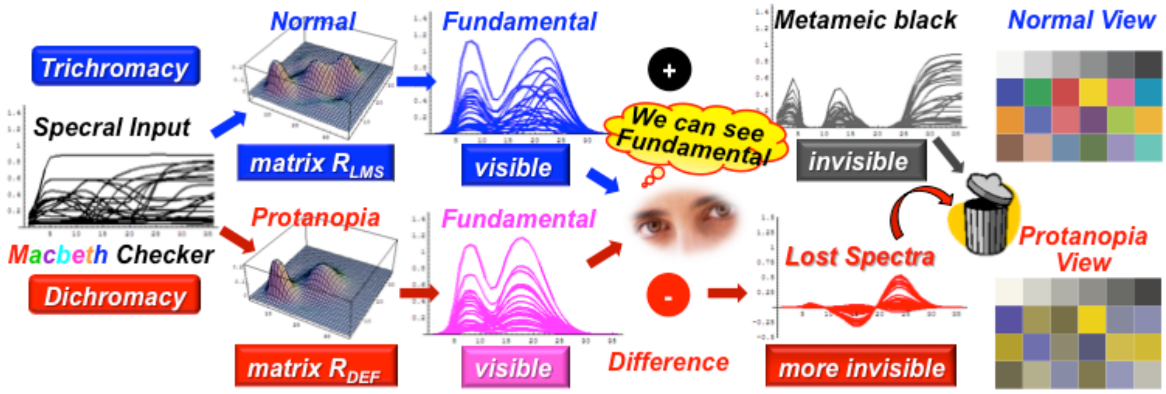

Figure 1: What color spectra are visible and lost to the color deficient?

2.2 Foundation of Projection Matrices onto Color Deficient Spectral Space

In this paper, typical four types of color deficiencies are simulated with *LMS* cone spectral sensitivities for normal and anormalous trichromat (DeMarco & Pokorny & Smith, 1992). The projection matrix $\boldsymbol{R}_{DEF}$ for each color deficient is created from a set of dichromatic and anomalous trichromatic cone responses (Figure 2).

$$\boldsymbol{R}_{DEF} = \boldsymbol{A}_{DEF}(\boldsymbol{A}^t_{DEF}\boldsymbol{A}_{DEF})^{-1}\boldsymbol{A}^t_{DEF}\ :=\boldsymbol{R}_P\ or\ \boldsymbol{R}_D\ or\ \ \boldsymbol{R}_{aP}\ or\ \boldsymbol{R}_{aD}$$

$$\boldsymbol{A}_{DEF}\ :=\boldsymbol{A}_P\ or\ \boldsymbol{A}_D\ or\ \ \boldsymbol{A}_{aP}\ or\ \boldsymbol{A}_{aD}$$

$$\boldsymbol{A}_P = [m(\lambda)\ s(\lambda)]\ for\ protanopia,\ \boldsymbol{A}_D = [l(\lambda)\ s(\lambda)]\ for\ deuteranopia$$

$$\boldsymbol{A}_{aP} = [l_a(\lambda)\ m(\lambda)\ s(\lambda)]\ for\ protanomaly,\ \boldsymbol{A}_{aD} = [l(\lambda)\ m_a\ s(\lambda)]\ for\ deuteranomaly$$

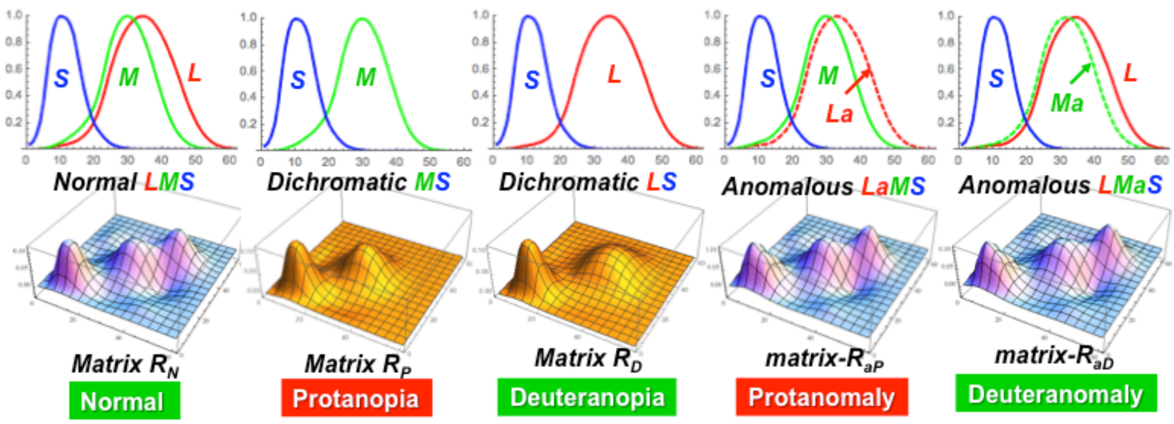

*Figure 2: Matrix-**R**$_{DEF}$ projection operators onto spectral CVD space.*

3. SIMULATION MODEL & RESULTS

3.1 Versatile Simulation Model for Dichromatic and Anomalous Trichromatic Vision

The proposed model simulates the color deficient appearance including the spectral-based daltonization and gray balance process in OCS. The model works compatible with both dichromat and anomalous trichromat by just selecting the projection matrix $\boldsymbol{R_{DEF}}$. First, the *fundamental* $\boldsymbol{C}^{*}_{LMS}$, visible spectrum to normal is captured with a sRGB camera and secondly projected to the *fundamental* $\boldsymbol{C}^{*}_{DEF}$ visible to the deficient. Thirdly, the lost spectrum $\Delta\boldsymbol{C}^{*}$ is calculated by taking the difference in $\boldsymbol{C}^{*}_{LMS}$ and $\boldsymbol{C}^{*}_{DEF}$. Next, the lost spectra $\Delta\boldsymbol{C}^{*}$ is re-used to daltonize the confusing color visibility by the optimal spectral shift algorithm. Finally, the corrected *fundamental* spectra are displayed on sRGB monitor throiugh the inverse transforms of (spectral to *LMS*), (*LMS* to *OCS*) and (*OCS* to *sRGB*). In the opponent-color process, the achromatic grayness is kept in the complete orthonormal *YCrCb OCS* (Kotera, 2014) (Figure 3).

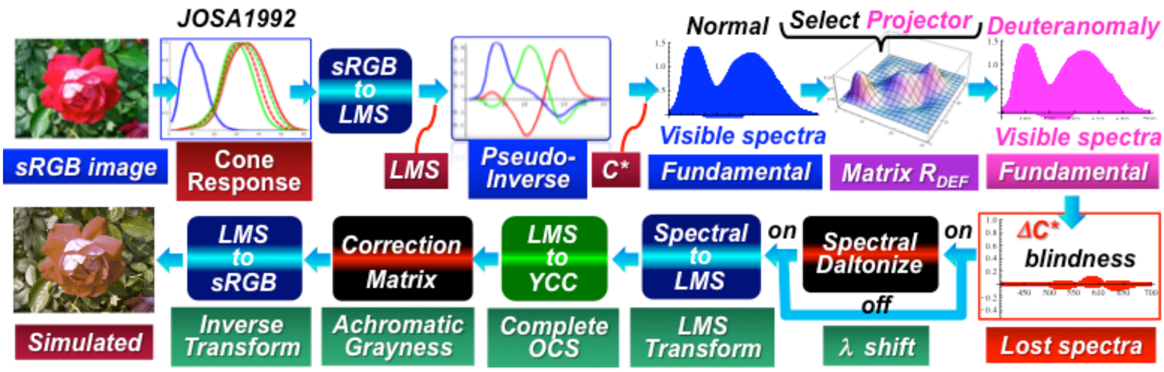

Figure 3: Spectral CVD model compatible with dichromacy and anomalous trichromacy.

3.2 Getting *Fundamental* for Scene from sRGB Camera Image

Since the *fundamental* $\boldsymbol{C}^{*}_{LMS}$ (spectrum visible to normal) carries the tristimulus value $\boldsymbol{T}_{LMS}$ as same as the input spectrum $\boldsymbol{C}$, it's exactly recovered by the pseudo-inverse transform (Kotera, 1996) from $\boldsymbol{T}_{LMS}$. Hence, the actual scene spectrum visible to normal vision is obtained from sRGB image without using expensive spectral camera as follows.

$$\begin{aligned}\boldsymbol{C}^{*}_{LMS} &= \boldsymbol{P}_{INV}\boldsymbol{T}_{LMS} \ \text{, where } \boldsymbol{P}_{INV} = \boldsymbol{A}_{LMS}(\boldsymbol{A}^{t}_{LMS}\boldsymbol{A}_{LMS})^{-1} \\ &= \boldsymbol{P}_{INV}\left(\boldsymbol{M}_{XYZ\to LMS}\right)\left(\boldsymbol{M}_{sRGB\to XYZ}\right)\boldsymbol{sRGB}_{IMG} \ ; \boldsymbol{M}_{P\to Q} = P \text{ to } Q \textit{ transform matrix}\end{aligned}$$

3.3 Lost and Visible Spectra to Color Deficient

The fundamental $\boldsymbol{C}^{*}_{DEF}$ (spectrum visible to the color deficient) is obtained by operating the matrix $\boldsymbol{R}_{DEF}$ on the trichromatic fundamental $\boldsymbol{C}^{*}_{LMS}$ and the lost spectra $\Delta\boldsymbol{C}^{*}_{DEF}$ from the normal vision is given by taking the difference in $\boldsymbol{C}^{*}_{LMS}$ and $\boldsymbol{C}^{*}_{DEF}$ as

$$\boldsymbol{C}^{*}_{DEF} = \boldsymbol{R}_{DEF}\boldsymbol{C} = \boldsymbol{R}_{DEF}\boldsymbol{C}^{*}_{LMS}, \quad \Delta\boldsymbol{C}^{*}_{DEF} = \boldsymbol{C}^{*}_{LMS} - \boldsymbol{C}^{*}_{DEF} = \left(\boldsymbol{R}_{LMS} - \boldsymbol{R}_{DEF}\right)\boldsymbol{C}^{*}_{LMS}$$

3.4 Reviving Lost Spectra for Daltonizing Color Deficient Visibility

Though the lost spectrum $\Delta\boldsymbol{C}^{*}_{DEF}$ is invisible if left as it is, we can revive it for daltonizing the confusing color visibility by shifting its distribution into the visible wavelength region.

ΔC^{*}_{DEF} is shifted by λ_{SHT} in a manner of rotate-left and added to the *fundamental* C^{*}_{LMS}.
The daltonized *fundamental* ${}_{DAL}C^{*}_{LMS}$ is given by

$$ {}_{DAL}C^{*}_{LMS}(\lambda) = C^{*}_{LMS}(\lambda) + \Delta C^{*}_{DEF}(\lambda - \lambda_{SHT}) $$

The optimal shift wavelength λ_{OPT} is determined to maximize the function $\Psi_{OPT}(\lambda_{SHT})$.

The total evaluation function $\Psi_{OPT}(\lambda_{SHT})$ is defined by combining the spectral fitness $\Psi_{FIT}(\lambda_{SHT})$ and the spectral difference $\Psi_{DIF}(\lambda_{SHT})$ to and from the normal vision as

$$ \lambda_{OPT} = \lambda_{SHT} \; for \; \Psi_{OPT}(\lambda_{OPT}) = \max_{\lambda_{SHT}=0}^{\lambda_{max}-\lambda_{min}} \{\Psi_{OPT}(\lambda_{SHT})\} $$
$$ \Psi_{OPT}(\lambda_{SHT}) = w\Psi_{FIT}(\lambda_{SHT}) + (1-w)\{1 - \Psi_{DIF}(\lambda_{SHT})\}. $$

$\Psi_{FIT}(\lambda_{SHT})$ and $\Psi_{DIF}(\lambda_{SHT})$ are estimated by summing up the power spectra (squared norm) for all the pixels g_j (j=1~J) in sRGB image as follows (Kotera, 2012).

$$ \Psi_{FIT}(\lambda_{SHT}) = \sum_{j=1}^{J} \left\| \{\Delta C^{*}_{DEF}(\lambda - \lambda_{SHT}), g_j\} \right\|^{2} $$
$$ \Psi_{DIF}(\lambda_{SHT}) = \sum_{j=1}^{J} \left\| \{\Delta C^{*}_{DIF}(\lambda - \lambda_{SHT}), g_j\} \right\|^{2} \; for \; \Delta C^{*}_{DIF}(\lambda) = (R_{LMS} - R_{DEF})\, {}_{DAL}C^{*}_{LMS}(\lambda) $$

The weighting factor w is adjusted to maximize the visibility for the confusing colors (w=1) or minimize the visual spectral gap (w=0) from the normals after the daltonized image is viewed by the color deficient. Very fortunately, in many cases for dichromats, the function $\Psi_{FIT}(\lambda_{SHT})$ takes its maximum value at $\lambda_{SHT} = \lambda_{OPT}$ and simultaneously, the function $\Psi_{DIF}(\lambda_{SHT})$ goes down to a quasi-minimum point around at the same wavelength.
The proposed algorithm dramatically improved the image visibility and naturalness after daltonization with default weight w=0.5 much better than that by popular simulator Vischeck (Brettel model). (Figure 4: sample "wild strawberries" for Deuteranopia).

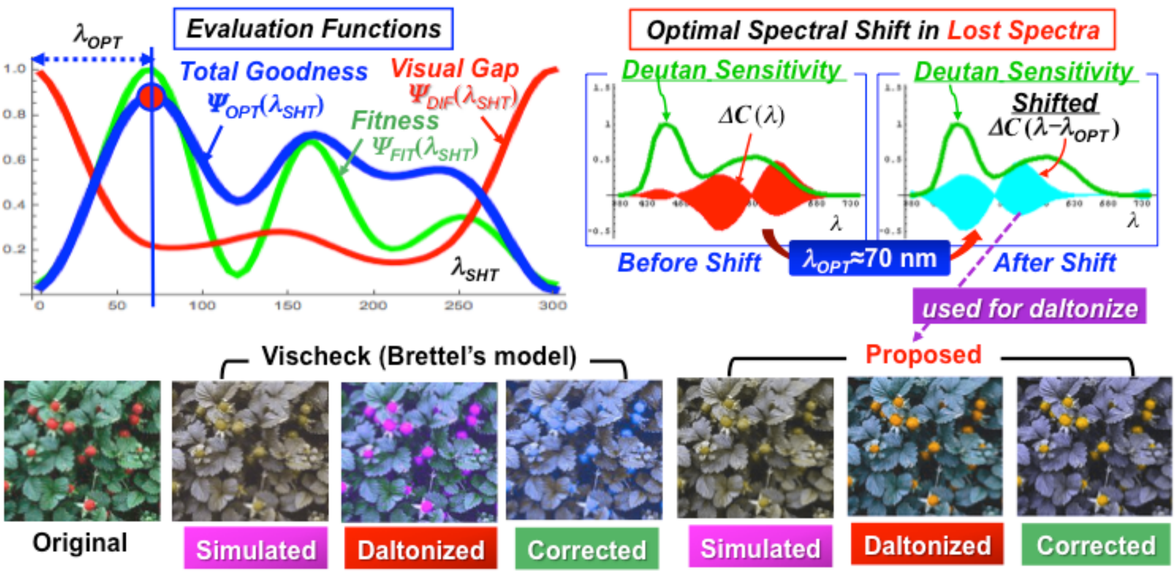

Figure 4: Daltonization for correcting CVD visibility by reusing lost spectra

3.5 Keeping Achromatic Greyness in Opponent-Color Process

Following the cone response **stage-1**, the *LMS* stimulus is encoded to a luminance-chrominance YC_RC_B signals in the next opponent-color **stage-2**. Since the opponent-color system is thought to work for the color deficient as well as the normal, the YC_RC_B signals should keep the achromatic grayness. Because a simple anomalous trichromatic simulation model (S. Yang, 19xx) only with **stage-1** caused coloring problem for the neutral gray input, the correction process to guarantee the achromatic grayness is introduced to the pathway in **stage-2** (Machado et al, 2009).

In this paper, an achromatic greyness process different from Machado's is introduced. Assuming *EE* (Equal-*Energy*) white spectrum input $\boldsymbol{W}_{EE}(\lambda)$ to the normal vision, the visible spectrum ${}_{EE}\boldsymbol{C}^*_{LMS}$, its *LMS* cone response $\boldsymbol{T}_{LMS}$, and the corresponding *opponent-color* signals YC_RC_B should satisfy the achromatic grayness of (Y=1, $C_R=C_B=0$) as

$$[Y\ C_R\ C_B]^t_{EE} = M_{LMS\to YCC}\cdot {}_{EE}\boldsymbol{T}_{LMS} = [1\ 0\ 0]^t : \textit{achromatic grayness}$$

$${}_{EE}\boldsymbol{T}_{LMS} = [L\ M\ S]^t_{EE} = \boldsymbol{A}_{LMS}\cdot {}_{EE}\boldsymbol{C}^*_{LMS}(\lambda): \textit{LMS tristimulus value for EE white}$$

$${}_{EE}\boldsymbol{C}^*_{LMS}(\lambda) = \boldsymbol{R}_{LMS}\boldsymbol{C}^*_{EE}(\lambda) = \boldsymbol{R}_{LMS}\boldsymbol{W}_{EE}(\lambda)\ \textit{for}\ \boldsymbol{W}_{EE}(\lambda) = [1\ 1\ 1\ \cdots\cdots\ 1]^t$$

The linear transform matrix $\boldsymbol{M}_{LMS\to YCC}$ to meet this condition is obtained by coupling $\boldsymbol{M}_{LMS->XYZ}$ (CIECAMO2) with $\boldsymbol{M}_{XYZ\to YCC}$ (Complete OCS, Kotera, 2014) as

$$M_{LMS\to YCC} = \left(M_{XYZ\to YCC}\right)_{Kotera}\left(M_{LMS\to XYZ}\right)_{CIECAMO2} = \begin{bmatrix} 0.4889 & 0.1336 & 0.3775 \\ 1.0038 & -0.7900 & -0.2138 \\ 0.0344 & -0.4718 & 0.4374 \end{bmatrix}$$

Indeed, YC_RC_B values to *EE* white for normal is verified to keep the perfect grayness as

$$[Y\ C_R\ C_B]^t_{EE} = M_{LMS/YCC}\cdot \boldsymbol{A}_{LMS}\boldsymbol{W}_{EE}(\lambda) = \left[1.00\ \ -8.3\times10^{-17}\ \ -1.1\times10^{-16}\right]^t \cong [1\ 0\ 0]^t$$

Since the spectrum ${}_{EE}\boldsymbol{C}^*_{DEF}$ visible to color deficient for *EE* white is lost by $\boldsymbol{\Delta C}^*_{DEF}$ against normal vision, its *LMS* or YC_RC_B responses deviate from $[1\ 1\ 1]^t$ or $[1\ 0\ 0]^t$ as given by

$${}_{DEF}[Y\ C_R\ C_B]^t_{EE} = M_{LMS\to YCC}\cdot {}_{EE}\boldsymbol{T}_{DEF}$$

$${}_{EE}\boldsymbol{T}_{DEF} = [L\ M\ S]^t_{EE} = \boldsymbol{A}_{DEF}\cdot {}_{EE}\boldsymbol{C}^*_{DEF}(\lambda)_{EE}\ \textit{for}\ \boldsymbol{C}^*_{DEF}(\lambda) = \boldsymbol{R}_{DEF}\boldsymbol{R}_{LMS}\boldsymbol{W}_{EE}(\lambda)$$

Actually, the deviations from YC_RC_B =[1 0 0] are estimated for each type of deficient as

$[Y\ C_R\ C_B]_{EE}$=[0.912 -0.180 -0.006] (protanopia)
$[Y\ C_R\ C_B]_{EE}$=[1.005 -0.032 -0.019] (deuteranopia)
$[Y\ C_R\ C_B]_{EE}$=[1.005 0.012 0.001] (protanomaly)
$[Y\ C_R\ C_B]_{EE}$=[1.002 -0.013 -0.008] (deuteranomaly)

Hence, the inverse correction matrices to guarantee the achromatic grayness are inserted in the route between (*LMS* to YC_RC_B) and (YC_RC_B to *sRGB*) transforms in Figure 3.

3.6 Simulation Results in Comparison with Other Models

The simulation results for the dichromat and anomalous trichromat are compared with typical color blindness simulators with some daltonization effects (Figure 5). Though the simulated CVD appearances look to be much the same across the models, the proposed daltonization function worked better clearly than others for rescuing the dichromatic blindness, but not so distinct for the anomalous trichromats, due to the smaller lost spectra.

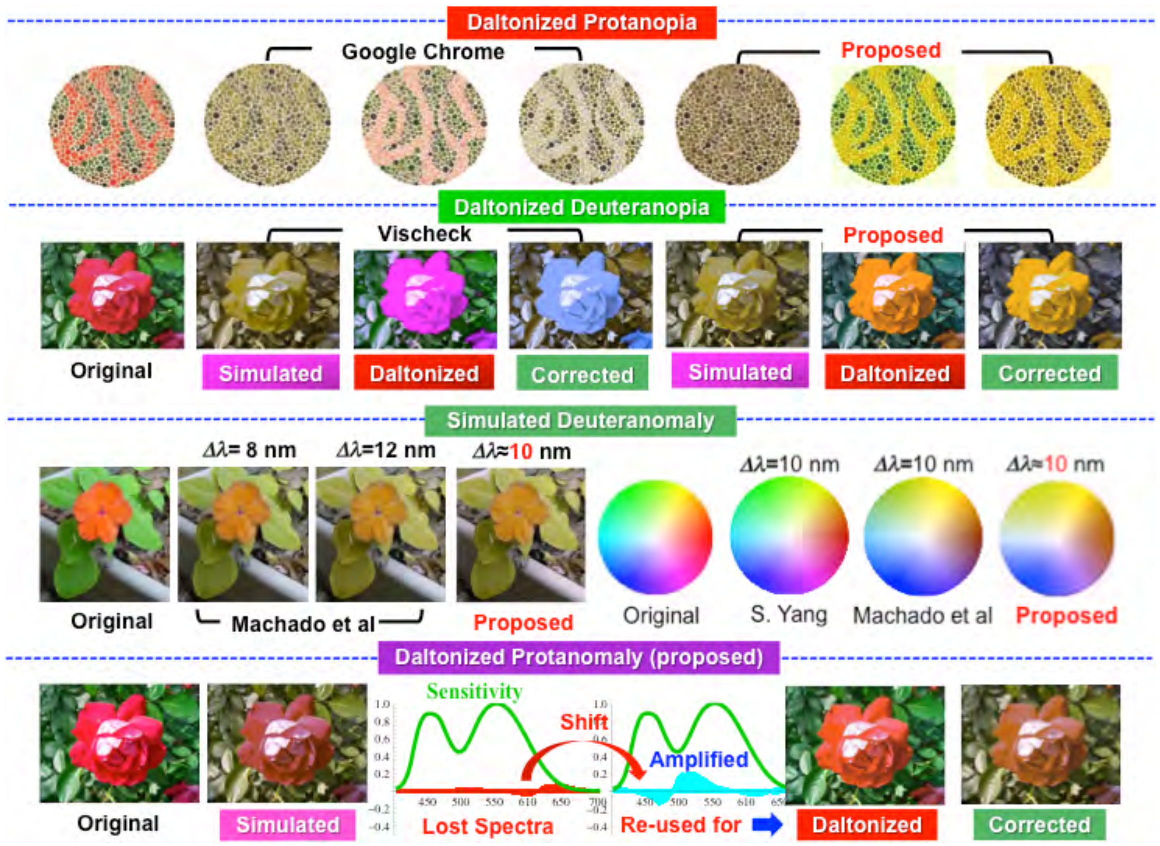

Figure 5: Comparisons in CVD simulation and daltonization effects

4. CONCLUSIONS

A Spectral-based CVD model developed from dichromacy into anomalous trichromacy. The proposed algorithm, quite different from 2D-3D corresponding pair process based on Brettel's, can estimate the visible, invisible, and lost spectra from a usual sRGB image. The model demonstrated how the lost spectrum is revived and used for daltonizing the scene visibility much better than other methods. Though its effects are remarkable for the dichromats, but still insufficient for anomalous trichromats and needs more future works.

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Colour Information in Design

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ABSTRACT

This study is concerned with identifying which types of colour information are useful in design. An analysis of the literature (299 journal papers and 10 textbooks) identified thirteen types of colour information. The importance of these thirteen types was explored through an online survey (N=62) with participants (identified through LinkedIn with a strong interest in packaging and branding) and face-to-face interviews (N=10) with senior designers and brand managers. The results from the online survey and the interviews were broadly consistent (r^2=0.66) and identified *harmony, perception, meaning, psychology,* and *printing* as being particularly important.

1. INTRODUCTION

Gradually the world would become more colourful (Leeuwen, 2011). In a demonstration of this statement, we can find the proliferation of colour in product categories that were previously largely black or white – e.g., kettles, toasters. In the retail industry, colour in packaging is a key differentiator as most warehouse supermarkets more or less offer the same shopping experience through their formats of stocking and display. Colour conveys products' messages, and influences consumers' attention and their purchase decision-making. Yet despite the importance of colour in design, it has tended to be regarded as secondary. Throughout the design process, a considerable range and volume of information is generated, used, referred to, and consulted with (Baya *et al*., 1992). Useful information in design can assist to save duplication of effort and time and to simulate creative energies (Wodehouse and Ion, 2010). According to the Cambridge Dictionary of Sociology (Turner, 2006), information is defined as uncertainty reduction, patterned abstraction, and knowledge. In the Oxford Dictionary of Environment and Conservation (Park and Allaby, 2013), information is interpreted data which is useful for making decisions or arriving at new facts. In the Oxford Dictionary of Psychology (Colman, 2009), information is knowledge acquired by learning. Synthesising these conceptions of information, this study defines colour information as interpretations, abstractions and knowledge about colour data in various fields, which include natural sciences, technology, art, psychology, cultural studies, history, and design. Colour is a meta-discipline that crosses various academic boundaries such as science, design, art, history and education. Due to the multi-disciplinary nature of colour, it is not clear whether colour information is effectively utilised in the design process. Furthermore, although developing technology makes it easy to access to variety formats of colour information via publications, websites, or mobile Apps, there are many unreliable sources especially on the internet. Colour information is a relatively new area that has not yet been addressed in detail by design research practically or theoretically. In this sense, it is noticeable that there is currently a lack of study on colour as information in design. This study will provide valuable insights for designers and brand managers informing which colour information are useful for their design process.

2. METHOD

Multiple methods such as analysing literature, online survey and face-to-face interviews with designers and brand managers were carried out to explore which colour information is useful in design. Firstly, 299 journal papers were searched by the keyword 'colour' in Colour Research and Application (CRA) which is a primary journal for colour field for 2011-2013 and ten academic books on colour which could be generally found in library were investigated using title analysis. The title of a document gives a compact summary (Senda and Sinohara, 2002), and the title analysis provides insight into topics of relative current interest (Ruben, 1992). The title terms presented in the 299 journals and the ten books were counted using online word frequency. In the CRA journal, titles predominantly focus on 'harmony', 'measurement', 'printing', 'perception, 'preference' and 'light'. In the ten colour references, titles and contents frequently concern; *design, harmony, theory, printing, art, history, perception, psychology, trend, naming, symbolism, culture* and *preference*. Analysing these terms, thirteen types of colour terms were identified (Table 1). The thirteen types of colour terms are not intended to be definitive or exhaustive. For example, there is no obvious rationale to restrict this survey to hard-copy books or journals and exclude internet sources. Nevertheless, these terms for colour information provide a holistic overview of current topics and relative interest in the colour academic field. Using these thirteen types of colour information, an online questionnaire and face-to-face interviews were conducted to identify useful colour information in the design process. For the online survey, LinkedIn was used as the main online platform to recruit relevant designers and brand managers to participate in the survey. Sixty-two responses were collected for the online questionnaire. For the interviews, ten senior designers and brand managers were interviewed.

In the online survey participants were asked to rate (using a slider bar) on a scale of 0-100 how important each of the thirteen types of colour information were to them in their design work (where 0 = no importance at all and 100 = vital). In the interviews participants were asked whether they considered each type of information to be important (so their responses were binary).

3. RESULTS AND DISCUSSION

Table 1. The thirteen types of colour information used in this study

Colour in art and design: famous artists' or designers' colours.
Colour harmony: colour combinations which arouse a pleasing effect.
Colour history: how a particular colour was developed.
Colour and light: principles of light such as wavelengths and frequencies.
Colour meaning: what is meant by a colour in different cultures or product categories
Colour measurement: measuring properties of colour or using colour measurement devices.
Colour notation: colour numbers or names to describe or communicate colour.
Colour perception: which colours attract consumers' attention.
Colour preference: individual's favourite colour.

Colour printing: the quality of colour printing.	
Colour psychology: behaviour and mental experience on colour.	
Colour theory: supposition or a system of ideas intended to explain colour.	
Colour trend: colours which are on-trend or popular.	

Figure 1 represents the results of the online survey. The figure shows the mean score for importance for each information type. The error bars show ± 1 standard error of the mean. Without performing formal statistical analysis (which will be presented in a future paper) it is clear that the standard deviations of the mean are small compared to the differences in mean scores in many cases. *Printing* gave the strongest response. *History* gave the weakest response. *Printing, harmony, meaning, psychology* and *perception* are all important. *Notation, theory, preference* and *trend* are of lesser importance. The others seem not important at all.

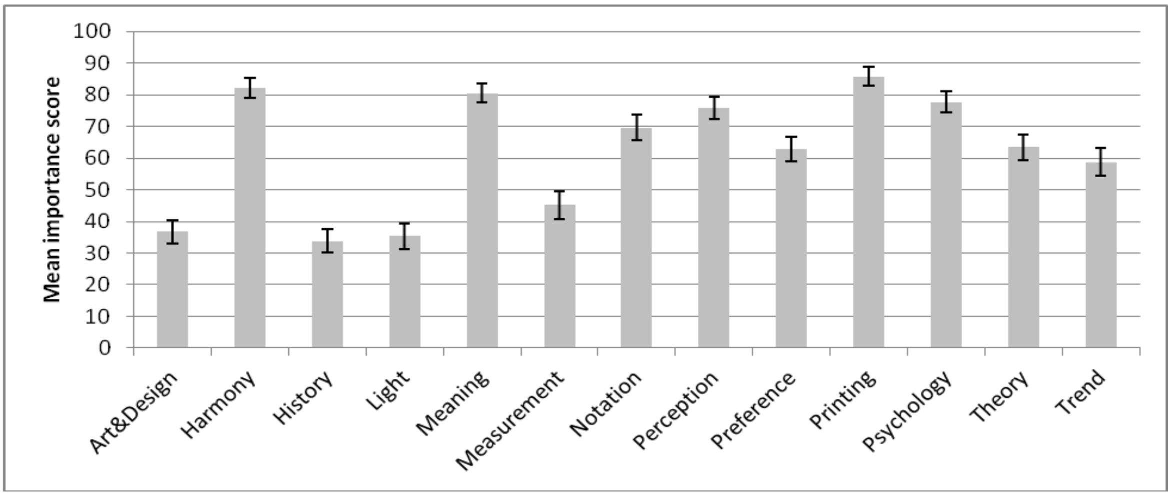

Figure 1: The result of online survey.

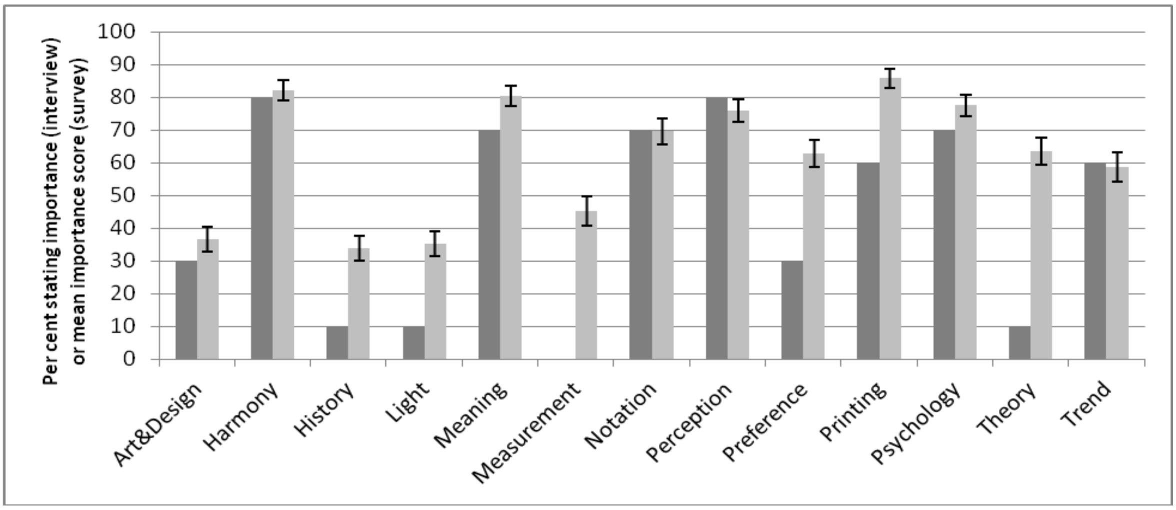

Figure 2: The result of face to face interview (dark grey) and the result of online survey (light grey).

Statistical analysis of the interview responses is more difficult partly because the sample size was low (N=10) and partly because the responses were binary rather than interval data. Nevertheless, if the per cent of participants who state that a colour information type is important is calculated (Figure 2) then it can be seen that *harmony, perception, meaning, notation* and *psychology* gave the strongest response.

If the per cent importance (from the interviews) is compared with the mean importance scores (from the surveys) then there is strong agreement (see Figure 2) between the two studies ($r^2 = 0.66$). Taken together, if the average of the per cent importance and the mean importance scores is calculated then the following types are deemed to be important *harmony, perception, meaning, psychology,* and *printing* because the mean is greater than 70%.

4. CONCLUSIONS

This work sought to identify the types of useful colour information in the design process. A review of the literature identified thirteen terms for further study. Results from an online survey (N=62) and interviews (N=10) showed strong agreement with *harmony, perception, meaning, psychology,* and *printing* identified as areas of importance in the design process.

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Relationship between Perceived Whiteness and Color Vision Characteristics

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ABSTRACT

We used a liquid crystal color display to present various near-white stimuli, equivalent to a Munsell Value of 9.5 and a Munsell Chroma of 0.25, and had observers with normal color vision (N-type) and observers with color vision deficiencies (P-type, Pa-type, D-type, Da-type) evaluate respective relative whiteness. Compared to N-type observers, observers with color vision deficiencies, regardless of their color vision type, showed a tendency to evaluate perceived whiteness as being lower for the stimuli ranging from reddish hue to yellowish hue, including the long-wavelength component. Differences in evaluation results among observers with color vision deficiencies were smaller than those of N-type observers.

1. INTRODUCTION

Fluorescent whitening agents and bluish dyes are added to white clothing and printer paper to evaluate the increased perceived whiteness of these objects. This is done to take advantage of the color components that contribute to the perception of brightness (Katayama and Fairchild 2010). Until now, research on the effects of color on perceived whiteness has been conducted on observers with normal color vision (Ganz 1979). However, comparisons with color deficient observers (Gegenfurtner and Sharpe 1999), who account for a certain portion of the population, have not to be made. This study investigates the relationship between the color vision characteristics of observers and perceived whiteness, with regard to near-white stimuli of a variety of hues.

2. EXPERIMENTAL APPARATUS AND METHOD

We used a liquid crystal color display (Eizo CG223W), on which a white point was adjusted to match the chromaticity of the standard illuminant D65. Twelve types of near-white stimuli were then presented to the observers. We adjusted the hues of the stimuli to be exactly 10PB, 3PB, 5B, 7BG, 9G, 3G, 3GY, 5Y, 4YR, 4R, 7P and N in Munsell notation; the lightness was adjusted to 9.5 in Munsell notation; and the Munsell Chroma was set to 0.25 with the exception of the achromatic stimulus N, using a color luminance meter (Minolta CS-100). Figure 1 shows the chromaticity distribution of the stimuli. The rectangle mark in the figure indicates the chromaticity point of D65 and the two oblique lines indicate the boundaries of the tint index, $T_w = 2$ and $T_w = -4$, for the CIE whiteness formula. The viewing angles of the square-shaped stimulus were approximately 4 degrees and the stimulus pair was displayed on an N7 equivalent achromatic background for the side-by-side comparison.

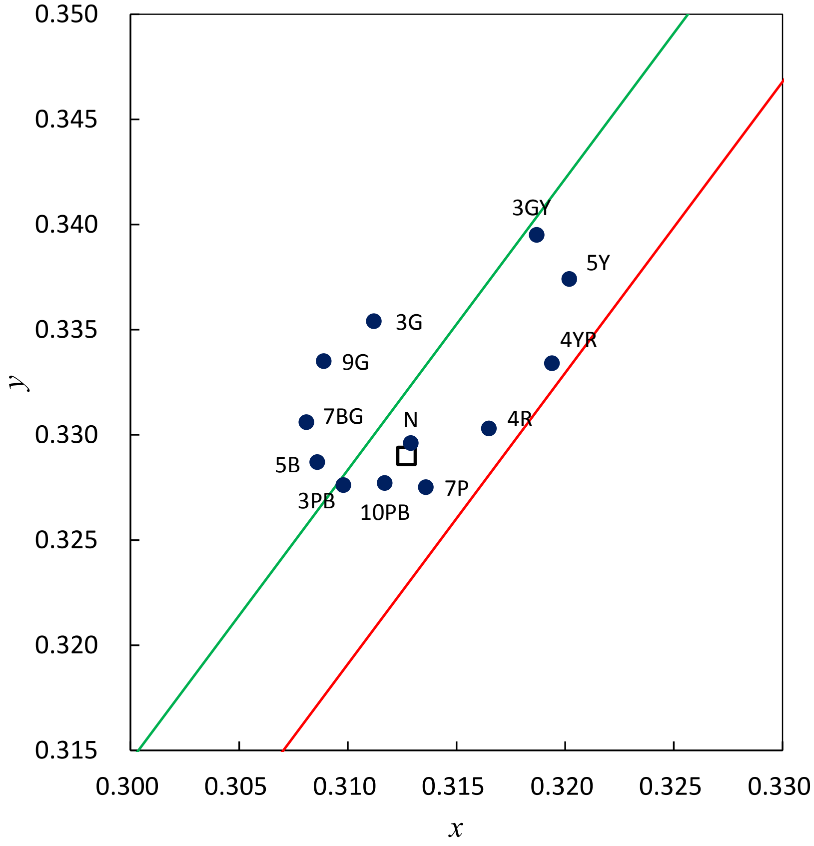

Figure 1: Chromatisity distribution of the stimuli.

After the observers adapted to the N7 background displayed on the liquid crystal color display for one minute, they were asked to select the stimulus which they thought to be whiter from the pair of near-white stimuli. The stimulus pairs were presented in random order, and the observers evaluated each of them twice.

3. OBSERVERS

The observers consisted of 15 persons with normal color vision (N-type), seven persons with Dichromatic Protanopia (P-type), four persons with Anomalous Trichromatic Protanomaly (Pa-type), seven persons with dichromatic Deuteranopia (D-type), and three persons with Anomalous Trichromatic Deuteranomaly (Da-type). The color vision characteristics of the observers were confirmed using the Ishihara Color Test and the Panel D-15 Test. The average age of the observers were as follows: N-type; 27.0, P-type; 55.1, Pa-type; 56.0, D-type; 50.4 and Da-type; 66.3. All of the N-type observers were female and all of the observers with color vision deficiencies were male.

4. RESULTS AND DISCUSSION

By testing the consistency of the results of the paired comparisons made by each observer, it was confirmed that the results were statistically significant. The differences in the results between the P-type and the Pa-type observers, and the differences in the results between the D-type and the Da-type observers were small. Therefore, we analyzed them as P_Pa-type

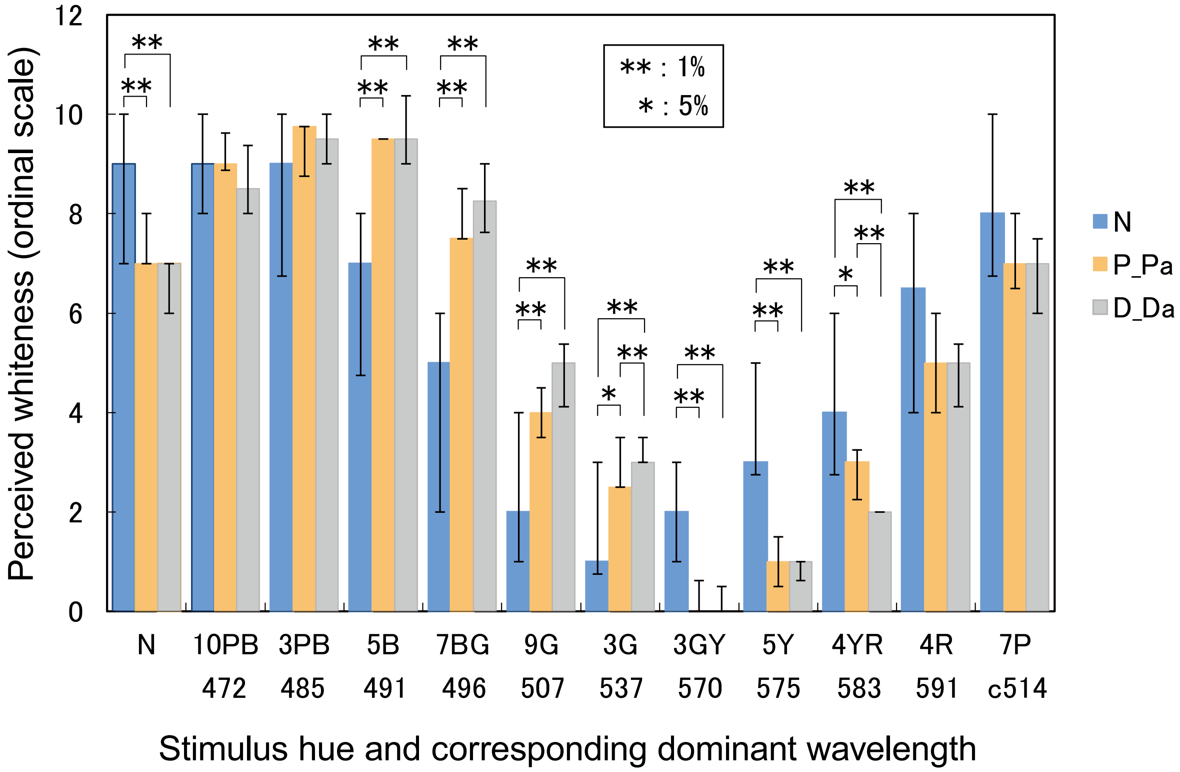

Figure 2: Median of the perceived whiteness for each stimulus from the evaluation results of each observer group (N-type, P_Pa-type, D_Da-type).

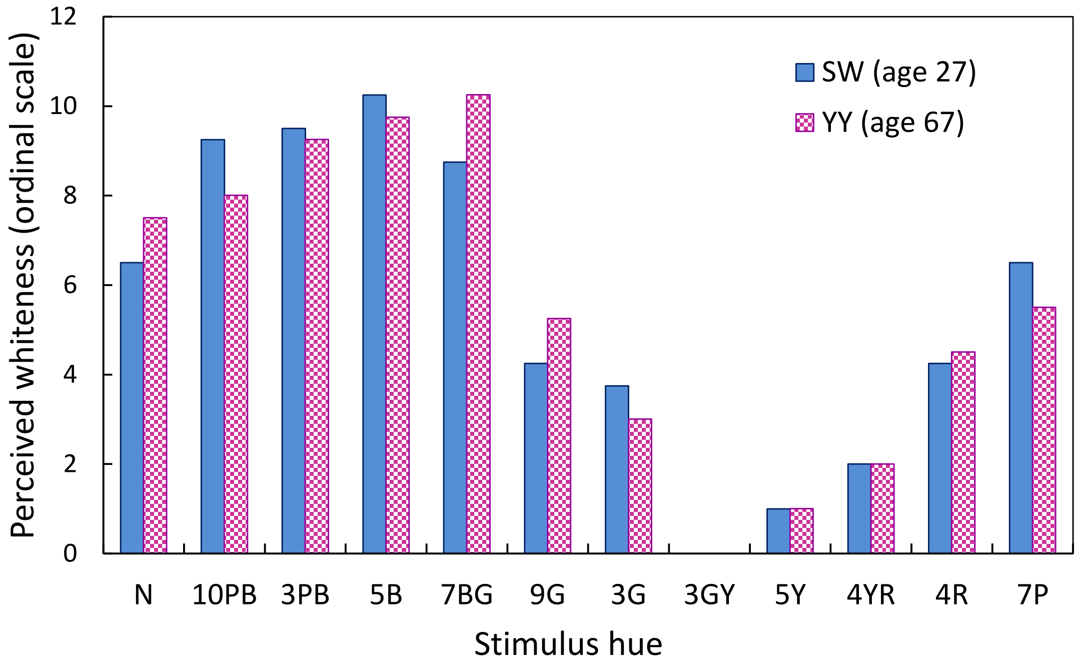

Figure 3: Comparison between the youngest and the oldest D-type observer.

and D_Da-type, respectively. We obtained the median of the perceived whiteness for each stimulus from the evaluation results of each observer group (N-type, P_Pa-type, D_Da-type). The results are shown in Figure 2. The abscissa represents the Munsell Hue and dominant wavelength of each stimulus, and the ordinate represents the relative rank value for perceived whiteness. In this figure, a higher ordinate value denotes a higher perceived whiteness. The error bars represent the median plus or minus the 25th percentile. Multiple comparison results among the three observer groups are also denoted.

The overall evaluation results show that there was a tendency for perceived whiteness to be evaluated as low for stimuli ranging from green hue to yellow-green hue regardless of color vision characteristics. However, some differences were observed among the three observer groups. The average age of the observers with color-vision deficiencies was higher than that of the N-type observers. Thus, we investigated the effect on whiteness evaluation with age. Among the D-type observers, the evaluation results of the youngest observer (SW: 27 years of age) and those of the oldest observer (YY: 67 years of age) are shown in Figure 3, respectively. The abscissa in the figure represents the Munsell Hue of the stimulus, and the ordinate represents the rank value for the perceived whiteness. As Figure 3 shows, large differences in evaluation results between the observers were not observed. Similarly, in the other observers with color vision deficiencies, no differences in evaluation tendencies were observed. Thus, our study focused only on color vision characteristics.

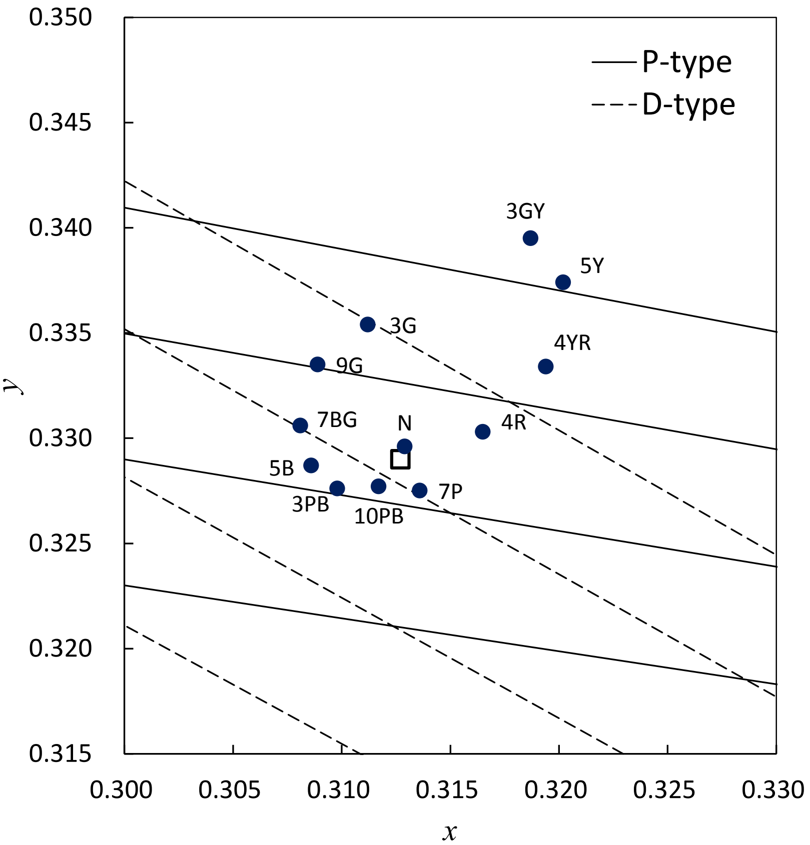

Figure 4: Relationship between the chromaticity of the stimuli and the color confusion loci.

The evaluation results for P_Pa-type and D_Da-type observers were similar, and significant differences were observed only for 3G and 4YR stimuli. However, significant differences were observed in the results between N-type and color deficient observers regarding eight stimuli. Overall, the P_Pa-type and the D_Da-type observers had a tendency to evaluate perceived whiteness as being lower for the stimuli, ranging from reddish hue to yellowish hue, including the long-wavelength component, compared to the N-type observers. This is thought to be caused by the P_Pa-type and the D_Da-type observers having lower sensitivity in long-wavelength for brightness perception compared to the N-type observers.

Next, Figure 4 shows the relationship between the chromaticity of the stimuli and the color confusion loci. The solid lines in the figure represent the P-type color confusion loci and the broken lines represent the D-type color confusion loci. In conjunction with the results shown in Figure 2, the P_Pa-type and the D_Da-type observers evaluated perceived whiteness at almost the same level as the greenish and reddish stimuli along the color confusion loci. Also, the length of the error bars shown in Figure 2 indicates that inter-observer variability in color deficient observers was smaller than that for N-type observers. This might be due to N-type observers having individual internal criteria when evaluating reddish-white or greenish-white as being whiter.

5. CONCLUSIONS

The results of examining the relationship between the perceived whiteness and color vision characteristics showed the following conclusions:

(1) Regardless of color vision characteristics, perceived whiteness was evaluated as being low for near-white stimuli with hues ranging from green to yellow-green.

(2) The difference in results between P-type and Pa-type observers, and the difference in results between D-type and Da-type observers was small.

(3) The results for P_Pa-type and D_Da-type observers were similar, and significant differences were observed only for 3G and 4YR stimuli.

(4) Compared to N-type observers, P_Pa-type and D_Da-type observers had a tendency to evaluate perceived whiteness as being lower for reddish stimuli and to evaluate perceived whiteness as being higher for greenish stimuli.

(5) The inter-observer variability for color deficient observers in the evaluation was smaller than that for N-type observers.

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An Experiment of Color Rendering with 3D Objects

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ABSTRACT

The Color Rendering Index was developed by CIE in order to measure how accurate a light source is at reproducing the color appearance of the lighted scene. This index has been used for many years by research and industry but unfortunately it tends to fail the scoring of the new LED-based lighting systems, as demonstrated by many experiments.

Many attempts to develop a more reliable index have been done, but a definitive method has not been found yet. In developing alternative color rendering indices, the aim is to achieve an index able to help in choosing a light source, maximizing the perceived quality of its color appearance reproduction. An index with a very high or a very low score is easy to interpret, but the goal is to attain a color-rendering index able to scale changes in color shift proportional to our vision between the two extremes.

One aspect not enough investigated in literature, is the influence of the characteristics of the observed scene in the color appearance preservation under varying illuminants. The presented work aims at investigating appearance variation of real non-flat objects under varying light sources, according to human color sensation. During the experiment participants had to compare a set of 3D color samples observed under a reference light source and under a test light source. Participants' answers were recorded through a questionnaire. Finally, results are compared with a set of alternative color rendering indices.

1. INTRODUCTION

The Color-Rendering Index (CRI) is the actual standard to specify the visual rendering properties of a light source (CIE, 1995). With the advent of new types of lighting devices, the CRI has shown its limits, that is the ability of having measurements in accordance with the human visual system perception (Joist-boissard, Fontoynont and Blanc-gonnet, 2009; Brueckner, Bodrogi and Khanh, 2009; Sandor and Shanda, 2005). The standard method for calculating the Color-Rendering Index does not succeed in predicting the visual response under narrow band light sources, such as three-band fluorescent lamps or white LEDs (Narendran and Deng, 2002; Bodrogi et al., 2004). These types of light sources show a rather low Color-Rendering Index, but a pleasant visual appeal and a good preservation of color. Many attempts to standardize a new method for the calculation of the color rendering have been made, but no one seems to be definitive.

In general, color rendering indices are computed in relation to a reference light source, therefore a maximum score is expected when considering light sources very close to the reference one. Difficulties arise in having a color rendering index able to scale changes in color shift proportional to human vision. Aim of the test here presented is to assess how our visual system judges the color rendering of various light sources, in order to have a baseline to compare with available color rendering indices.

2. METHOD

The main goal of this research is to collect data about the color appearance variation according to the used light source, in order to analyze the relation between a set of color rendering indices and the evaluation given by users.

2.1 The Task

The experiment, involving 48 students of a high-school (21 females and 27 males), aged between 14 and 18 years, aimed to compare 3D color samples (orange, green, white, blue, yellow, and red bricks, part of the toy showed in Figure 1) observed under a reference light source and under a test light source (Table 2). Building a 3D scene introduces shadows and inter-reflections, created by complex geometries, in order to reproduce what happens in everyday scenes.

Observers were requested to evaluate the differences between each pair of brick color. A two-stage approach was proposed: at first, a qualitative assessment to make a rough categorization, evaluating if bricks are identical, similar, or different; in the second stage, participants had to assign a number between 0 and 100, according to the category previously chosen.

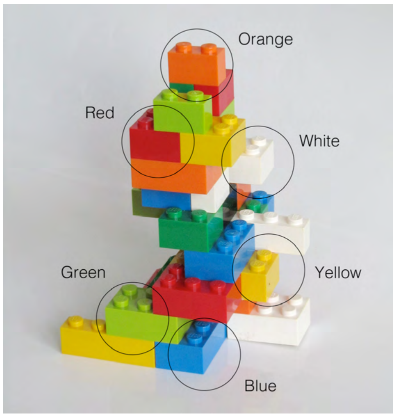

Figure 1: 3D building used in the experiment.

2.2 Experiment Setup

Four wood boxes have been constructed with size: 1 m × 1 m × 0.8 m. The inside of each box was covered with white paper. The upper part of the box was screened with a panel, to avoid direct light reaching the observers' eyes. Four identical plastic brick constructions have been placed inside the four boxes. Two light sources are housed in each box, and only one at a time was turned on. The experiments have been conducted in a dark room without time limits. Observers accomplished the experiment after a light adaptation period. The whole test has been carefully explained in advance and continuously supervised by one of the authors, to solve any possible doubt of the observers.

2.3 Light Source

Six light sources have been tested: three fluorescent, one halogen, and two LED lamps. Another halogen light source was used as reference, having the color-rendering index equal to 100. In Table 1, some of the features of the light sources used in the experiment are described.

Table 1. Light sources used in the experiments.

Light source	L.S. #1	L.S. #2	L.S. #3	L.S. #4	L.S. #5	L.S. #6	Ref. L.S.
Power (W)	20	11	11	8	3	30	42
Flux (lm)	1250	650	600	345	270	806	630
Lux (lx)	913	546	457	338	171	470	390
CCT	2969	7566	4393	3441	3178	3239	3050
Type	Fluo.	Fluo.	Fluo.	LED	LED	Halo. IRC	Halo.

Note that the second light source (L.S. #2) has a CCT of 7566 K, very different from the others. The choice of utilizing this lamp lied in the will to test it as an extreme condition. Time has been given to the observers to adapt to the average luminance level, similar in all the boxes.

2.4 Results

In Table 2, a set of calculated color-rendering indices is shown: Standard CIE CRI, CRI R96a (CIE, 1999), CQS (Davis and Ohno, 2006), CRI2012 (Smet et al., 2013), CRI-00 (Geisler-Moroder and Dur, 2009), CRI-CAM02 UCS (Li et al., 2012), GAI (Freyssinier-Nova and Rea, 2010), RCRI (Bodrogi and Brueckner, 2009), as well as the indices estimated by the users. Although the GAI and CQS are not fidelity indices, it was decided to test them too, for comparison purposes. Data are plotted for each light source in Figure 2, where the column filled in black represents the participants' answers.

In the following some comments about the effect of the different light sources are given.

L.S. #1 (Fluorescent): the observers give a score of 86. The standard CRI, the CAM02UCS and CQS give a score around 80 to the light, in line with the result of the observers.

L.S. #2 (fluorescent): R96a (with a score of 79) is the method that better estimates observers' evaluations (78).

L.S. #3 (Fluorescent): even if in all the cases the algorithms underestimate the observers' result (82), each method produces a good approximation of the result, with scores in a range between 74 (RCRI) and 80 (CRI00, CAM02UCS, CQS).

L.S. #4 (LED): all the methods give a good approximation to the observers' evaluation (80), with the exception of GAI which underestimates the result.

L.S. #5 (LED): the various methods give very different scores. CQS (71) and CRI2012 (69) get closer to the result of the observers (70).

Table 2. Color rendering indices calculated for each light source for the methods described and users evaluation.

Light source	L.S. #1	L.S. #2	L.S. #3	L.S. #4	L.S. #5	L.S. #6
Std. CRI	80	83	78	83	63	98
CRI 00	76	86	80	84	63	98
GAI	45	98	79	61	40	57
R96a	58	79	78	84	62	75
CAM02UCS	79	85	80	84	67	97
CQS	80	85	80	82	71	96
RCRI	71	89	74	89	62	100
Ra2012	68	69	76	85	69	99
User 3D	86	78	82	80	70	91

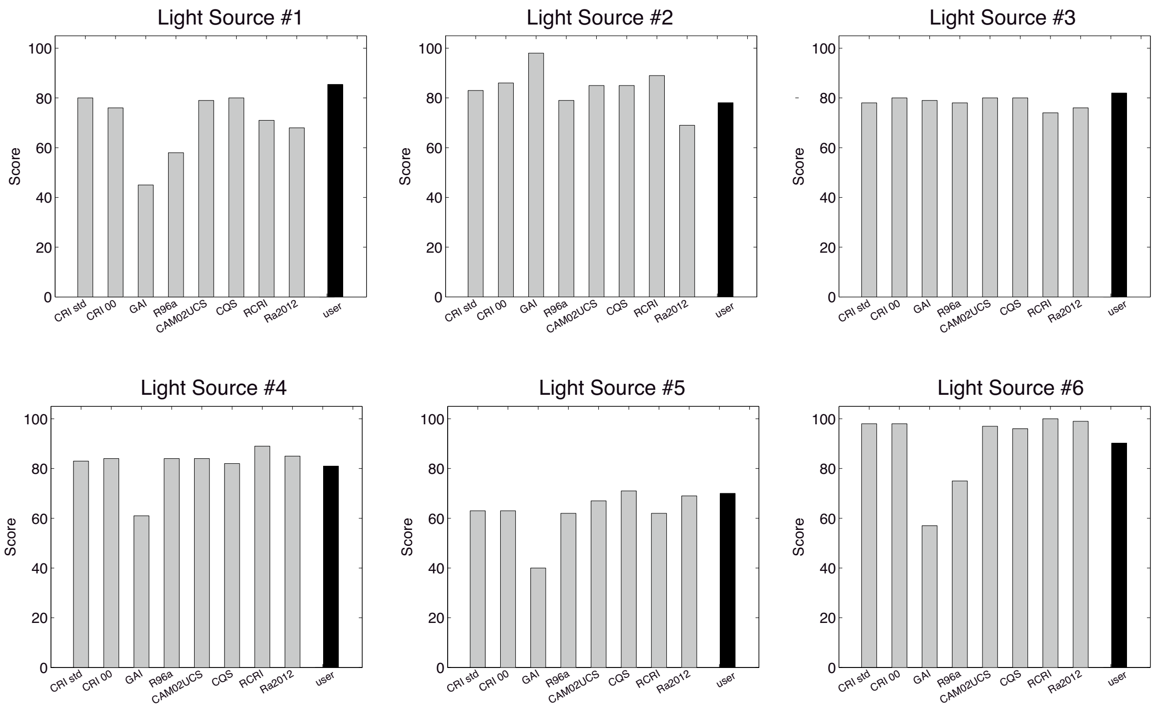

Figure 2: Comparison between the calculated and perceived color rendering indices for each light source. The bars represent: the standard CIE CRI Ra, CRI 00, GAI, R96a, CAM02UCS, CQS, RCRI, CRI2012, and the index evaluated by the users (black bar).

L.S. #6 (Halogen). All the methods except GAI (57) and R96a (75) overestimate the observation result (91). This is due to the fact that the halogen light source has a spectrum that can be approximated with a black body radiation. Therefore, the reference light source calculated by the various methods is almost identical to the light source to test, resulting in a high CRI.

The Pearson correlation coefficients have been calculated: the method that better represents the sensation of the observers, for this experiment setup, is the Standard CRI (0.875), followed by CAM02UCS (0.821), CQS (0.819), CRI 00 (0.779), CRI2012 (0.630), RCRI (0.629), R96a (0.115), and GAI (0.02).

For more details about the experiments and the results, refer to the work of Fumagalli, Bonanomi and Rizzi (2015).

4. CONCLUSIONS

A test involving users have been designed, in order to attain a data to better understand the mechanism of color rendering assessment. During the experiment participants had to compare a set of 3D color samples observed under a reference light source and under a test light source. Users' result were then compared to a set of CRIs available in literature.

Assessing color rendering among various light sources is a complex task. This process involves many aspects that can lead to different results: the colors under test, the user's experience, the context in which colors are analyzed, and many other factors. Calculating the correlation indices between user observations and a set of CRIs shows that the standard CRI is the method that best performs in this case.

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Adapting and adapted colors under colored illumination

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ABSTRACT

The state of chromatic adaptation was investigated by measuring the adapted color for the adapting color by the environment-stimulus independent illumination technique. Seven colors were employed for a subject room and the subject judged the color appearance of an achromatic test patch placed in a test room through a window between the two rooms. The angle from the adapting color to the adapted color was obtained. The angles were read out from other works available in journals and they were all plotted on one graph. The angle did not follow the opponent relation. That is, the unique red adapting color did not cause the adapted color to be the unique green. There were only two adapting colors that gave the opponent colors in the adapted color. The effect of saturation of the adapting color on the adapted color was investigated and no significant effect was found.

1. INTRODUCTION

The state of chromatic adaptation could be known by the apparent color of an achromatic patch placed at the center of a uniform colored background, the phenomenon being known as the simultaneous color contrast. If the background is red the apparent color or adapted color is green, for example. The adapted green is very pale, however, to be used to investigate the chromatic adaptation in detail. Vivid adapted color can be obtained by the two rooms technique or the environment-stimulus independent illumination technique developed by Ikeda and his colleagues[1)]. Even if the psychophysical color expressed by x and y chromaticity coordinates are made equal for a wide area of the retina in both techniques, the uniform colored background and the two rooms, the color appearance of the test patch obtained is almost achromatic by the former, while it is very vivid by the latter[2)]. In the present experiment the two rooms technique was employed and the color appearance of an achromatic test patch was measured by the elementary color naming method for seven different colors of illumination for a subject room. To show the relationship between the color appearance of illumination of the subject room and the color appearance of a test patch the angle from the former to the latter was calculated on the polar diagram used in the opponent colors system. An additional experiment was carried out, where the saturation of the illumination of the subject room was changed and the color appearance of the test patch was measured.

2. APPARATUS

Figure 1 shows the apparatus composing of two rooms, a subject room and a test room separated by a wall on which a large window W of the size 40 cm wide and 30 cm high was opened so that the subject could see an achromatic test patch T made of a white board without any scratches and placed against the back of the test room. It was illuminated by two fluorescent lamps Lt of the daylight type.

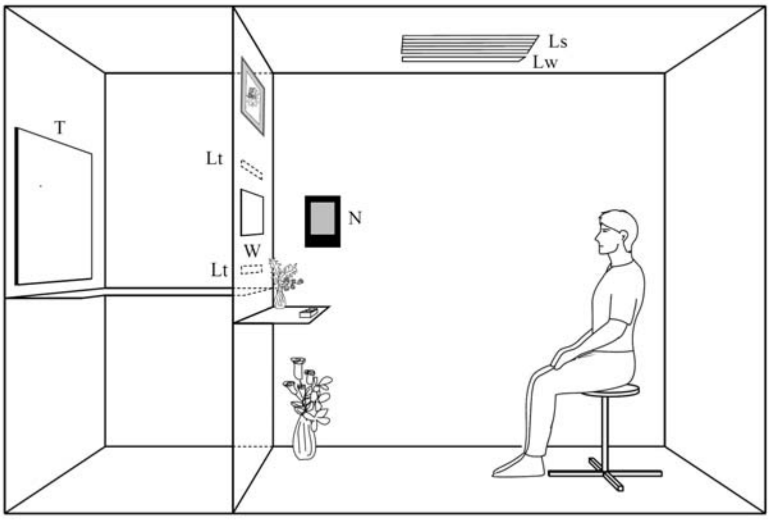

Fig. 1 Apparatus composing of a subject room (right) and a test room (left).

The distance from the subject to the window W was 180 cm and the visual angle of W became 13° × 10°. The subject room was decorated with various objects to simulate a normal room. The five ceiling fluorescent lamps in the subject room Ls were covered by a colored film to give a colored illumination to the subject room. One of the lamps was adjustable in its intensity. To change the saturation of the color another fluorescent lamp Lw was attached to the ceiling.

Seven different colored films were employed for the subject room and their chromaticity coordinates u'v' are shown by open circles in Fig. 2 denoted as CRC3. The illuminance measured on the front shelf in the subject room was kept at 50 lx for all the colors. The subject's task was to judge the color appearance of the window W by the elementary color naming method. The measurement was repeated for five times at different sessions. The horizontal illuminance near to T on the shelf of the test room was kept at 9 lx. In the additional experiment on saturation five colors of illumination of different saturation were employed for red and green illumination as shown in Fig. 3, by open circles for red and open squares for green. The illuminance was not particularly controlled and it varied for different saturation.

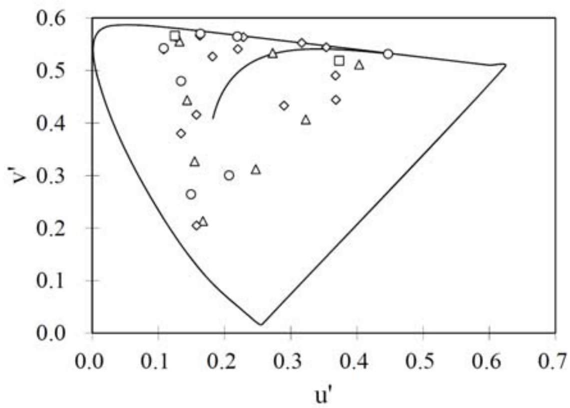

Fig. 2 Colors employed for the subject room illumination. △, Rits[3]; ◊, CRC1[4]; □, CRC2[2]; ○, CRC3, present work.

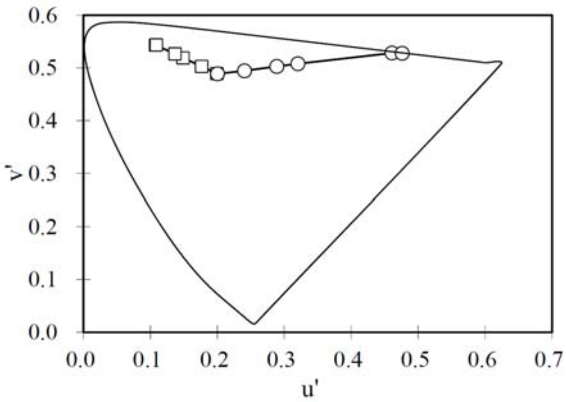

Fig. 3 Colors employed for the subject room illumination in the saturation experiment. ○, red; □, green.

An achromatic patch N of N6 in Fig. 1 was used for the measurement of the color appearance of the subject room. At the measurement the window W was made small, 2 x 2 cm^2, through which a subject looked at N and judged color with the elementary color naming method. The horizontal plane illuminance in front of the white board was kept at 130 lx. The measurement was repeated for five times.

Five subjects participated in the main experiment and two of them in the additional experiment, all normal in color vision as tested by the 100 hue test.

3. RESULTS AND DISCUSSION

For any color of illumination the entire field of the window appeared uniformly colored. Subjects perceived as if a colored paper was pasted on the window, which implied that the subjects perceived the window as an object placed in the subject room. Results of subjects CP and KC from the main experiment are shown in Fig. 4 by a polar diagram for the case of reddish blue illumination. R, Y, G, and B indicate the unique hues of red, yellow, green, and blue and the hue appearance obtained by the elementary color naming is shown by the angle from the unique red. The amount of chromaticness is shown by the radiant distance from the center becoming 100 % at the outmost circle. Open circles show the color appearance of the subject room judged from the test room through a small window, which we called the adapting color. Open squares show the color appearance of the test patch of white board judged from the subject room on the large window, which we called the adapted color. Small symbols indicate five repetitive judgments and large symbols connected by lines through the origin indicate their average. We see that the variance within a subject is not large but the variance among subjects is large.

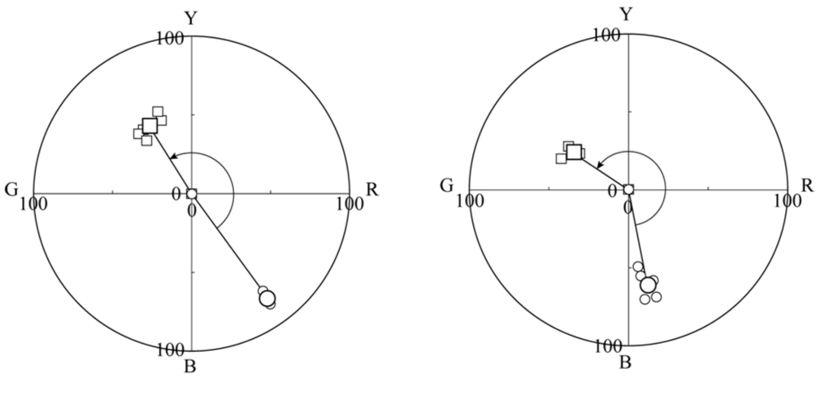

Fig. 4 Adapting and adapted colors for a reddish blue illumination color. ○, adapting color; □, adapted color. Subjects CP (left) and KC (right).

We are interested in the relationship between the adapting color and the adapted color and we obtained the angle from the former to the latter, $\Delta\theta$ measured in anticlockwise as shown in the diagram of the subject CP and KC. It was 176° in CP and 225° in KC. We took the average of $\Delta\theta$ for all five subjects for all the seven colors of illuminations and plotted them for the adapting angle. The results are shown by open circles in Fig. 5. The abscissa gives the adapting angle in degree and the ordinate the angle difference $\Delta\theta$. A horizontal dotted line indicates $\Delta\theta = 180°$.

In the past there are other similar data available, though for different purposes in some cases[2-4)]. We read out $\Delta\theta$ from their papers which are listed in Table 1 together with number of subjects, the window size, number of colors investigated, and the color appearance mode. The present work is specified as CRC3. The illumination colors

Table 1 Works used to obtain $\Delta\theta$ plotted in Fig. 5.

Authors	Sub	Test size	Colors	Mode
Rits	5	6cm circluar	8	Object
CRC1	5	4x4 cm^2	14	Object
CRC2	4	4x4 cm^2	2	Object
CRC3	5	40x30 cm^2	7	Object

triangles for Rits[3], open diamond for CRC1[4], open squares for CRC2[2], and open circles for the present work, CRC3, in Fig. 2.

All the angles $\Delta\theta$ read out from these works are plotted together for the adapting color by different symbols in Fig. 5. For the data of CRC1, CRC2, and CRC3 the standard deviations of subjects are shown by short vertical bars. It is clear from these data that $\Delta\theta$ is not necessarily 180° for the adapting color. In fact the exact opponency between the adapting color and the adapted color takes place at only two adapting colors, yellowish green and reddish blue. The data can be approximated by a sine curve as shown by a thick line.

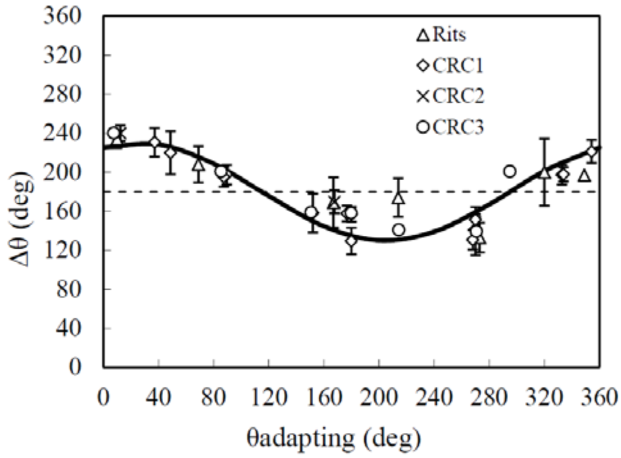

Fig. 5 The angle from the adapting color to the adapted color plotted for the adapting color. Data from four researches are plotted together.

The data in Fig. 5 were obtained by various authors and the experimental condition was inevitably different among them as to the illuminance and the saturation. To see the effect

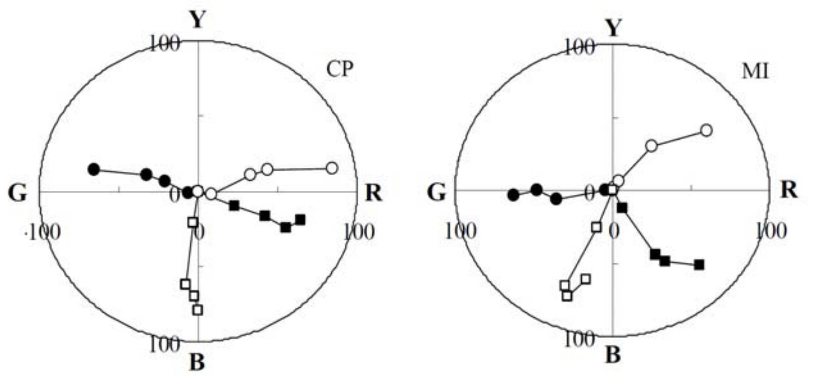

Fig. 6 Adapting and adapted colors for a red (open symbols) and green (filled) illumination. Circles, adapting color; Squares, adapted color. Subjects CP and MI.

of the saturation of the illumination in the subject room the additional experiment was done where the saturation was changed in the red and green colors that were employed for the main experiment as shown in Fig. 3. The results of the color appearance of the test patch are shown for the two subjects CP and MI in Fig. 6. Circles show the color appearance of the illumination and squares that of the test patch. There is observed change in the color appearance of the test patch for different saturation of the illumination but small.

The effect of the luminance of the test patch was investigated by Ikeda et al.[3]. Again there was observed the effect but small.

To conclude the adapting and adapted colors are roughly opposite in the opponent colors diagram but not exact. When the angle from the former to the latter is plotted the curve obeys sinusoidal shape.

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Color constancy depends on initial visual information

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ABSTRACT

The concept of the recognized visual space of illumination RVSI asserts that the color appearance of objects is determiend by the adapted brain to the color of illumination of the space where the objects are placed and then the color constancy holds. Without any object in a space there should be no recognition of the space and no color constancy. The object necessary for the recognition of a space is called the initial visual information IVI. In this paper number of flowers was increased to increase the IVI complexity and the color appearance of a white board placed in the space was measured to see the effect of IVI for the color constancy. Only a small piece of a flower already gave a space recognition and the color constancy to some extent. With increase of complexity of IVI the white board became more white and many flowers surrounded by side walls gave almost perfect color constancy. As an additional experiment still smaller IVIs were investigated and it was found that even a pair of white petals already helped the brain to construct a space perception.

1. INTRODUCTION

The color constancy is a well known property of the visual system and many scientists studied on this phenomenon from two different approaches. One is to emphasize the cone adaptation at the retina and the other is to emphasize the brain adaptation. The former is expressed as the bottom up thinking and the latter the top down thinking. Ikeda's RVSI concept is one of the top down thinking and the present paper was carried out along the theory[1)]. The RVSI theory says that when a person enters a room he/she recognizes the space, understands the illumination filling the space, and adapts to the illumination[2)]. He sees objects in the space with the adapted brain and sees a white object as almost white whatever the illumination color may be, the phenomenon being called the color constancy. It was clearly shown by Pungrassamee et al.[3)] and Ikeda et al.[4)] that the color appearance of an achromatic patch returned achromatic when a subject could recognize the existence of the space where the patch was placed to confirm the RVSI concept. A question how much information or initial visual information IVI of the space is needed to recognize the existence of the space is an interesting question and Phuangsuwan et al.[5)] showed only a small information could construct the space recognition for the color constancy to take place. Their finding showed that the first smallest IVI that they employed was already enough to produce the color constancy. In the present paper several IVI, which were considered very small IVI, were employed to know IVI necessary to construct a space recognition and thus to produce the color constancy.

2. APPARATUS AND EXPERIMENT

The two rooms technique or the environment-stimulus independent illumination technique was employed to carry out the experiment. It was composed of two rooms as shown in Fig. 1, a subject room where a subject stayed and a test room where a test patch was placed. There was opened a large window W of the size 40 cm wide and 30 cm high on the separating wall through which a subject observed a test patch for judging the color of the patch by the elementary color naming method. The entire apparatus was of the size, 300 cm deep, 120 cm wide, and 200 cm high. The subject room was decorated by objects to simulate a normal room. At the viewing distance of 180 cm the window W was the size 13° x 10° arc of visual angle. At the back wall of the test room a white board WB of about L* = 94 was vertically placed, which served as a test patch. It is large enough to fill out the window W when a subject observed it.

The inside of the subject room was pasted by a white wall paper of about L* = 86. The room was illuminated by five fluorescent lamps of the daylight type Ls. The intensity of one of them was adjustable by a light controller. The lamps were covered by a color film to give a colored illumination for the subject room. Four color films, red, yellow, green, and blue were prepared and the illuminance was adjusted to 50 lx when measured on the front shelf. Figure 2 shows their chromaticity points by open circles. Diamond and square symbols indicate the white board WB and D65. The test room was illuminated by the same fluorescent lamps Lt as the subject room at one of four horizontal plane illuminances, 0.5, 1, 3 and 9 lx when measured just in front of WB and on a shelf at the height 85 cm from the floor.

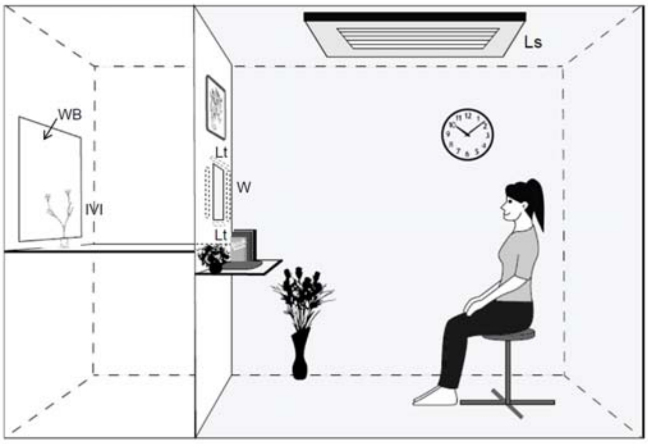

Fig. 1 A scheme of apparatus.

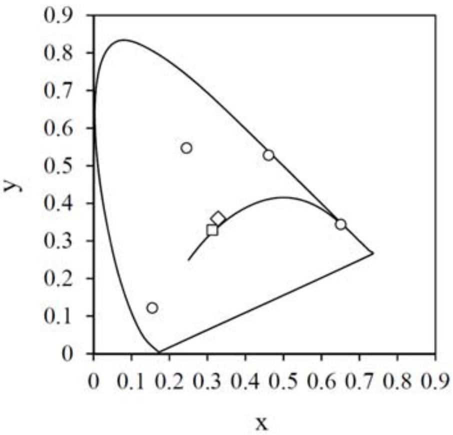

Fig. 2 Colors of illumination.

We first prepared seven initial visual information IVI, I_1 through I_7, as shown in Fig. 3. They were made of artificial flowers, white carnation, green leaves, red rose, and green fern. They were inserted into a white vase with blue line decoration.

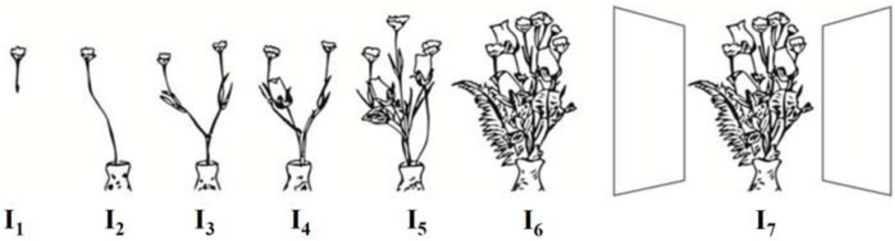

Fig. 3 Initial visual information.

The IVI I_7 was the same flower as I_6 but with walls at both sides to help subjects to perceive a more complete space[6, 7]. The wall was a cardboard of pale yellow with some texture of very low contrast. The lightness was L* = 82. Beside these seven IVI we showed subjects no object at all, which was denoted as I_0. IVI I_1 could not be put in a vase and was hung by a thin string from the ceiling. Each IVI was placed near WB as shown in Fig. 1 and the flower(s) sometime touched WB. Subject could not see the bottom portion of the vase as indicated in Fig. 3.

The subject's task was to judge the color of the white board WB nearby the flowers but avoiding their shadow by using the elementary color naming method. Five repetitions were conducted for the measurement for each condition; IVI, illuminance level, and illumination color. Five subjects, MI, MK, CP, KC, and PL with normal color vision participated in the experiment.

3. RESULTS AND DISCUSSION

Without any object but the white board only in the test room, namely with the condition of I_0, subjects saw only uniform color over the window W and pasted on W. In other words the subjects recognized the color belonging to the subject room. With I_1 the subjects could notice the white board in the test room implying the perception of the space.

In Fig. 4 the amount of chromaticness perceived on WB is shown on the ordinate for IVI number on the abscissa. The data points from I_7 are plotted at 9. Those were obtained for 1 lx illuminance of the test room and for the red adapting color. Squares were from the subject MI and circles from KC. Short vertical bars show the standard deviation of five repetitions. In these cases the SD of MI is larger for almost every IVI than KC but in some other conditions (not shown) MI showed smaller SD than KC. Difference between the two subjects is not small but in both subjects showed a similar tendency of decrease of chromaticness for larger IVI. With I_0 subjects saw adapted color on the window W as if there was pasted a paper of that color. With I_1 or with one piece of carnation flower they suddenly recognized the existence of the space of the test room and could perceive the surface of white board, which eventually decreased the amount of chromaticness as seen in Fig. 4. The chromaticness of the white board continuously decreased and the whiteness increased for larger IVI. With I_7 the white board appeared almost white to imply the color constancy.

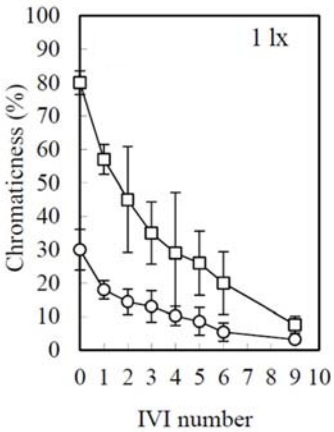

Fig. 4. Chromaticness plotted for IVI for red illumination. Squares, subject MI, and circles, KC.

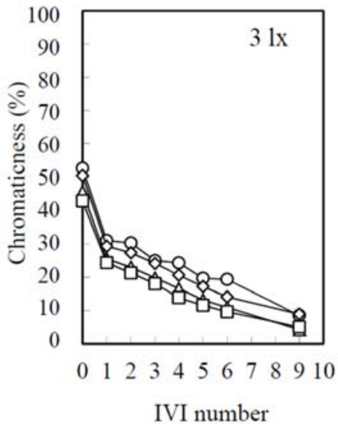

Fig. 5. Chromaticness plotted for IVI for red (circles), yellow (triangles), green (diamonds), and blue (squares).

Figure 5 shows the averaged amounts of chromaticness of five subjects for four illumination colors for different IVI, circles for red, triangles for yellow, diamonds for green, and squares for blue in the case of 3 lx test room illumination. Four curves showed very similar tendency. The drop of chromaticness at I_1 from I_0 was quite large. Amount of chromaticness of about 50% dropped down to about 30% with only one flower of carnation.

The average of four curves of Fig. 5 was taken and they are shown by circles in Fig. 6. In the figure the numbers of I_1 through I_6 were all increased by 6 so that the number of I_1 became I_7 (revised), for example. The number of original I_7 was also revised to become 14.3. The revision of the IVI number was conducted to approximate all the data points on a regression line as shown by a solid line, which can be written as Chr = - 2.9 × IVI + 47.9. In this way of plotting we can see that there remains a wide gap between I_0 and I_1 or I_7 (revised). It is amazing that even one piece of carnation flower already worked as initial visual information to construct an RVSI for the test room to some extent. With I_7 or $I_{14.3}$ (revised) the chromaticness went down to about 10% to show almost complete color constancy. The side walls were very effective for the recognition of a space and eventually for the color constancy.

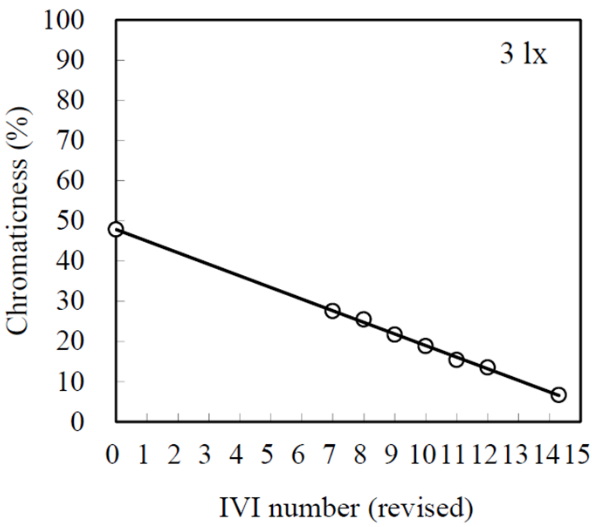

Fig. 6. Chromaticness plotted for the revised number of IVI.

An additional experiment was conducted to fill data points between I_0 and I_1 in Fig. 6 by further reducing the amount of IVI. The new IVIs are a pair of white petals, a green leave, and a white bud of carnation flower with a short green stalk as denoted I_A, I_B, and I_C, respectively, and shown in Fig. 7. Those were directly pasted on white boards WB. In the experiment the previous I_1, I_3, and I_5 were mixed proving 6 IVIs altogether. Four colors of illumination were employed at 50 lx same as the main experiment and only 3 lx of illumination in the test room was investigated. Five subjects, MI, TT, CP, KC, and KT participated in the experiment, three of whom, MI, CP, and KC participating in the previous experiment also.

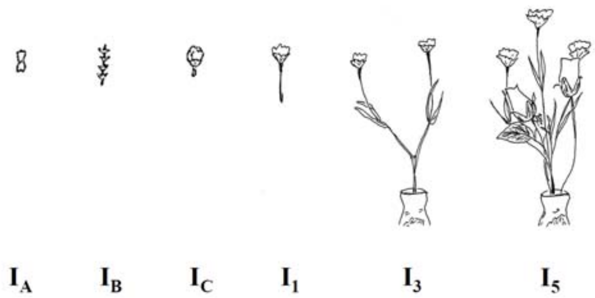

Fig. 7. Initial visual information in additional experiment.

IVI was randomly presented for one illumination color and the judgment was repeated 5 times for each IVI, and also for each illumination color.

Amount of chromaticness is shown in Fig. 8 for all the five subjects in the case of yellow illumination. The abscissa gives the IVI and the ordinate the chromaticness in percentage. With I_0 the chromaticness was very high and it gradually decreased for increasing IVI. There is a large individual variance but the property of a gradual decrease was held in common. The average of five subjects was taken for four colors of illumination, respectively, and is shown in Fig. 9 by different symbols. The property of gradual decrease of chromaticness for increase of IVI is seen commonly among the colors

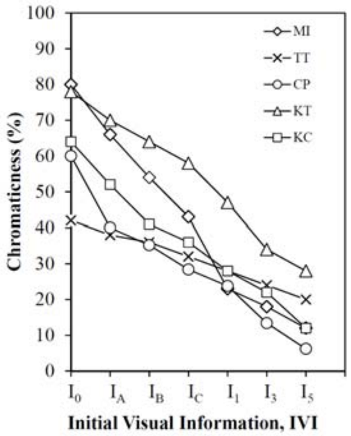

Fig. 8. Chromaticness plotted for IVI from 5 subjects.

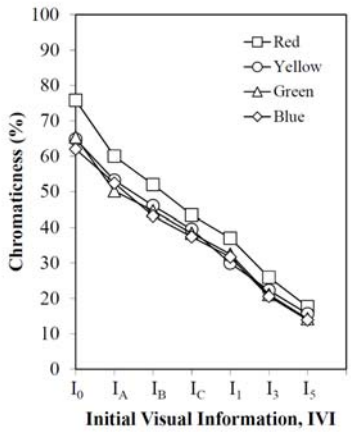

Fig. 9. Chromaticness plotted for IVI for illumination colors.

though the vertical positions of curves differ slightly. However, the vertical position should vary depending on the saturation of the illumination color and the relatively close vertical position of four curves is a coincidence by chance.

To fill the gap between I_0 and I_1 in Fig. 6 the results of three subjects who participated both in the main experiment and the additional experiment were averaged for all the colors in both cases. The results are shown in Fig.10 by open circles for the main experiment and filled circles for the additional experiment. They come very close with each other constructing one straight line of Chr = - 4.2 × IVI + 61.3 when the IVI number was slightly revised, I_A to 2, I_B to 4, and I_C to 5.5. The dashed line was obtained by this formulae.

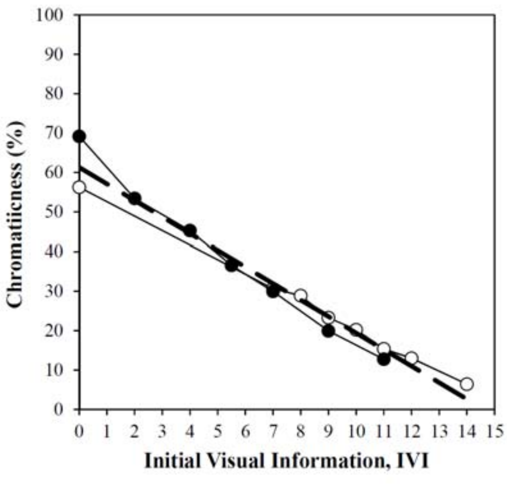

Fig. 10. Chromaticness for revised IVI. The average of three subjects.
○*, the main experiment;* ●*, the additional experiment*; — — —, regression line.

To conclude only a pair of white petals already worked as meaningful initial visual information to construct a space perception and the color constancy.

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Neighboring Color Effect on the Perception of Textile Colors

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ABSTRACT

In this study, the effect of the spatial and colorimetric attributes of neighboring color on color perception in textiles was investigated. Totally 240 woven color combinations were constructed in which each of three test colors, that is, cyan, magenta, and yellow, is placed with 20 different neighboring colors in varying proportions in stripe paradigms. The test colors were then visually assessed by 12 normal color-vision observers using a magnitude estimation method estimating the lightness, colorfulness, and hue values through the comparison with reference samples consisting solely of each test color. According to the obtained visual estimates, each test color has the different color attribute most affected by neighboring colors: lightness for magenta, colorfulness for yellow, and hue for cyan. In terms of overall color, cyan was perceived most differently from its actual, i.e. physically measured, color under the influence of neighboring colors. It was also revealed that these neighboring color effects generally become more apparent and varied with an increment in the size of the neighboring colors.

1. INTRODUCTION

Color is an attribute of visual sensation perceived in the context of various internal and external factors such as its size, shape, surface property, surround/background, and illumination geometry. This study focuses on the effect of surround, i.e. neighboring color, on color perception. The neighboring color effect can be described as *simultaneous contrast* in which a stimulus changes in color appearance depending on the particular relationship with its neighboring color. The simultaneous contrast has been importantly applied in the fine art and design practice, and textile design is one of the areas where this phenomenon is most frequently used in many different forms to create new color appearances.

Previous studies (Jameson & Hurvich 1961; Luo et al. 1995; Ware & Cowan 1982) in general investigated the simultaneous contrast effect in a center-surround paradigm with a single fixed proportion of the two color fields. Stripes, another most often used pattern in textile applications, also have this effect although the extent would be less large as one color in the pattern is not completely surrounded by another. Also in the previous studies, four psychological primaries, red, yellow, green, and blue, were usually used as test colors induced, and only a limited number of inducing colors were included.

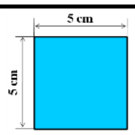
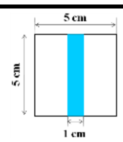
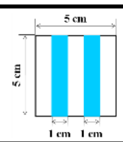
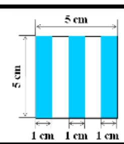
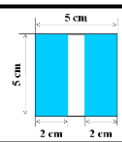
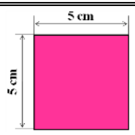
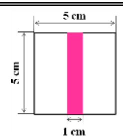
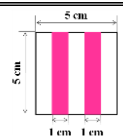
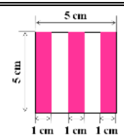
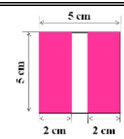
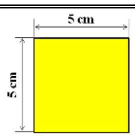
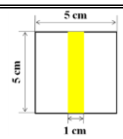
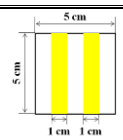
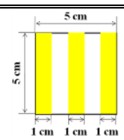
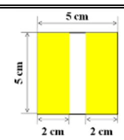
The work described here investigated the effect of a large range of neighboring colors in different sizes and arrangements on the perception of cyan, magenta, and yellow in striped woven textiles. The principal aims of the work were to 1) analyze the varying extents of the neighboring color effect depending on the test color, 2) discover the color attribute most affected for each test color, and 3) investigate the effect of the spatial attributes of the neighboring colors.

2. METHOD

2.1 Sample Preparation

In total, 243 woven fabric samples were constructed in 1/4 sateen weaves using a LX3202 Staubli jacquard machine. Among them, three are reference samples consisting of a single test color, that is, one of cyan, magenta, and yellow, and 240 are test samples that are test/neighboring (induced/inducing) color combinations in striped paradigms (Table 1). In the samples, white yarns (L*=92.97; a*=-0.46; b*=1.58) were consistently used for warp, and cyan (L*=50.48; a*=-19.76; b*=-38.14), magenta (L*=51.20; a*=62.45; b*=0.86), and yellow (L*=84.87; a*=-0.60; b*=88.37) yarns were used for weft in varying proportions to produce 21 woven colors varying in lightness, colorfulness, and hue (in case of test colors, each single color was used for warp and weft). All the yarns were made of polyester, and the yarn diameter and fabric density were 0.125mm and 47×40/cm, respectively.

Table 1. Sample designs.

	Reference sample	Test sample (T* + N**)			
	100%T	20%T+80%N	40%T+60%N	60%T+40%N	80%T+20%N
Design					
Number	1	20	20	20	20
Design					
Number	1	20	20	20	20
Design					
Number	1	20	20	20	20
Total	1×3=3	80×3=240			

***T: Test color**

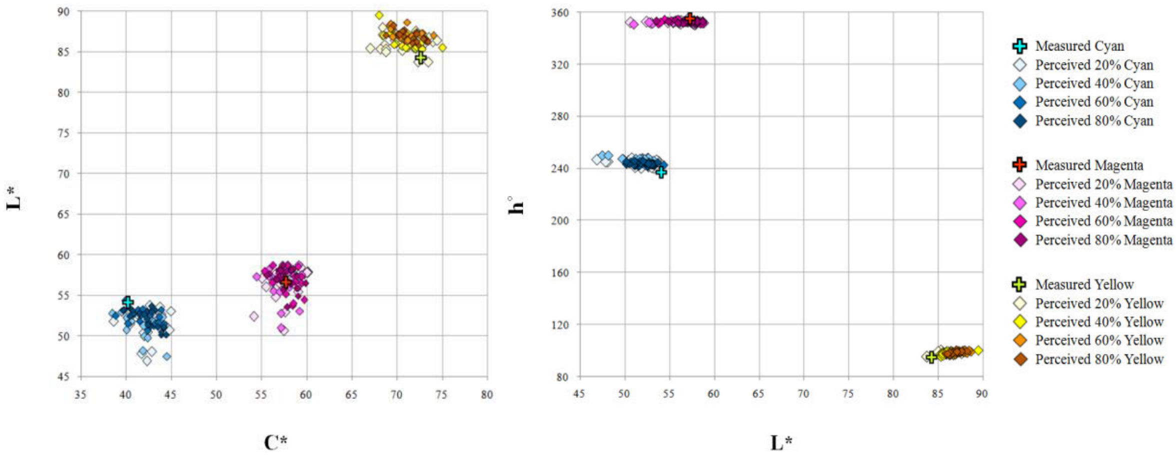
****N: Neighboring color**

2.2 Visual Assessment

Twelve normal color-vision observers conducted visual assessment using a magnitude estimation method for test samples, i.e. test/neighboring color combinations, in the Verivide CAC 120 light cabinet set to the CIE standard illuminant D65 (illumination/viewing angles: 45/0). The test samples were given one by one in a random order with a relevant reference sample, i.e. a single test color, and its physically measured color attributes. Based on the given data, observers were asked to estimate the lightness L*, colorfulness C*, and hue h˚ values of each test color in the test samples through the comparison with the reference sample.

3. RESULTS AND DISCUSSION

Totally 2,880 estimations were made for 240 test samples, that is, three test colors placed with 20 different neighboring colors in four different proportions. The mean estimates were distributed in CIELAB color space as shown in Figure 1 in which crosses represent physically measured test colors (cyan: L*=54.36, C*=40.11, h˚=238.53; magenta: L*=56.95, C*=57.20, h˚=357.04; yellow: L*=84.52, C*=72.33, h˚=95.18), and diamonds are the visually assessed test colors. In each test color set, there was a discrepancy not only between the measured and the perceived colors, but also between the perceived colors depending on their proportions in the test samples. Also, a different distribution range was observed for each test color. These findings indicate that the extent of the neighboring color effect differs according to test colors and their proportions.

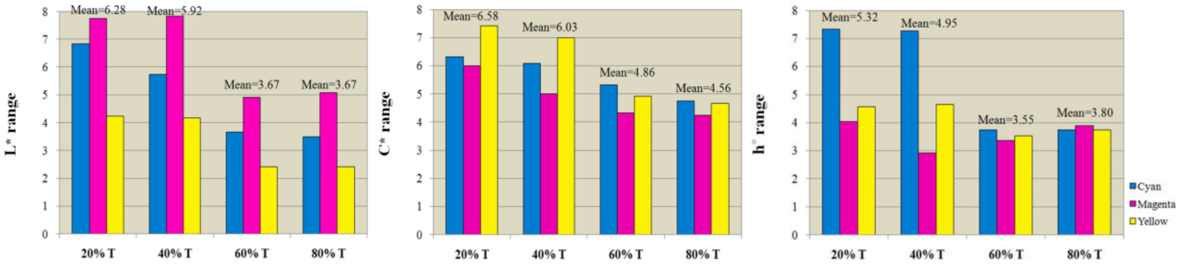


(a) *(b)*

*Figure 1: Distribution of physically measured and visually assessed test colors on (a) CIE L*C* plane and (b) CIE L*h˚ plane.*

The mean color ranges of perceived cyan, magenta, and yellow were calculated and compared in terms of lightness, colorfulness, and hue as shown in Figure 2. In general, cyan has the widest range of estimated h˚ values, magenta has the widest range of estimated L* values, and yellow has the widest range of estimated C* values. This indicates each of these color attributes for each test color is most affected by neighboring colors (in terms of the variation between estimates). According to the proportions of test colors, there was a general tendency that the color ranges of the perceived test colors become wider when their proportions become lower. It implies when a color is placed with or surrounded by another color in a dominant size rather than a small size, the effect of the neighboring color becomes more apparent and varied.

As the discrepancy between the measured and the perceived test colors, cyan was found to be perceived most differently from its actual color, especially in terms of hue (Δh˚=5.9), under the influence of neighboring colors having the average $\Delta E_{CMC(2:1)}$ value of approximately 4. In the perception of lightness and colorfulness, cyan and magenta, regardless of their proportion, were generally perceived as darker and more saturated than the actual colors, while yellow was perceived as lighter and less saturated with neighboring colors.



(a) *(b)* *(c)*

Figure 2: Comparison of the ranges of perceived (a) L, (b) C*, and (c) h˚ values according to test colors and their proportions.*

4. CONCLUSIONS

Three woven test colors, that is, cyan, magenta, and yellow, placed with 20 different neighboring colors in varying proportions were visually assessed to investigate the effect of neighboring color on color perception in textiles. The obtained visual estimates revealed the most affected color attribute of each test color, i.e. hue of cyan, lightness of magenta, and colorfulness of yellow. In terms of overall color, cyan was perceived most differently from its actual color under the influence of neighboring colors. In addition, these neighboring color effects were found to become more apparent and varied in general with an increment in the size of the neighboring colors.

Further work will be done to discover the significant attributes of neighboring colors affecting each of the perceived lightness, colorfulness, and hue of test colors through statistical analyses. These significant neighboring color effects will be modeled.

ACKNOWLEDGEMENTS

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The impact of light at the perception of colours in architecture

State of the art study and suggestions for further research

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ABSTRACT

This paper presents results of the state of the art study carried out at Light & Colour Group at NTNU in 2014. The aim was to present an overview of contemporary research dealing with the impact of natural light, sometimes modified by different glazing types, at the perception of colours in architecture. This was considered as an essential exercise for identifying areas that are missing from the research map of this topic. Based on this study, suggestions for future research were formulated.

About 100 papers were found in: Science Direct, Scopus, Sage and Wiley online libraries using the following keywords: Light, Coloured light, Colour, Vision, Colour shift, Colour temperature, Visual perception, Window Glazing, Transmittance, Spectral composition, Visual comfort and Smart window.

The most interesting founding is that a considerably large number of papers, especially from the last 10 years, present studies of a new generation of dynamically responsive glazing called "smart windows". Smart window notion comprise different glazing technologies that can be reversibly switched from a closed to a transparent state resulting in thermal and optical properties that can be dynamically controlled (Lee et al. 2004). Most of the reported studies examined the effect of switchable glazing on visual and thermal comfort, but very little has been found regarding the effect of different types of smart windows on the perception of surface colours and consequently on colour shift.

1. INTRODUCTION

All of us live within three-dimensional reality that is changing continuously. Our perceptive and cognitive systems have been formed within this context. Colour and light together construct our mental image of space. The experiences of colour and light are interdependent and cannot be analysed separately (Arnkil et al. 2012).

Obviously, one of the lively elements of the built environment is light. It offers a vital connection between the individual, the building and the nearby outdoor environment. Light in a building can be perceived from various viewpoints such as: its necessity for working and living, whether natural or artificial, its source (if artificial), and finally its adverse feature, i.e. expense. Daylight has been the main source of light during centuries and is still appreciated as the most favourable for human health and well-being, therefor is should be considered as a main source of light, while electrical light as a supplement enabling illumination when and where it is impossible to illuminate by natural light.

We know that colour is not the property of objects, spaces or surfaces; it is the sensation caused by certain qualities of light that the eye recognizes and the brain interprets.

Therefore, light and colour are inseparable, and, in the design of the human habitat, equal attention must be devoted to their psychological, physiological, visual, aesthetic, and technical aspects.

The colour of surrounding influences experience of light and the need for lighting. The qualities of light (intensity, directionality, distribution, etc.) are essential for our perception of colour. Colour and light in constructed spaces influence our experiences and feelings, our comfort and our physiological well-being. A thorough investigation of the simultaneous and interrelated human perception of light and colour in architectural space was carried out by the Scandinavian research group SYN-TES (Fridell Anter and Klaren 2010) and a systematic literature review was carried out by Karin Fridell Anter (2013).

The current development in the glass and glazing technologies results with new products, e.g. windows, glass-façades or glass roof elements e.g. with high-tech coatings on the glass. Increasingly often they have chromatic features that influence the spectral power distribution of the light passing through them. We may compare many modern glazing products to a colour filters situated in the building envelope openings. Such filters may change the perception of colours in interiors and the perception of outdoor colours while observed through a "filter-glazing". A colour shift of surface colours may occur. Also one of the crucial aesthetic issues in architecture, namely the visual appearance of building facades, depends considerably on the optical qualities of the glazing.

The impact of different spectral compositions of light on colour perception could be one of the interesting research topics. To find more about the actual state of the art in research, a comprehensive literature study was carried out in the Light & Colour Group, at the Norwegian University of Science and Technology, NTNU, in Trondheim, Norway.

2. METHOD

The literature review helps to ensure that the design of a new research project is original, but at the same time it often gives inspiration for new and creative ideas. Additionally, the review of different studies enables comparing and combining of results and that have a value that no single study can have. Another special reason to do literature review is that it let researchers to address broad questions (Prinstein 2012).

The present study involves different methods, from clearing the area of interest, searching in database to finding and studying relevant articles. In this study the narrative review approach was used. This is a more traditional approach that provides qualitative descriptions of the results of many previous studies.

The search was carried out online on literature available at Norwegian University of Science and Technology (NTNU). Considering English language publications starting from the year 1938 was the only limitation for the review.

Selected keywords (Table 1) were combined in the chosen databases. Each combination of words also resulted in a link called related articles in the databases. Combination of two or three keywords in addition to a single word helped to narrow the search result and to find the articles that were really relevant. We ended up skimming a long list of abstracts to identify the related articles. We used Science Direct, Scopus, Sage and Wiley online libraries and because of using the same keywords, there were some overlapping's in the results. Actually it was advantageous; we could be sure that those articles have good quality. The variety of articles about the colour and light was high but most of them were related to thermal and emotional effects of light or colour. Screening was done by reading the abstracts and choosing the most relevant for the following two topics: light and colour interaction and perception of colour under different lighting sources.

Table 1. Keywords used in database search.

Keywords		
Light	Coloured light	Transmittance
Colour	Colour shift	Spectral composition
Vision	Colour temperature	
Window	Visual perception	
Glazing	Visual comfort	
Smart window	Visual environment	
Electrochromic Glazing		

Additionally, some webpages were visited to find out the state of the art regarding technical development in industry.

4. CONCLUSIONS

The scope of this article limits us to present only the most interesting findings. We have found that the need of knowledge about spatial (as opposite to flat) visual perception was often neglected in colour research. By reviewing the existing we found that the perception of colour illuminated by light having different spectral composition and passing through different glazing types is one of the research gaps in this regards.

As expected, numerous papers deal with light and colour at the general level. The most interesting finding is that a considerably large number of papers, especially from the last 10 years, present studies of a new generation of dynamically responsive glazing called “smart windows”. Smart window notion comprise different glazing technologies that can be reversibly switched from a closed to a transparent state resulting in thermal and optical properties that can be dynamically controlled (Lee et al. 2004). One example of smart window technology is the electro-chromic (EC) glazing which is controlled by a small applied voltage. In the closed state the EC glazing has a very strong chromatic feature, e.g. a dark blue colour. Most of the reported studies examined the effect of switchable glazing on visual and thermal comfort, but very little has been found regarding the effect of different types of smart windows on the colour shift, and consequently on the perception of visual environment.

According to the literature review, glazing type is not necessarily considered as an issue effecting visual perception. There is a general lack of understanding regarding the performance and effect of smart windows, as a new generation of dynamic responsive glazing in real-world environments, on colour perception.

According to Kumar (2005), formulating a research question is considered as “the first and most important step in the research process”. The state of the art study aided us to formulation of the two main research questions for the future research:

1. *How is the perception of colour influenced by light?*

2. *What will be the consequences of using smart window technology for visual environment?*

The secondary questions will be:

What are differences between standard glazing and different glazing types form smart window technologies?

What is the impact of light passing through a smart window at the total indoor visual environment?

How does the colour of the façade made of smart windows looks from different distances?

To what extent are different colours of light accepted in interiors?

This research project (PhD) started with the exploration of the impact of color temperature of light at the perception of surface colors. The experiment expolring this issue (question 1) was done in September 2014 in connection with the "Colour in the City" exhibition in September 2014 in Trondheim and is described in the paper (Arbab and Matusiak 2015).

Further, the consequences of using smart window technology for the visual environment in interiors will be examined (question 2). All behavioral data analysis requires a combination of empiricism and interpretation, and it can be argued that both quantitative and qualitative approaches, components, data, and/or strategies for analysis are necessary to adequately understand human behavior, whether individual, group, or societal (Bazeley 2012).

In order to carry out comprehensive analysis about the impact of light on color perception there is a need to merge qualitative and qualitative approaches; the strengths of both could provide the best understanding while it can give meaning to numbers by narrative, pictures and words (Johnson and Onwuegbuzie 2004). Nagy Hesse-Biber (2010) asserts that triangulation adopts a positivistic perspective by default. This method is employed when a researcher seeks to validate quantitative statistical findings with qualitative data results. Yet the assumption underlying triangulation is the positivistic view that there is an objective reality in which a given truth can be validated.

The theoretical and empirical studies draw our attention to a number of objectives for future study regarding various aspects of visual adaptation and the difficulties of measuring and describing human experiences of light and color in the diverse and complex situations of real life.

The main methodology will be experimental research to evaluate the different aspects of visual perception in three different experimental phases that are parts of a long-term study on the relation between light characteristics and color perception

According to the Joroff and Morse Model, range of research in this project would be somehow social science research.

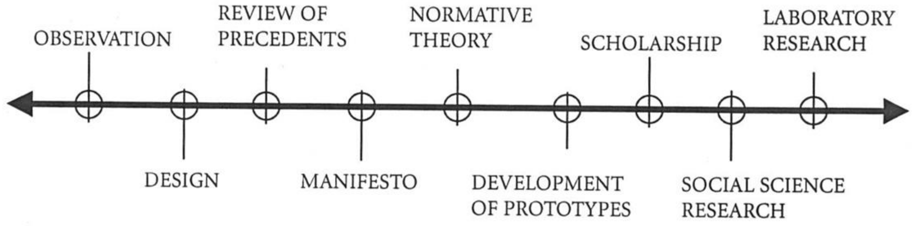

Figure 1. Michael Joroff and Stanley Morse's conceptual framework for architectural research (Joroff and Morse 1983).

At the last, statistical analyses would be needed to compare qualitative and quantitative measures. The intention is to further understand the interaction between light and color as perceived by humans.

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Evaluation of Cloth Roughness and Smoothness by Visual and Tactile Perceptions: Investigation of Cloth Photography Method for Online Shopping

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[3] Kyoritsu Women's University

ABSTRACT

The purposes of this study were to clarify differences that arise in the assessment of cloth texture, particularly cloth roughness or smoothness, using visual and tactile evaluations, and to investigate a method for producing cloth photographs for online shopping websites that observers could use to assess the degree of roughness or smoothness of the cloth. Two evaluation experiments were conducted. The first experiment was a visual evaluation (VE), in which the surface textures of actual pieces of cloth were evaluated solely by visual examination. The other was a visual and tactile evaluation (VTE), in which cloth textures were evaluated using both visual and tactile examination. The characteristics of cloth roughness and smoothness were examined in each experiment. The results showed that the roughness of many types of cloth was overestimated when VTE was conducted and that smoothness was underestimated when VE was conducted. The second experiment was conducted to evaluate cloth surface textures using digital photographs of pieces of cloth taken at different distances between the cloth and the camera. Object distances that produced the same or similar evaluation results were examined and clarified using VE of the photographs. We thus confirmed that the method used in this study can be used to take photographs that users of online shopping websites can use to determine the degree of roughness or smoothness of cloths.

1. INTRODUCTION

In recent years, online shopping for clothes has grown in popularity.[1] However, because most retailers offer only visual information such as pictures of clothes, there may be discrepancies between an item's visual image and its actual appearance and physical comfort. To address this problem, visual and tactile measures that can be used to assess differences between images of clothes in pictures and the look and feel of the actual items are required. In a previous study (Ishikawa et al. 2013), we conducted two fabric identification experiments to assess an observer's accuracy in identifying both an actual piece of cloth and a photograph of the same cloth, based on his/her visual and/or tactile responses. These experiments involved the participants' performing the following: 1) blind touch identification of an actual piece of test cloth after they observed a photograph of the

[1] http://www.soumu.go.jp/johotsusintokei/whitepaper/ja/h23/index.html

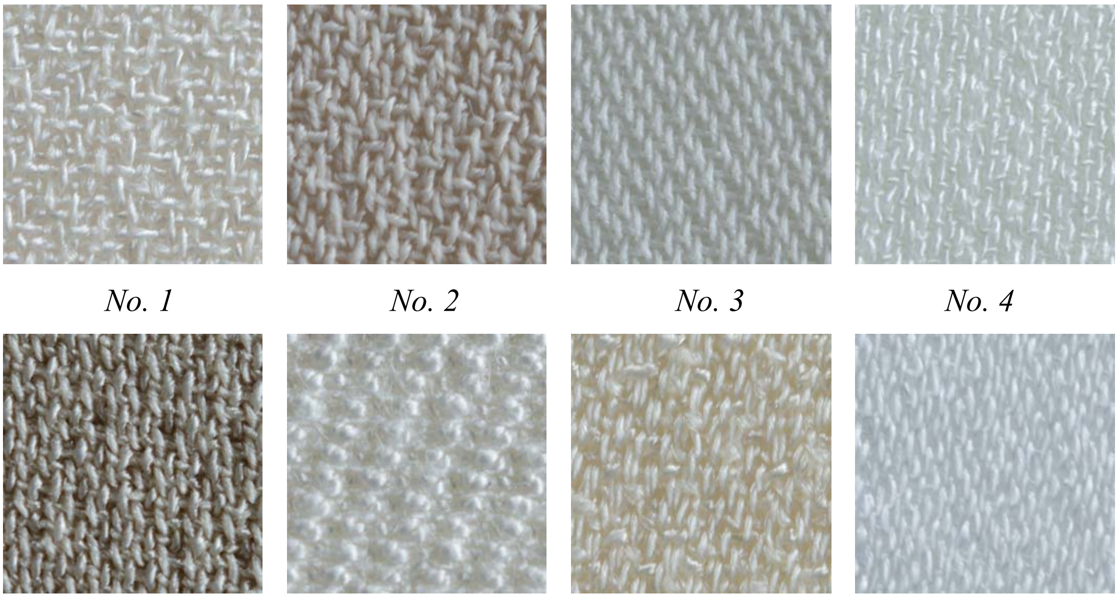
same cloth and 2) visual identification of an actual piece of cloth while they reviewed a photograph of the same cloth. The results indicated that even if an actual piece of cloth and a high-quality photograph are presented to observers, some types of cloth are identified at a low level of accuracy. Therefore, there are considerable differences between perceiving the actual characteristics of a piece of cloth and evaluating a photograph of the cloth. Although the latter evaluation method is mostly established in the field of psychophysiology, the photography method is largely based on the photographer's abilities. If the photography conditions corresponding to the evaluation results for the cloth texture are clarified, many types of cloth could be identified at high levels of accuracy. Many previous studies clarified that the terms roughness and smoothness are important words in evaluating cloth texture (Brockman 1966, Kawabata 1980, Sakita 2006, Ishikawa et al. 2014a). Therefore, a method to photograph a piece of cloth that can make it easy to evaluate cloth texture in terms of roughness or smoothness was investigated in this study to improve the accuracy of the online shopping experience. In Experiment 1, two evaluations were conducted. One was a visual evaluation (VE), in which the surface textures of actual pieces of cloth were evaluated solely by visual examination. The other was a visual and tactile evaluation (VTE), in which cloth textures were evaluated using both visual and tactile examinations. The characteristics by which roughness and smoothness were evaluated were examined in each experiment. The results showed that roughness was overestimated for many types of cloth when VTE was conducted and that smoothness was underestimated when VE was conducted. In Experiment 2, the surface textures of pieces of cloth were evaluated using digital photographs shot at different distances between the cloth and the camera. Object distances that produced the same or similar evaluation results were examined and clarified using VE of the photographs. We thus confirmed that the method examined in this study can be used to take photographs from which users of online shopping websites can determine the degree of roughness or smoothness of fabrics.

2. EXPERIMENT

2.1 Experiment 1: VE and VTE using actual cloths

2.1.1 Experimental conditions

Eight types of test fabrics were prepared for use in VE and VTE testing. The fabrics used were ones which, in a preliminary experiment, designers were able to differentiate from each other based on touch. The base colors of the fabrics were white and beige, and the materials used included polyester and triacetate. Figures 1(a-f) are photographs of the fabric samples. The fabric stimuli presented in the VE and VTE testing were produced by affixing the test fabrics shown in Figure 1 to 400 mm x 275 mm boards. In the VE testing, roughness and smoothness were evaluated using visual perception alone, whereas in the VTE testing, roughness and smoothness were evaluated using both visual and tactile perception. In both sets of tests, participants sat in chairs and observed the fabric stimuli on a table at a distance of 40 cm from their eyes. The horizontal illuminance of the fabric stimuli was 499 lx. Roughness and smoothness were rated separately on 7-point unipolar rating scales (0 = not like that; 2 = a little like that; 4 = like that; 6 = very much like that). The participants were ten engineering students in their twenties.



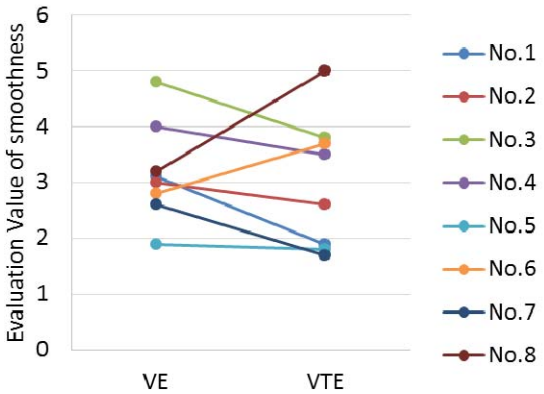
No. 1 No. 2 No. 3 No. 4

No. 5 No. 6 No. 7 No. 8

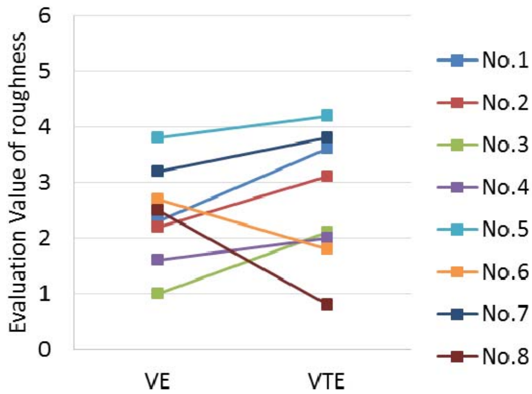
Figure 1: Test cloths.

2.1.2 Results and Discussion of Experiment 1

Figures 2(a-b) show the results of the smoothness and roughness ratings. The mean VE and VTE ratings are indicated for each fabric. As Figure 2(a) shows, for six of the eight fabric types, the VTE rating for smoothness was lower than the VE rating. In contrast, Figure 2(b) shows that for the same six fabrics, the VTE was higher than the VE rating. These results indicate that touching a fabric led to rating it as rougher (less smooth). The results also suggest that because judgments based on visual perception of fabric texture tend to lead to rating it as smooth, it is necessary to include indicators that emphasize the roughness of a fabric.



(a) Results for smoothness



(b) Results for roughness

Figure 2: Results of VE and VTE

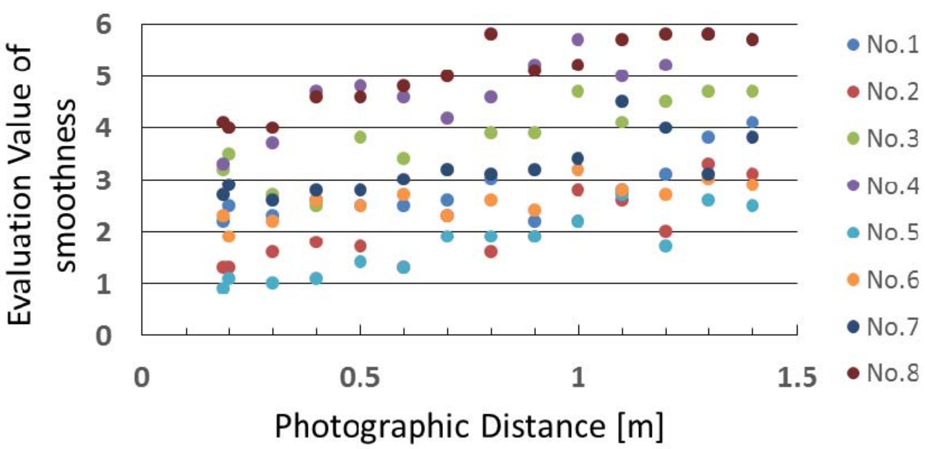
2.2 Experiment 2: VE using photographs of cloths

2.2.1 Experimental conditions

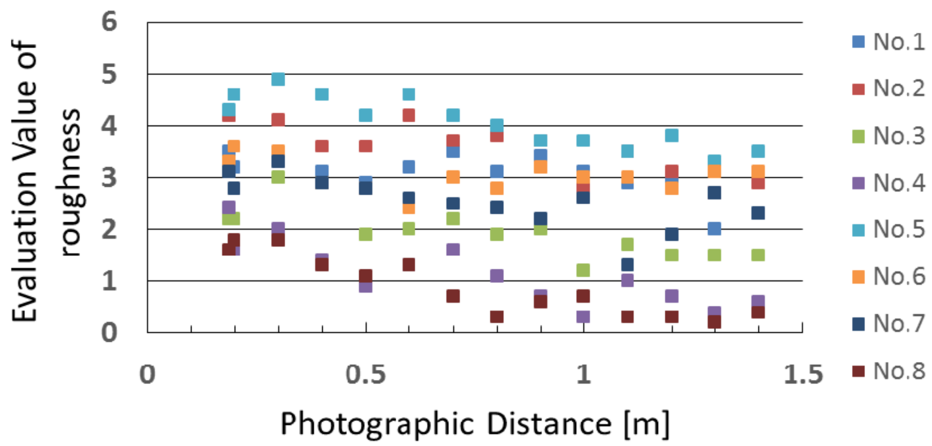
The fabrics were photographed to produce images for use in the experiment. When photographing fabrics, methods that involve adjusting the magnification of the lens can be considered, but because of the possibility of color aberration and other unwanted effects, a different photographic method was selected, in which the camera lens and other settings are held constant while the distance from the camera to the object is varied. The fabric stimuli used in Experiment 1 were fixed in place, and 13 different photographs of each fabric were taken using a Nikon D7000 camera and an AF-S Micro NIKKOR 60-mm F2.8G ED macro lens, with the photographic distance varied from 0.185m to 1.4 m. At the time of shooting, the camera was set to an ISO sensitivity of 100, an aperture of f/6.3, and a shutter speed of 1/30 s. An Apple Cinema Display A1081 (1680 × 1050 resolution) was used in the ratings experiment, and the images were clipped to 1680 × 1050 px and displayed across a full screen.

2.2.2 Results and Discussion of Experiment 2

Figures 3(a-b) display the results of the fabric smoothness and roughness ratings at various photographic distances. The figures show a trend of smoothness ratings tending to increase and roughness ratings tending to decrease as the photographic distance increases. In addition, over the range of photographic distances, there is little fluctuation in the relative smoothness and roughness rankings of the fabrics, indicating that fabric smoothness and roughness ratings change almost uniformly in response to changes in photographic distance, regardless of fabric type.



(a) Result of smoothness



(b) Result of roughness

Figure 3: Result of photography's VE against change in photographic distance

3. ANALYSIS AND DISCUSSION

Through analysis of correlations and mean errors, we examined which of the conditions in Experiment 2 yielded results that were most consistent with the results of the VE and VTE ratings of smoothness and roughness of fabric stimuli in Experiment 1. The results indicated that for VE ratings, a photographic distance of 0.5 m represented the condition for which the results of Experiments 1 and 2 were most consistent, with a correlation of approximately 0.7 and a mean error value of approximately 0.1. On the other hand, for VTE ratings, the photographic distance range of 0.5 to 0.7 m represented conditions for which the results were most consistent, with correlations centered at approximately 0.7 and mean error values centered at approximately 0.1. These findings suggest that for the photographic environment used in this study, photographs taken at a distance in the range of 0.5 to 0.7 m from the object best capture the smoothness and roughness of actual pieces of fabric when they are seen and touched. In the future, it may be necessary to confirm this with replication studies that simulate actual online shopping.

4. CONCLUSIONS

To investigate the methods used to photograph fabrics for online shopping, the differences in the ratings of the roughness and smoothness of the textures of various fabrics were examined, and the differences in rating results obtained for fabrics evaluated by visual examination alone versus fabrics evaluated by both visual and tactile examination were investigated. Fabrics examined by the former method (visual evaluation alone) tended to be perceived as smoother than fabrics examined with the latter method (visual and tactile evaluation). Roughness and smoothness ratings were then obtained for fabrics using photos taken from various distances. By investigating which photographic conditions were consistent with the actual roughness and smoothness ratings, we determined the most suitable distances at which photographs should be taken to assist online shopping website users in accurately assessing fabric texture. In the future, in addition to conducting studies to verify these results, we plan to analyze the relationships between the special features of fabric photographs (such as spatial frequency, contrast, and average brightness) and roughness and smoothness, and thereby identify the key image features in the evaluation of roughness and smoothness In addition, we plan to investigate other related issues, such as the influence that differences in experience with and knowledge of clothing can have on such evaluations (Ishikawa et al. 2014b).

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STUDY OF COLOR PREFERENCES OF GAC FRUIT BLENDED WITH MIXED MUSHROOM JUICE

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ABSTRACT

The effect of different ratios of mushroom and gac fruit juice on sensory and color properties of mixed mushroom (Shitake, Golden and Angel) and gac fruit juice were studied. Mixed mushroom and gac fruit juice prepared to do a variety test by using bael as sweetener, namely sensory evaluation and color measurement. Firstly, preparation of mixed mushroom juice and gac fruit juice were sliced into small pieces and washed with clean water. Blending of aliquots were performed continuously until homogeneous by using an electric blender. After that, juices were heated at temperature 80°c. Physical properties (color measurement) was measured by Hunter and Sensory evaluation was done by using 9-hedonic scaling test. The results showed that the values of L*, a* and b* depending on different ratio of mixed mushroom and gac fruit juices. The using of higher gac fruit juice gave much lightness, but less of gac fruit revealed higher intensity of a* and b*. Sensory evaluation showed that the the highest average of the mean of attributes color and overall acceptability were treatment 5 with an average 6.93 and 7.73, respectively. There were significant differences ($P \leq 0.05$) for attributes color and overall acceptability. Treatment 5 revealed that gave the best overall acceptability and color. From the information above can be used in developing color of products in form of health drinks, covers the essential nutrients needed in the future to meet the demands of consumers, which has increased steadily and expanded, in the large level in beverage industry.

1. INTRODUCTION

The aspect and color of the food surface is the first quality parameter evaluated by consumers and is critical in the acceptance of the product. The color of this surface is the first sensation that the consumer perceives and uses as a tool to accept or reject food. The determination of color can be carried out by visual (human) inspection or by using a color measuring instrument. In order to carry out a more objective color analysis, color standards are often used as reference material. Unfortunately, their use implies a slower inspection and requires more specialized training of the observers. For this reason it is recommendable to determine color through the use of color measuring instrumentation. At present, color spaces and numerical values are used to create, represent and visualize colors in two and three dimensional space (Trusell Saber and Vrhel, 2005). Gac fruit has high levels of carotenoids, especially β-carotene and lycopene, are found in gac fruit aril, the brightly colouredflesh covering the seeds. (Aoki.et al. (2002) The advantages of mixed mushroom extracts (Shitake, Golden and Angel) are studied as possible treatments for diseases, such as cardiovascular disorders. Some mushroom materials, including polysaccharides, glycoproteins and proteoglycans are under basic research for their potential to modulate immune system responses and inhibit tumor growth. (Gao et al., 2005)

The aim of this study was to evaluate effect of different ratios of mixed mushroom and gac fruit on color measurement in gac fruit blended with mixed mushroom juice and sensory evaluation.

2. METHOD

2.1 Mixed Mushroom Juice and Gac Fruit Juice Preparation

Fresh mushrooms (Shitake, Golden and Angel) and gac fruit are the main ingredients (see Table1.) in the production of mushroom juice and gac fruit juice were sliced into small pieces and washed with clean water. Blending of aliquots were performed continuously until homogeneous by using an electric blender. After that, juices were heated at temperature 80°c for 15 minutes and cooling at room temperature (Batu, 1990; Wirivutthikorn and Jenkunawatt, 2014)

Table 1. Mushroom Juice and Gac Fruit Juice Production.

Ingredients	Treatment				
	1	2	3	4	5
Mixed mushroom juice (ml)	65	55	50	50	55
Gac fruit juice (ml)	20	20	25	35	25
Sugar (g)	15	25	25	15	20
Dried bael (g)	15	15	15	15	15

2.2 Sensory Evaluation

The sensory evaluation was carried out 30 panelists consisting of panelists in Rajamangala University of Technology Thanyaburi, Thailand. Sensory evaluation was done by 9-hedonic evaluation. Panelists are asked to determine the level of preferences on each treatment using hedonic scale of 9 points (1: dislike extremely, 2: dislike very much, 3: dislike moderately, 4: dislike slightly, 5: neither like nor dislike, 6: like slightly, 7: like moderately, 8: like very much, 9: like extremely) based on attributes of color and overall acceptability. (Wirivutthikorn and Jenkunawatt, 2014)

Color Measurement

The sample of mixed mushroom juice and gac fruit juice from each treatment were prepared for color measurement using a Spectro Dens A407077 Premium (D-61462, Germany). Color was recorded and shown using brightness (L*), redness (a*) and yellowness (b*)

3. RESULTS AND DISCUSSION

1. Color of Juice

Table 2. Value of L,a*,b* .*

Value	Treatment				
	1	2	3	4	5
L*	35.3	33.2	35.9	40.4	31.1
a*	-0.1	3.6	3.4	-1.7	1.7
b*	12.6	18.0	2.9	4.0	22.5

From the above results, The values of L*, a* and b* and physical appearance depending on different ratio of mixed mushroom and gac fruit juices. The using of higher gac fruit juice gave much lightness, but less of gac fruit revealed higher intensity of a* and b* (Wirivutthikorn and Jenkunawatt, 2014)

2. Sensory Evaluation

In sensory evaluation, the highest average of the mean of attributes color and overall acceptability were treatment 5 with an average 6.93 and 7.73, respectively. There were significant differences ($P \leq 0.05$) for attributes color and overall acceptability of juice in each treatments. Treatment 5 indicated that the highest scores both of color and overall acceptability (Wirivutthikorn and Jenkunawatt, 2014)

4. CONCLUSIONS

The uses of different ratios of raw material preparation has effects on quality of mixed mushroom and gac fruit juice. Treatment 5 revealed that gave the best overall acceptability and color.

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Luminance Contrast of Thai Letters Influencing Elderly Vision

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ABSTRACT

We investigated the effect of luminance contrast between text and background on legibility of Thai letters. Three groups of subjects; young (18-23 yrs.), elderly (58-66 yrs.), and simulated elderly (young wored cataract experiencing goggle) participated in this research. The stimulus configuration was a row of ten random Thai letters presented on an LED display. The letter's size was 0.35 degree at 246 cm viewing distance. The luminance contrast between text and background was composed of five levels of positive polarity and five levels of negative polarity. The subjects viewed the stimuli in a room which illuminated at 0 and 300 lux. The first task of each subject was to report those 10 random letters. Reading performance was calculated in term of percentage of correct answer. For the second task, the subjects was asked to rate the reading easiness of those letters. The results showed that the elderly required higher contrast letter than the young. For positive polarity, reading performance and easiness score of the real elderly were slightly lower than those of the other two groups. For negative polarity, result of the real elderly under 0 and 300 lux was slightly different. However, at low luminance contrast, reading performance and easiness score of the young under 300 lux was suddenly declined and significantly different from reading performance under 0 lux. For all groups of subject, minimum required contrast for easy reading is higher than minimum required contrast for correct reading. Even though all groups of subject could read the lower contrast letter but they felt that the lower contrast is not easy to read.

1. INTRODUCTION

Number of elderly population in Thailand has been growing. In 2025, the percentage of elderly people will be more than 15% and will become more than 25% in 2050 (Institute for Population and Social Research 2006; United Nations 2002). Therefore, we cannot discard this severe situation and have to prepare for the aging society. It is important to study the elderly vision in order to prepare the elder-friendly environment so that the elderly can maintain their quality of life and also their performance to live by themselves. One important aspect for the elderly is their loss of vision due to the cataract. Their crystalline lens become hazy which caused more scattered light in their eye. Therefore, they cannot see some small details clearly such as small Thai letters. In this research we then investigated the effect of luminance contrast between text and background on legibility of Thai letters. We selected an LED display as a source to present the letters becuse nowaday LED display is generally used to present information. However, its characteristic was not the same as the reflected paper because the LED display is a self emitting source. We thought that the LED display generally emit stronger light intensity than the reflected light from paper. We varied the luminance contrast between text and background and examined the reading performance and easiness of young and elderly people.

2. METHOD

2.1 Apparatus

The apparatus was composed of two rooms (a test room and a subject room) separated by a wall. The dimension of this apparatus was shown in Figure 1. Inside the test room, an LED display (Toshiba LED40PU200T) was placed and connected to a PC via HDMI cable. This LED display was used for presenting stimuli. The test room was covered by a black curtain to minimize external light. In the subject room, the internal wall was covered by a white wall paper. The room was also decorated by some stuff such as artificial flower, a doll, and books on a shelf in order to simulate the daily life used rooms. There was a set of four fluorescence lamps attached to the room's ceiling. The intensity of this set of four fluorescence lamps was adjustable to obtain the required illluminance level. The illuminance in this room was measured by a chroma meter (Konica Minolta CL-200A) placed on the shelf closed to the front wall. On the front wall which connected to the test room, a 5 cm × 30 cm aperture was cut at the subject eye's level. The subject looked through this aperture to see the stimuli which were presented on the LED display. The distance between the front wall and the subject's eye was fixed at 2 m.

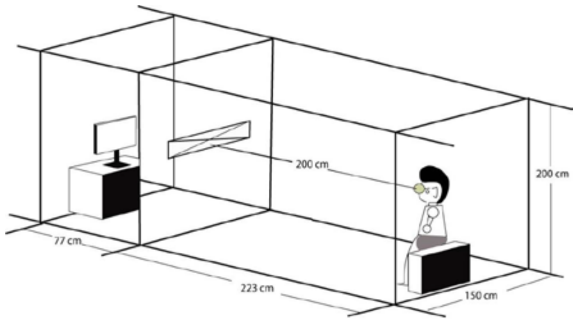

Figure 1: Schematic diagrams of the apparatus.(Rattanakasamsuk 2013)

2.2 Subjects

Three groups of subjects participated in this experiment. The first group was 30 undergraduated student (age between 18-23 years old.). We named this group as "*young*". The second group was five elderly people (age between 58-66 years old). This group was named as "*elderly*". For the third group, 30 young subjects were asked to wear cataract experiencing goggle during experiment. This cataract experiencing goggle was developed by Obama et al. (Obama et al. 2004). It was made from 58% transmittance filter, 14% of haze values filter and yellow filter in order to simulate the elderly vision. These 30 subjects was called "the simulated elderly". All subjects had normal or corrected to normal visual acuity.

2.3 Stimuli and Experimental Conditions

The stimulus configuration was a row of ten random Thai letters presented on an LED display. The letter's size and viewing distance were kept constant at 0.35 degree and 246 cm, respectively. The luminance of *"black"* and *"white"* background was constant at 0.01 and 147 cd/m^2, respectively. Two polarities of luminance contrast between letter and background was applied to the stimuli as shown in Figure 2. The first one was positive polarity (dark letter on *white* background). Five levels of luminance contrast for the positive polarity were set at -1.30, -0.95, -0.54, -0.37, 0.65, and 4.17. The second one was negative polarity (light letter on *black* background). Five levels of luminance contrast for the negative polarity were set at 0.30, 1.23, 2.48, 3.18, 3.60, and 4.17. Note that all luminance contrast was presented in term of log Weber contrast. The illuminance of the subject room was set at 0 lux for simulating night-time condition and set at 300 lux for simulating the indoor viewing condition.

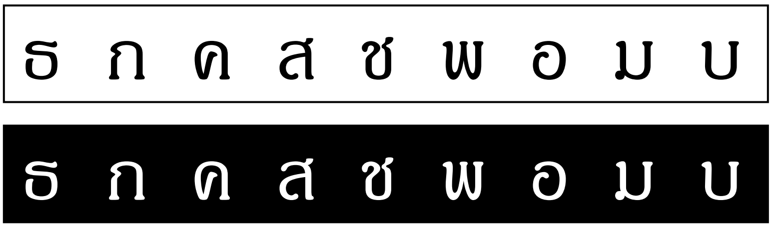

Figure 2: Example of stimuli. (Top) positive polarity and (Bottom) negative polarity.

2.4 Experimental Procedure

There were two tasks for each subject. The first task was reading performance task. The subject was asked to report each random letter. The reading performance was calculated by percentage of correct answer. The second task was reading easiness task. When the subject saw the stimuli, they were asked to rate the easiness of reading with five levels of score from 0 to 4. While 0 means *"unable to read/very difficult to read"*, 4 means *"very easy to read"*. These two tasks were done in separated sessions. Therefore, in each session, the experimenter selected one of the experimental conditions from the combination of two illuminance levels (0 or 300 lux), two contrast polarities (positive or negative polarity) and two tasks (reading performance or reading easiness). The subject was asked to sit in the experimental room and look around inside the room for two minutes. After two-minute adaptation, a line of ten random Thai letters was presented. The subject was asked to complete either reading performance task or reading easiness task. After finishing each trial, the new 10 random letter with different luminance contrast was presented. The subjects repeated the tasks until all five luminance contrast were presented.

3. RESULTS AND DISCUSSION

Positive Polarity (Dark Letter on White Background)

Figure 3 showed result of positive polarity. The two top panels showed results of reading performance task, and the two bottom panels showed result of reading easiness task. The left and right panels showed result obtained under subject room's illuminance at 0 and 300 lux. Circle, square, and triangle represented average result obtained from young, simulated elderly, and elderly respectively. The dashed lines were the regression line which obtained by fitting the data with logistic functions as shown in Equation 1.

$$y = \frac{1}{1+e^{(-ax-i)}} \qquad (1)$$

For reading performance task, we calculated the minimum required contrast for good reading performance at 75% correct answer. The results were shown in Figure 4 (Left). It clearly showed that the result of the young was not the same as the elderly and the simulated elderly. The reading performance of the young was better than that of the other two groups. The young could also read lower contrast letter under both 0 and 300 lux conditions. However, there was difference between the real elderly and the simulated elderly. The Reading performance of the simulated elderly seems not to be strongly influenced by environment light. On the other hand, reading performance of the elderly was significantly affected by environment. In case of 0 lux condition where all environments was dark but the adjacent background only looked bright, the reading performance was significantly lower than that in the 300 lux.

For reading easiness task, we calculated the minimum required contrast for easy reading at easiness score 3. The results were shown in Figure 4 (Right). The results showed that even all subjects could see the low contrast letter but they felt that the letter was uneasy or uncomfortable to read. They required contrast between letters and background at least -0.528, 0.095 and 0.253 for the young, the simulated elderly and the elderly, respectively.

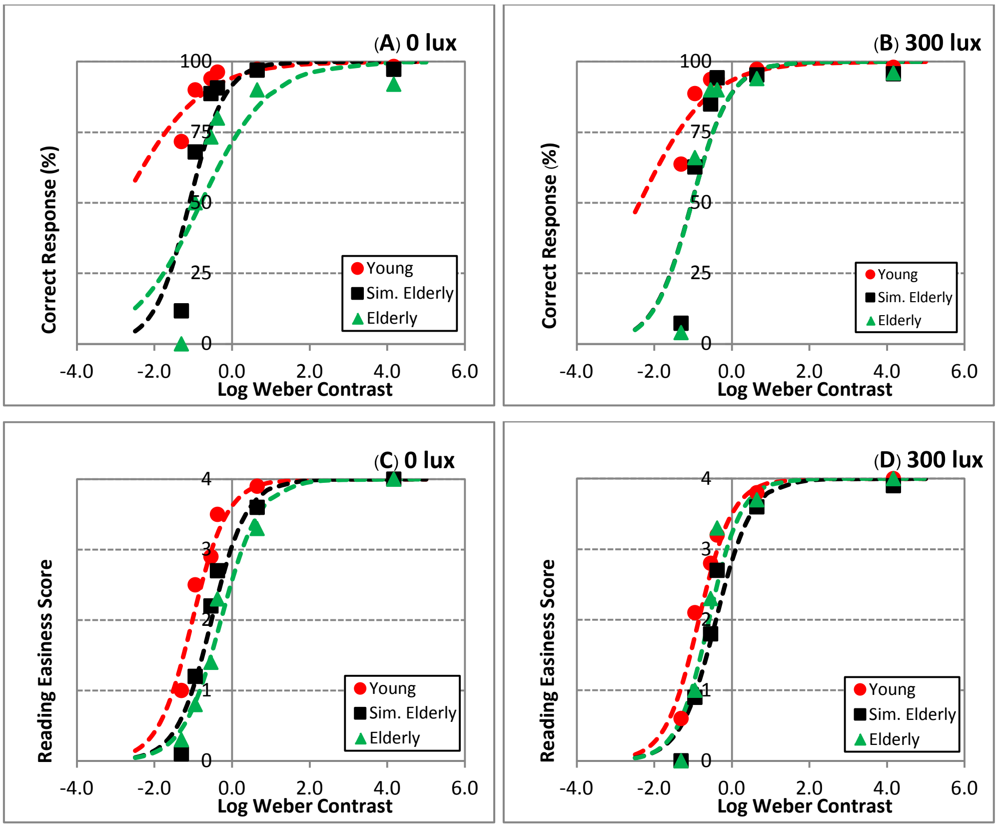

Figure 3: Result of positive polarity. (Top) reading performance task (Bottom) reading easiness task.

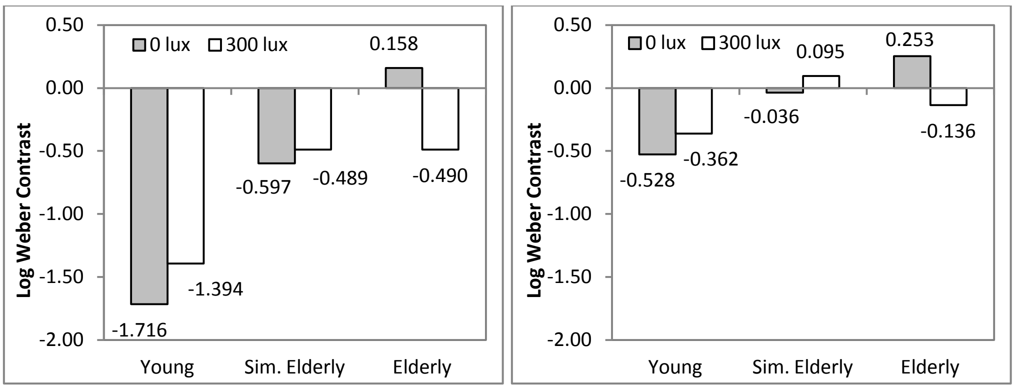

Figure 4: Minimum required contrast for positive polarity from (Left) reading performance task and (Right) reading easiness task.

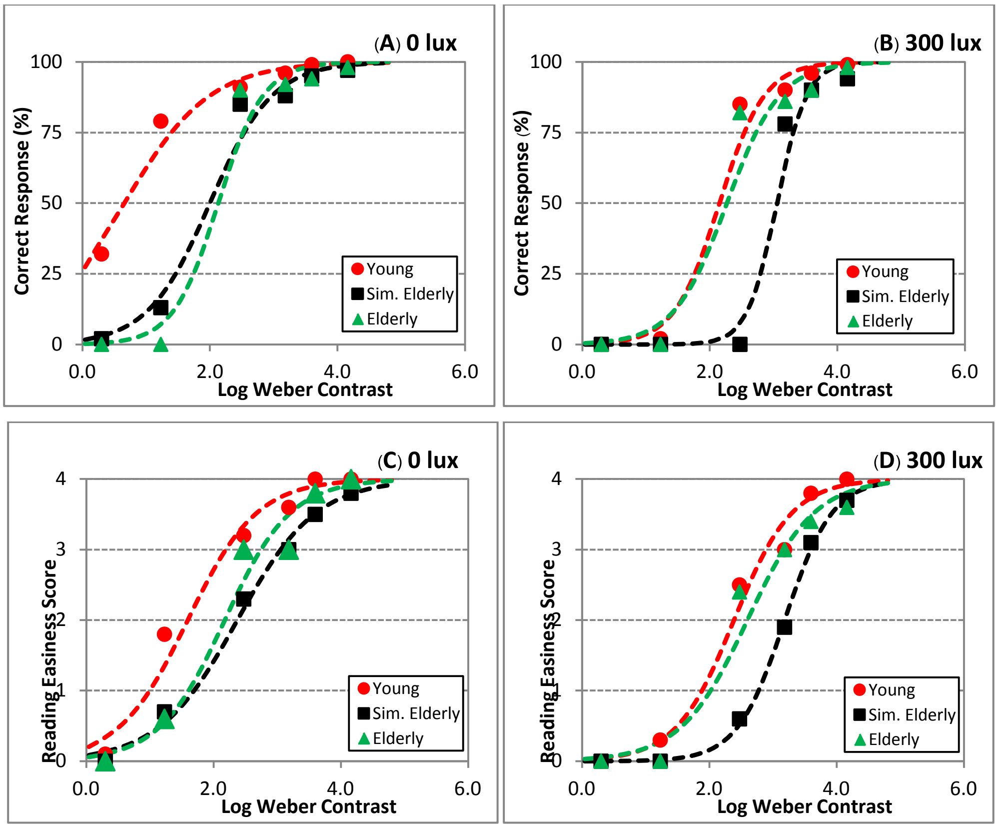

Figure 5: Result of negative polarity. (Top) reading performance task (Bottom) reading easiness task.

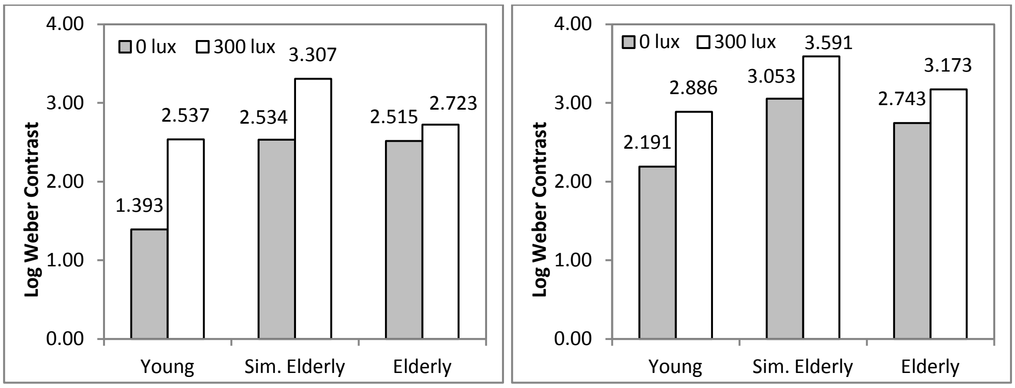

Figure 6: Minimum required contrast for negative polarity from (Left) reading performance task and (Right) reading easiness task.

Negative Polarity (Bright Letter on Black Background)

The results of negative polarity were shown in Figure 5 and 6. At any contrast level, the reading performance of the young was still better and the easiness score was still higher than the simulated elderly. These lowering reading performance and easiness score of the simulated elderly were mainly due to the cataract experiencing goggle. The goggle caused scattered light which disturbed the sharpness of letter and possibly covered some minor detail of the letter so that the subject could not clearly and comfortably see the letter. However, we found that the room illuminance showed slightly effect on reading performance of the elderly. The minimum required contrast for the elderly under both case were nearly identical. But the room illuminance strongly affected the reading performance of the young and the simulated elderly. The reading performance of both groups was suddenly declined when the room illuminance increased. We asked the subject to describe their perception. Both young and simulated elderly reported that when the room was bright (300 lux condition), they felt like a lot of reflected light come through their eyes. This situation caused them to unable to see the bright letter on the black background clearly. But when we asked the elderly, they reported that no noticeable difference on their perception between 0 and 300 lux condition. This report was unexpected because we all know that the scattered light in the eye of the elderly and the scattered light from cataract experiencing goggle should be higher when the environment was bright. Therefore the elderly should be more under influence of room illuminance than the young. But our results contradict to this fact.

4. CONCLUSIONS

Our results showed that the elderly required higher contrast letter than the young. For all groups of subject, minimum required contrast for easy reading is higher than minimum required contrast for correct reading. Even though all groups of subject could read the low contrast letter but they felt that the low contrast is uneasy to read.

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Color rendering analysis based on color pair evaluation under different LED lighting conditions

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ABSTRACT

Most color rendering measures are concentrated on the precise rendering of a single color under the test illuminant comparing with the standard illuminant, and few studies estimate an illuminant by the rule of the color difference between color pairs. Hereby, this study focuses on the color discrimination of two colors under individual illuminants. Based on the psychophysical method of gray scale, a visual experiment was carried out to test the effects of LED lightings on the color difference of color pairs with Munsell color samples. A panel of 10 observers participated in the color discrimination evaluations under 12 lighting conditions, including 2 levels of illuminance and 6 correlated color temperatures (CCTs) ranged from 2000K to 10000K in a LED light booth. The experimental results indicate that the illuminant has obvious impacts on the visual color differences, but the effects are different for the color pairs with differences of hue, lightness or chroma.

1. INTRODUCTION

Solid-state lighting technology based on light emitting diodes (LEDs) is now emerging as a cost-competitive and energy efficient alternative to conventional lightings. The narrowband LED light sources make them different from other light sources and so are important for the evaluation of color rendering. One of the key characteristics of light sources for interior lighting is their color rendering property. If the color rendering is poor, the light source would not be useful for interior lighting. The CIE color rendering index (CIE-R_a) is the most widely used measure for quantifying the color rendering performance of light sources. However, many papers have been published that the CIE-R_a is not appropriate for evaluating the color rendering property of LED lighting (Ohno, 2005). Hence, some other matrics, such as CRI-2012 (Smet, 2013) and Color Quality Scale (CQS-Q_a/-Q_p) (Davis, 2010), have been developed to focus on color fidelity or preference. In addition, the color discrimination index (CDI) (Thornton, 1972) suggested by Thornton evaluates color appearance under the illumination provided by the conventional light sources, which is used to predicte how well the lighting can discriminate color differences in hue.

2. METHOD

2.1 Sample Preparation

Almost all procedures for color rendering evaluation are based on the calculation of the color rendering of either a set of selected multiple color samples or of a gamut of colors. This is correct when the spectrum of the light source is more or less continuous. However, the uneven spectra of LED light sources make it difficult to account for the color differences that occur with many different color samples. Hereby, this study focuses on the color discrimination of two colors under individual illuminants. In this study, the 6 test CCTs of 2000 K, 2700 K, 3450 K, 5000 K, 6500 K and 10000K as well as 2 illuminance levels of 500 lx, and 1000 lx were adopted, which were combined as 12 predefined lighting conditions in total. All experimental setups were achieved by a light booth of Just Normlicht consisting of six kinds of narrowband LEDs with wavelength peaks across the visible spectrum, with its inner wall being painted as the neutral color of Munsell N6. The measured relative spectral power distributions (SPDs) of the 12 test lighting conditions actually used in the assessments, via the tele-spectroradiometer of Konica Minolta CS-2000, are shown in Figure 1. A panel of 10 subjects with normal color vision participated in the visual experiments, all of whom were graduate students in Zhejiang University.

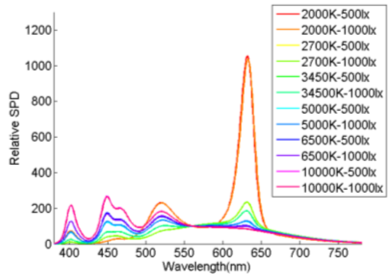

Figure 1: The relative spectral power distributions of 12 test lighting conditions.

A total of 16 groups of color samples were selected from Munsell color order system, as listed in Table 1, including all the 5 primary hue and 5 middle hue. Each color sample group comprised a reference color sample and several test color samples, and the color differences between the reference color and the test colors were one of the three cases, i.e. hue differences or chroma differences or lightness differences. Therefore, there were 73 pairs of color differences in total, involving 16 pairs of hue differences, 26 pairs of lightness differences, and 31 pairs of chroma differences.

Table 1. The 16 groups of color samples selected from Munsell color order system.

Reference	Test color samples					
5Y6/4	7.5Y6/4	5Y5/4	5Y7/4	5Y6/6	5Y6/2	
5GY6/8	2.5GY6/8	5GY6/10	5GY6/6	5GY7/8	5GY5/8	
2.5G6/6	5G6/6	2.5G6/8	2.5G6/4	2.5G7/6	2.5G5/6	
10BG6/4	10BG6/2	2.5BG6/4	7.5BG6/4	10BG7/4	10BG6/6	10BG5/4
10P6/8	10P7/8	10P6/10	2.5RP6/8	10P6/6	7.5P6/8	10P5/8
5Y8/10	5Y8/8	5Y8.5/10	5Y7/10	5Y8/12		
5YR8/4	7.5YR8/4	2.5YR8/4	5YR8/2	5YR8/6	5YR7/4	
7.5P4/10	7.5P3/10	7.5P5/10	7.5P4/12	10P4/10	7.5P4/8	5P4/10
10PB4/10	10PB3/10	10PB4/12	10PB5/10	10PB4/8		
7.5B5/10	7.5B4/10	5B5/10	7.5B6/10	10B5/10	7.5B5/8	
7.5GY7/10	7.5GY6/10	7.5GY8/10	7.5GY7/8	5GY7/10		
2.5GY8/10	2.5GY7/10	2.5GY8/12	2.5GY8/8			
10YR7/12	10YR7/14	10YR7/10	10YR6/12	10YR8/12		
10R6/12	2.5YR6/12	10R5/12	10R6/10	10R6/14		
5R4/14	5R4/12	5R5/14	7.5R4/14			
7.5RP4/12	7.5RP5/12	7.5RP4/10	5RP4/12	10RP4/12		

2.2 Experimental Procedure

The experiment was carried out in a dark room with a psychophysical method of gray scale, and all the subjective estimations must rate the color differences of the Munsell sample pairs by referring the gray scale. Note that there are 9 levels of gray scales at the interval of 0.5, with the lowest gray scale of 1 representing the largest color difference and the greatest scale of 5 labelling the least color difference. The viewing angles for each color pair was 2° with the illumination and viewing geometry of 45/0. The whole experiment was divided into 12 sessions according to the 12 test lightings assigned randomly to the subjects, and in each session all the 73 color pairs must be rated by the individual subjects. A brief description about the experiment was presented to the subjects before each session, which began with a 3-min dark adaptation. Next, at the beginning of each test lighting condition, 1-min light adaptation was carried out (Ohta, 2006), and then the subjects were asked to estimate the color differences. Totally 8760 assessments were collected from this study [10 subjects × 73 pairs × 6 CCTs × 2 illuminances].

3. RESULTS AND DISCUSSION

3.1 Chromaticity differences of 73 color pairs under 6 CCT LED lightings

As some typical examples, Figure 2 depicts the chromaticity coordinates of the reference colors and their corresponding test colors for 4 groups of color samples in CIE1976UCS under the 6 CCTs of LED lightings, respectively. The 6 dots in each subfigure represent the chromaticity coordinates of the reference color for the corresponding color group under the 6 CCT lightings, respectively, and the crosses label the chromaticity coordinates of the test colors and the lines illustrate the differences of chromaticity coordinates between the reference and the test colors.

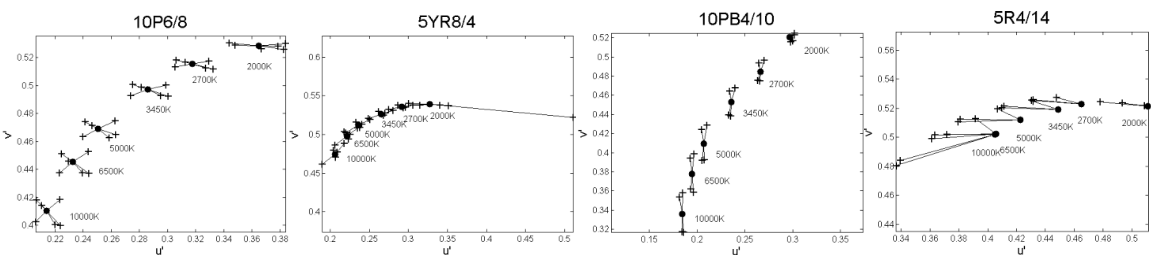

Figure 2: The chromaticity coordinates differences of 4 groups of color samples as typical examples under 6 CCTs of LED lightings, respectively, in CIE1976UCS diagram.

As shown in Figure 2, the chromaticity differences between the reference color 5YR8/4 and the test color 5YR8/2 under the CCT 2000 K is extremely large with comparison to those under the other 5 CCT lightings, implying that 2000 K is the most appropriate condition for discriminating this color pair among the 6 tested CCT LED lightings. While the chromaticity differences of the reference color 10PB4/10 with its test colors are very small under 2000 K, which indicates that the purple-blue is very difficult to be distinguished under such a low CCT of lighting. Moreover, the reference color 5R4/14 and its test colors show the largest chromaticity differences under 10000 K, which means so high a CCT as 10000 K is a rather helpful LED lighting condition for distinguishing the highly chromatic red colors. These results indicate that a lighting condition would induce great color differences for some specific colors but little color differences for other colors.

Therefore, a hypothesis could be proposed that a lighting endowed with high color discrimination property would show large mean color difference for the test color pairs.

3.2 Correlation of visual color difference with color rendering indices

In the gray scale comparison experiment, the subjective assessment for pairs of color differences was refereed by the grade values (G) of 9 levels gray scale, which must be converted into the visual color differences (ΔV). To do this, the transfer equations were fit between the ΔE^*_{ab} values of the 9 gray scales and the corresponding grades (G). With the quadratic equations, the ratings of 73 Munsell test color pairs can be converted to their visual color differences (ΔV), which could be regarded as the indicators to analyze the color discrimination property of the light source. Table 2 lists the Pearson correlation coefficients between the visual color differences (ΔV) and several related color rendering indices for the sample pairs, respectively, with hue difference, chroma difference, lightness difference, as well as all the test sample pairs. Among all cases, hue differences have relatively high correlations with all color rendering indices except for CRI-2012 (with s-curve function and simulated samples in its calculation, rather different from others), which means that hue difference is the most obvious component of the total color difference and so contributes evidently to the color rendering metrics of the lightings. On the other hand, CDI shows the strongest correlation with the hue difference due to its focusing on the color discrimation property of light sources by computing the gamut area of object colors in uniform chromaticity diagram. However, the correlations of ΔV with the related color rendering indices for the color sample pairs of chroma difference, lightness difference and overall color difference are poor, indicating no significant relevancy between them.

Table 2. The Pearson correlation coefficients betwen the visual color difference (ΔV) and the related color rendering indices.

ΔV	CIE-R_a	CQS-Q_a	CQS-Q_p	CRI-2012	CDI
Hue difference	0.64	0.51	0.58	-0.12	0.90
Chroma difference	0.03	0.02	0.33	-0.05	0.55
Lightness difference	-0.24	-0.10	0.15	0.20	-0.31
Overall color difference	0.26	0.24	0.45	0.01	0.48

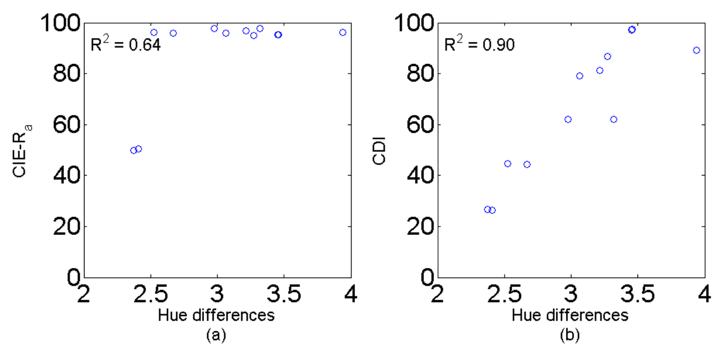

Figure 3: The relationships of hue differences with CIE-R_a (a) and CDI (b).

As mentioned above, the sample pairs with hue differences appear high correlations with the color rendering indices, among which CDI achieves the greatest Pearson correlation coefficient. Figure 3 illustrates the relationships between hue differences and CDI values, along with CIE-R_a, the present standard, as a comparison. The very likely reason may be that the indices except for CDI mainly focus on the fidelity or preference rather than the color discrimination property of the tested light sources. Thereby, a further study will be carried out in the future to investigate the essential relationships between the color discrimination ability and color rendering property of the LED lighting.

4. CONCLUSIONS

In this study, a psychophysical experiment was implemented to discuss the color discrimination property of LED light sources via the gray scale method using color sample pairs with various color differences under 12 lighting conditions. It is indicated that the LED lightings have obvious impacts on the visual color differences, while the effects are dependent upon the type of color differences, i.e. hue difference, chroma difference or lightness difference. In detail, hue difference shows strong correlation with CDI among all the situations. Hence, it needs further investigation to explore a way of assessing the color rendering property of an LED light source based on its color discrimination characteristics.

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The Relationship between Whiteness Perception of Watercolor Illusions and Color Vision Characteristics

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ABSTRACT

The relationship between how the white color regions of graphics are perceived and the color vision characteristics for the subjects with normal color vision and defective color vision was studies by using the conventional watercolor illusion graphics and newly-developed watercolor illusion graphics. The results revealed that the whiteness perception and the evaluation tendencies of the color in the white region were nearly identical regardless of color vision characteristics in both graphics.

1. INTRODUCTION

When a double-lined outline of a graphic is drawn in two chromatic colors, the color of the inner outline looks like bleeding in the enclosed regions. This phenomenon is known as the watercolor illusion (Pinna et al. 2001). Until today, we have shown that the perceived whiteness of the regions enclosed with the double-lined outlines varies with the combination of outline colors and that the combination of a blue inner line and a yellow outer line, a red inner line and a green outer line, or a blue inner line and a green outer line can increase the whiteness perception (Isawa and Suzuki 2011, 2012). In addition, we invented a new watercolor illusion graphic with horizontal stripes drawn in two chromatic colors and evaluated the perceived whiteness of the white region to confirm the same result as in the case of conventional watercolor illusion graphics (Isawa et al. 2009, Isawa and Suzuki 2014). However, it is unknown that whether or not the change in the whiteness perception attributed to the optic illusion occurs among the subjects with defective color vision because the series of research targeted the subjects with normal color vision. Thus, this study investigated the relationship between the whiteness perception of the watercolor illusion and the color vision characteristics of subjects.

2. EXPERIMENTAL OVERVIEW

The subjects consisted of 12 participants with normal color vision (N-type), 11 participants with protanopia or protanomaly (P-type), and 11 participants with deuteranopia or deuteranomaly (D-type).

The conventional watercolor illusion graphics and the new watercolor illusion graphics consisting of horizontal stripes in two chromatic colors were used as stimuli to be evaluated. In the new graphic, the outer colors of the double-lined outlines in the conventional graphic are placed on both sides of the white color region, and the horizontal stripes of the inner colors of the double-lined outlines are overlapped on them. In the following descriptions, the conventional watercolor illusion graphic is hereinafter referred to as WC, and the newly-developed watercolor illusion graphic as HS for simplicity. The stimuli placing the WC and the HS on the left and the right were presented to the subjects and the subjects were asked to compare the whiteness of each white color region. Three combinations of graphics were presented and were shown in Figure 1. The stimuli were printed on the photo papers.

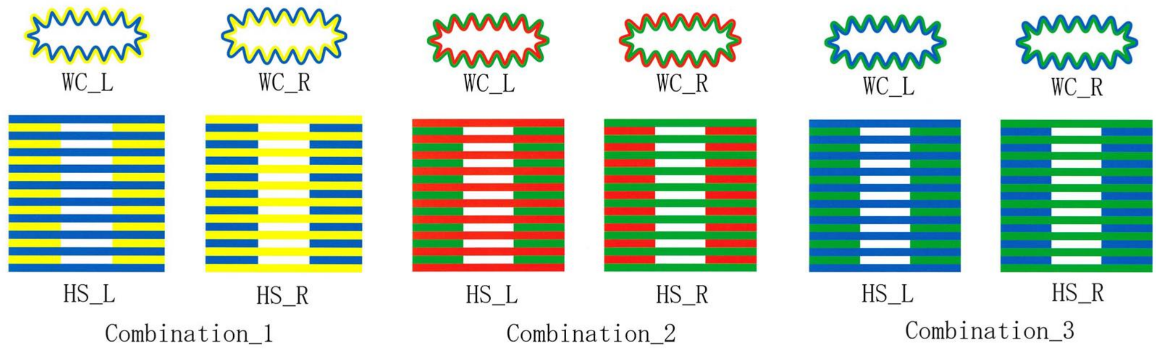

Figure 1: Stimulus combinations used in the experiment.

3. RESULTS AND DISCUSSION

All the subjects answered that the whiteness in the white region seemed different between the right and the left graphics on both the WC and the HS, except for the Combination 2 (combination of red and green). For the Combination 2, extremely few subjects with defective color vision answered that the whiteness in the white region in both left and right graphics seemed the same. Table 1 shows the number of the subjects who answered that the white region in the left and right graphics seemed the same. The denominator of each cell indicates the number of subjects.

Table 1: Number of the subjects who did not distinguish the whiteness difference between the left and the right graphics.

	Combination_1 Blue-Yellow		Combination_2 Red-Green		Combination_3 Blue-Green	
	WC	HS	WC	HS	WC	HS
N-type	0/12	0/12	0/12	0/12	0/12	0/12
P-type	0/11	0/11	1/11	1/11	0/11	0/11
D-type	0/11	0/11	2/11	0/11	0/11	0/11

For the Combination 1, regardless of color vision characteristics, 28 subjects out of all the 34 subjects answered that the white regions in the WC_L and the HS_L are “whiter”, “more clearly white” and “more vividly white” when comparing to the ones in the WC_R and the HS_R. For the Combination 2, more than half of the P-type subjects answered that the white regions in the WC_L and the HS_L are “more clearly white”, “more vividly white” and “more freshly white” when comparing to the ones in the WC_R and the HS_R. However, more than half of the D-type subjects answered that the white regions in the WC_R and the HS_R are “more brightly white”, “more beautifully white” and “whiter” when comparing to the ones in the WC_L and the HS_L. Two-thirds of the N-type subjects answered that the white region in the WC_L is "whiter" for the WC graphics; however, a little less than half of the N-type subjects answered that the white region in the HS_L is "whiter" for the HS graphics. Thus, a difference was found between the WC and the HS graphics. For the Combination 3, regardless of color vision characteristics, majority of the subjects answered that the white regions in both the WC_L and the HS_L are "whiter" when comparing to the ones in the WC_R and the HS_R. Most of the N-type subjects described the white regions of the WC_R and the HS_R as "yellowish white", while only a few of the P-type and the D-type subjects described them as "yellowish white". Table 2 shows the main results on how the subjects described the appearance of the white region of each graphic.

Table 2: Summary of the answers obtained from the subjects.

	Blue-Yellow			
	WC(Watercolor illusion)		HS(Horizontal Stripe pattern)	
	In comparison with Right, Left looks	In comparison with Left, Right looks	In comparison with Right, Left looks	In comparison with Left, Right looks
N-type	whiter clear white strong white	dull yellow yellowish dull	clear bright white whiter clear white	dull white yellow white yellowish
P-type	strong white clear white whiter	yellowish dull and yellowish white yellowish white	clear vivid white clear white bright strong white	dull yellow yellowish yellowish white
D-type	whiter clear and bluish white bluish white	a little yellowish yellowish white dull and grayish	whiter strong white bluish white	yellowish yellowish white natural white

	Red-Green			
	WC		HS	
	In comparison with Right, Left looks	In comparison with Left, Right looks	In comparison with Right, Left looks	In comparison with Left, Right looks
N-type	pinkish white pale pink whiter	a little coolish white greenish white greenish	clear white pinkish white pale pink	a little greenish white whiter greenish
P-type	clear white whiter a little pink	a little white less vivid white simple white	clear white white a little pink	a little dull a little dark and yellowish a little greenish
D-type	a little reddish yellowish dull white	whiter light white a little greenish	reddish a little pink pinkish	whiter clear white light and white

	Blue-Green			
	WC		HS	
	In comparison with Right, Left looks	In comparison with Left, Right looks	In comparison with Right, Left looks	In comparison with Left, Right looks
N-type	bluish white clear white whiter	yellowish dull white greenish	clear white whiter bluish	yellowish dull white yellowish white
P-type	whiter clear white bluish and vivid	a little yellowish greenish dull white	clear and vivid white whiter strong white	a little yellowish greenish dull white
D-type	whiter bluish white light white	greenish white natural white yellowish	whiter vivid white bluish white	dull white yellowish white greenish white

Reading through the answer results of the subjects, there is no effect of color vision characteristics on the whiteness perception due to the watercolor illusion in blue/yellow and blue/green combinations, while the whiteness perception varied depending on the color vision characteristics in red/green combination. In addition, for the combination of red and green, N-type subjects' whiteness perception due to the watercolor illusion was found to differ between the WC and the HS graphics.

4. CONCLUSIONS

The effect of chromatic color combinations on the whiteness perception in the watercolor illusion graphic was studied on the subjects with normal color vision and the subjects with defective color vision by using two types of watercolor illusion graphics. The results are summarized below.

(1) It was found that the change of whiteness perception attributed to the watercolor illusion was nearly in common regardless of the color vision characteristics.
(2) When combining red and green, it was found the whiteness perception in the white region was slightly different depending on the color vision characteristics.
(3) Excluding the combination of red and green, no difference in the whiteness perception in the white region was found between the conventional watercolor illusion graphics and the newly-developed watercolor illusion graphics.

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INFLUENCE OF DAYLIGHT ILLUMINATION IN THE VISUAL SALIENCY MAP OF COLOR SCENES.

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ABSTRACT

Visual saliency maps code topographically local conspicuity over the entire scene. They are based on image properties such as color, luminance or orientation. And because object colors depend on both the spectral reflectance of the surfaces and the spectral power distribution (SPD) of the light impinging on them it is plausible to check also the influence of that SPD on the saliency maps of color images. Preliminary results suggest some differences among the saliency maps under different daylight correlated color temperatures (CCTs), being minimum and maximum along the Orientation and BY channels, respectively.

1. INTRODUCTION.

The color signal of objects depend on the spectral reflectance of their surfaces and the SPD of the light impinging on them. The aim of this study is to determine the influence of daylight in the saliency maps of color images.

Studies in humans have shown that color can influence visual attention but only few studies concentrate on this issue. Amano and Foster (2014) found local color properties yield a better explanation of fixation position than other local achromatic properties. Hamel et al. (2014) improve the predictive power of Marat saliency model for video (2009) by incorporating color information to it. The analysis of neurophysiologically relevant color features by Frey et al. (2008) shows that the influence of color on overt attention depends on the type of image.

The saliency map is a biologically plausible model for bottom-up overt attention proposed by Koch and Ullman in 1985. In the review of the model by Itty et al. (1998), the visual saliency maps are topographical codifications of fixation position in visual search over the entire scene based on different image features such as luminance, orientation or color.

2. METHOD AND RESULTS.

In this work we have used a set of 1100 RGB 400x400 pixels images sorted in different semantic categories: Forests, Fields, Shores, Mountains, Beaches, Rivers (these six belong to Natural images) and Highways, Cities, Buildings, Interiors and Streets (that belong to Non-natural or artificial images). Every category has two subcategories: with or without objects pictures. The pictures are from the authors and from the SUN Database (Xiao et al. 2010).

2.1 Images simulation under different SPD of daylight.

Every RGB image was normalized to the range [0..1] and simulated under five different SPD of daylight characterized by their respective CCTs: 2735K, 4505K, 6479K, 10181K and 25889K between 400-700 nm. The simulation was made using Judd color matching functions (Judd 1951) and the Bradford chromatic adaptation matrix (Süsstrunk et al. 2001)

The real daylight SPDs were measured in Granada, Spain, from sunrise to sunset under different atmospheric conditions and covering a vast range of CCTs from 4800 up to 30,000 K (Hernández-Andrés et al. 2001). The simulated daylight SPDs were obtained with SBDART, a software tool to compute plane-parallel radiative transfer energy in clear and cloudy conditions within the Earth's atmosphere and at the surface (Ricchiazzi et al 1998) to cover CCTs below 4800 K.

Figure 1 shows an example (Forest picture with objects) of simulated images under the working SPDs of this work. We can see how the appearance of the image depends on CCT, the image looks more bluish when CCT is high and reddish when CCT is small. But is there any influence and/or change in the saliency maps for different CCTs?

Original Picture	2735K	4500K
		
6479K	10181K	25889K
		

Figure 1. Original and simulated pictures under five illuminants of CCTs 2735K, 45005K, 6479K, 10181K and 25889K.

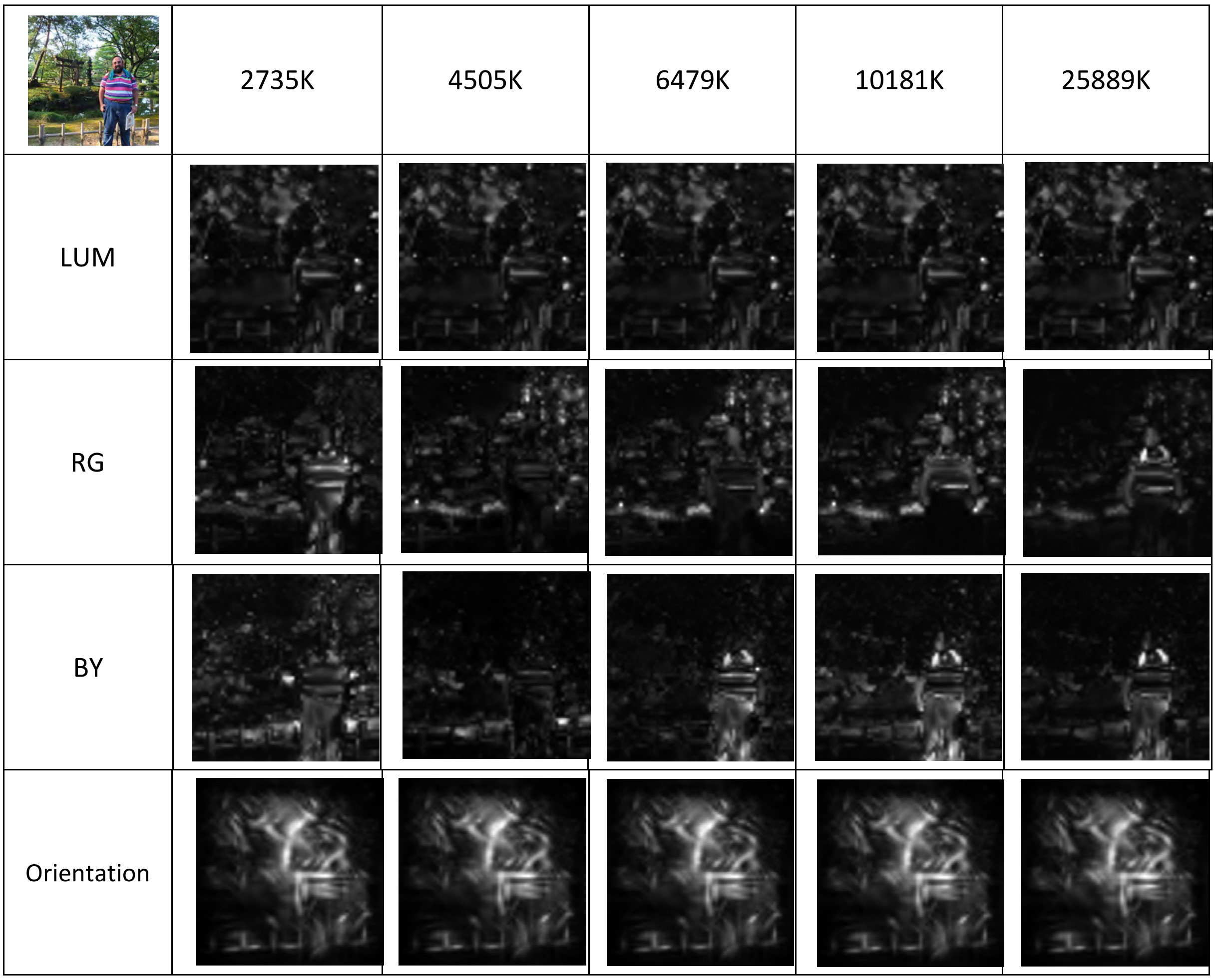
2.2 Saliency maps of color images under different daylight.

In the Itti-Koch algorithm (Itti et al. 1998) every picture is separated by linear filtering in three features: Intensity (Luminance), Color (which is classified in two opposite chromatic sub channels RG and BY) and Orientation (which is divided in four sub channels for different angles). The features maps are computed by a set of center-surround differences between a center fine scale and a surround coarser scale defined as the interpolation to the finer scale and a point-by-point subtraction.

A map normalization operator $\mathcal{N}(.)$ is applied to the features maps to globally promote them with a small number of strong peaks of activity (conspicuous locations) and suppress them with numerous comparable peak responses. These normalized features maps are reduced to central scale and added point-by-point yielding three conspicuity maps: Intensity, Color and Orientation. The saliency map is the average of the three conspicuity maps normalized by $\mathcal{N}(.)$ operator.

The Itti algorithm implemented by Harel (2013), which is a simplified version of Itti-Koch algorithm, was applied to the simulated images using a 0.5 threshold value. The conspicuity maps for each channel (including RG and BY chromatic sub channels) and the picture saliency map were found.

In Figure 2 we can see an example of conspicuity and saliency maps for a Forest picture with objects. The rows correspond to Luminance and Orientation channels, Chromatic RG and BY sub channels conspicuity maps and the global saliency map of the picture, columns show the CCTs of the different illuminant used in the study. Figure 2 suggest some changes in the color saliency maps (across their RG and BY sub channels) depending on the CCT.



GLOBAL

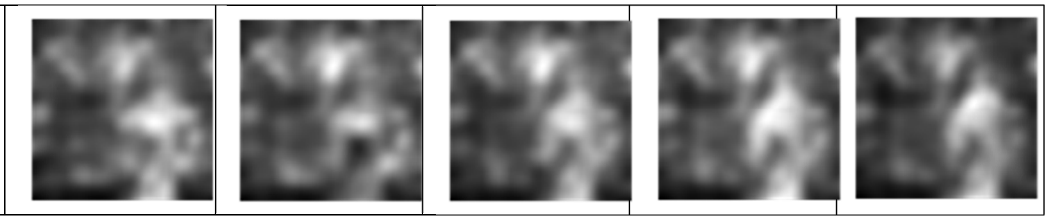
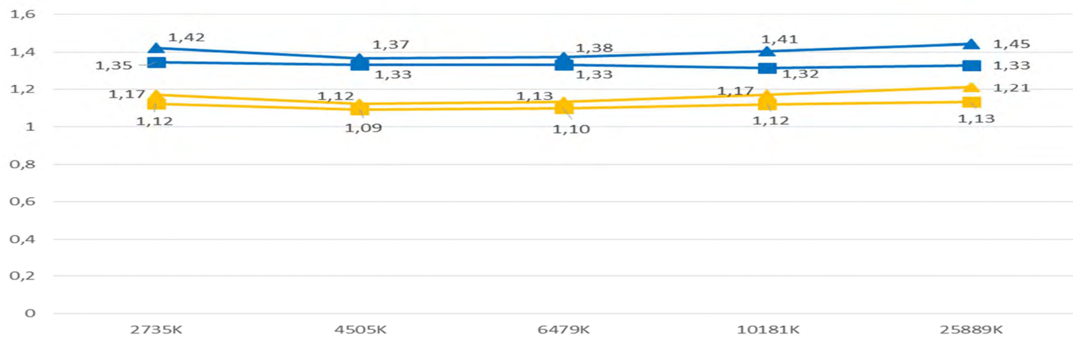


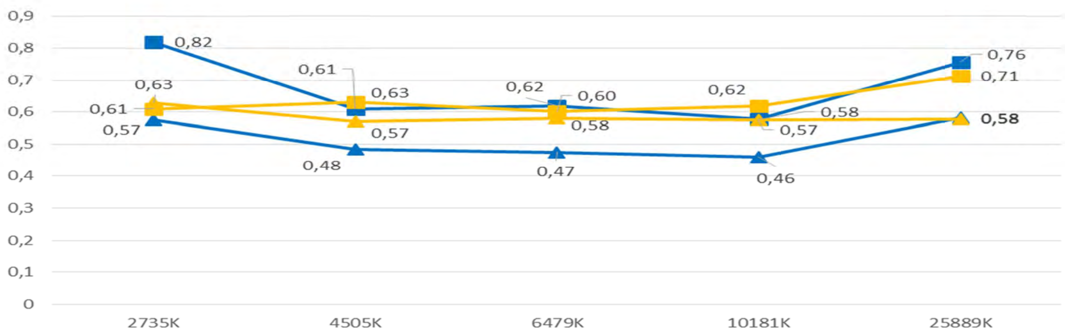
Figure 2. Example of the Luminance (LUM), Chromatic RG and BY sub channels and Orientation conspicuity maps and the saliency map (GLOBAL) of an image under five illuminants of CCTs 2735K, 45005K, 6479K, 10181K and 25889K.

To test if those changes were or not relevant the percentage of number of pixels with saliency above the threshold was calculated as a measure of the saliency for every channel of the pictures. Figure 3 shows the average percentage of pixels above 0.5 for natural and artificial images for Lum and Orientation channels, RG and BY chromaticity sub channels under the different illuminants.

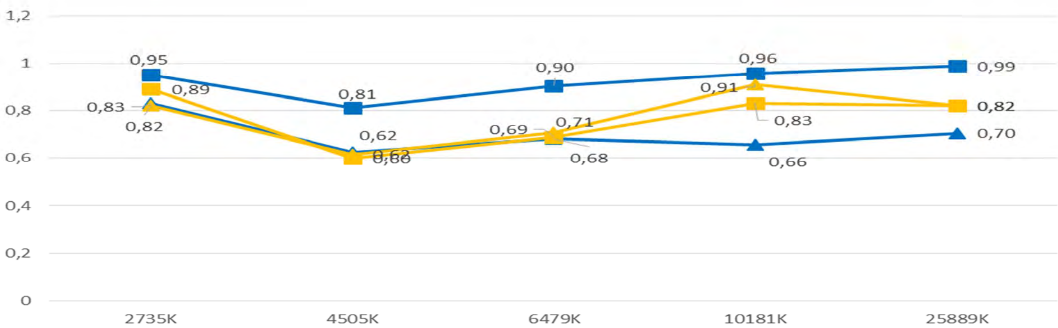
a



b



c



d

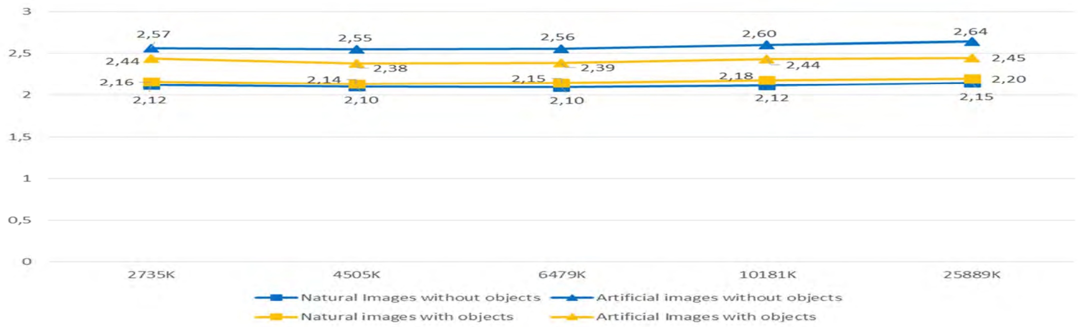


Figure 3. Graphs of the average percentage of pixels with saliency above 0.5 as a function of CCT: Luminance (a), RG (b) and BY (c) Chromaticity sub channels and Orientation (d).

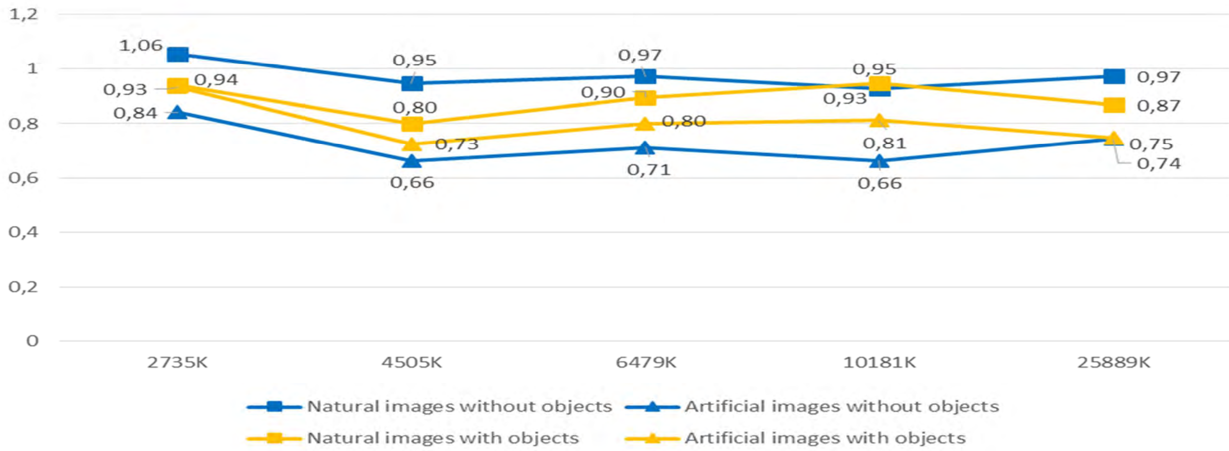


Figure 4. Graph of the average percentage of pixels with saliency above 0.5 as a function of CCT in the Color channel.

3. CONCLUSSIONS

In the range of working daylights used (CCT from 2,735 K to 25,889 K) Figure 3 results suggest differences among the saliency maps. These differences are minima in the Orientation channel and significant for the two chromatic RG and BY (maxima) sub channels.

Nevertheless those differences are small if we consider just one Color channel instead of two separately RG and BY sub channels in the Itti-Koch algorithm (Figure 4). It is a matter of further analysis to study if the use of combined or separately chromatic channels can influence invariant features (including conspicuity maps) linked to the pictures.

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Comparison between Multispectral Imaging Colors of Single Yarns and Spectrophotometric Colors of Corresponding Yarn Swatches

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ABSTRACT

While colors of single yarns and yarn swatches can be separately acquired by multispectral imaging systems and spectrophotometers, color comparison between single yarn and yarn swatch has not yet been well investigated. This paper compares multispectral imaging colors of single yarns and spectrophotometric colors of corresponding yarn swatches, using 100 pairs of single yarn and yarn swatch samples. Colors of the yarn swatch and single yarn samples were measured by a spectrophotometer Datacolor 650 and a multispectral imaging system, namely Imaging Colour Measurement (ICM), respectively. Lightness (L*) and hue (a* and b*) distributions, as well as color difference between single yarn and yarn swatche were analyzed in detail. Experimental results show that lightness (L*) and hue (a* and b*) values of single yarns acquired by multispectral imaging system are approximately 0.91, 0.88, and 0.91 times those of yarn swathes measured by spectrophotometer. The average color difference between single yarns and yarn swatches is 2.79 CMC(2:1) units.

1. INTRODUCTION

In textile and garment industries, spectrophotometers are widespread instruments that measure colors of fabrics. However, spectrophotometers cannot acquire spectral reflectance of single yarns but yarn swatches, which are individual yarns winded on a background card. A spectrophotometer can only measure the average color of a sample area presented in the aperture (Luo 2014). A single yarn is too small to cover the entire aperture of a spectrophotometer. In contrast, multispectral imaging (MSI) systems (Luo 2013, Shen 2007a, Shen 2007b) can provide not only the spectral information but also the spatial information of a sample. The spatial information facilitates direct color measurement of single yarns from multispectral images.

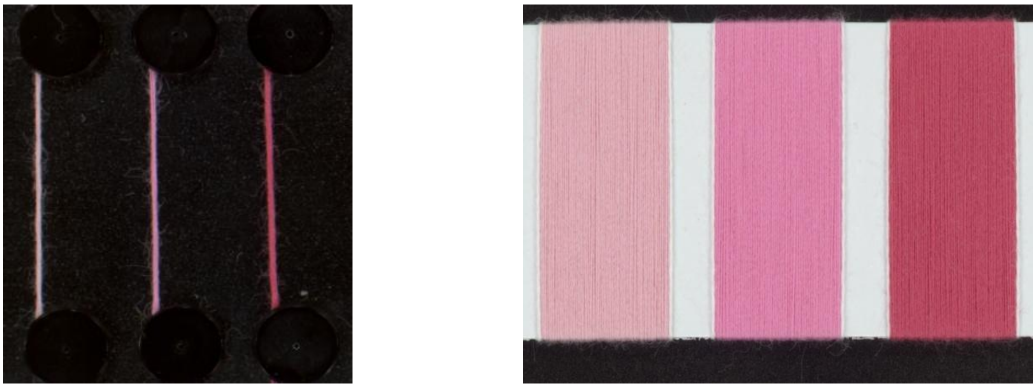
While colors of single yarns and yarn swatches can be separately acquired by multispectral imaging systems and spectrophotometers, color comparison between single yarn and yarn swatch has not yet been well investigated. This paper compares colors of single yarns and yarn swatches measured by multispectral imaging system and spectrophotometer using 100 pairs of single yarn and yarn swatch samples.

2. METHOD

2.1 Sample Preparation

100 pairs of single yarn and yarn swatch samples were prepared to carry out the experiment. These samples were collected from a garment manufacturing company in Hong Kong. The

material of these samples was cotton and yarn count was 80 Ne. As shown in Figure 1, single yarns (Figure 1a) were carefully winded on a white background card to constitute yarn swatches (Figure 1b).

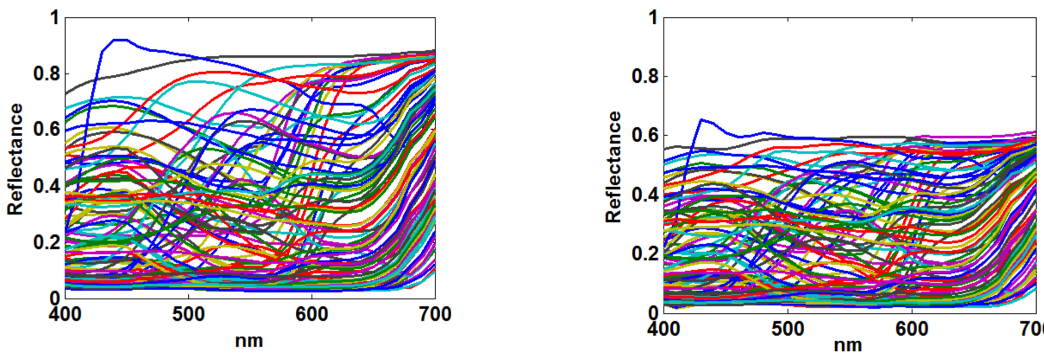


(a) (b)

Figure 1: Example of single yarns and corresponding yarn swatches. (a) single yarns; (b) corresponding yarn swatches.

2.2 Spectrophotometric Measurements

A Datacolor 650 spectrophotometer was employed to acquire reflectance of the yarn swatches. All the measurements were conducted under the 1964 CIE standard observer. The specular component excluded (SCE) and UV excluded modes were applied. Figure 2a shows reflectance of the 100 yarn swatches measured by the Datacolor 650.



(a) (b)

Figure 2: Reflectance of yarn swatch and single yarn samples measured by Datacolor 650 and ICM. (a) reflectance of yarn swatches; (c) reflectance of single yarns.

2.3 Multispectral Imaging Measurements

The reflectance of single yarns was acquired by a multispectral imaging system, namely ICM (Luo 2014). The ICM system was calibrated by reflectance of Macbeth ColorChecker Digital acquired by the Datacolor 650 spectrophotometer. The calibration result was 0.232 CMC(2:1) units. The reflectance of a single yarn measured by ICM was specified as the average reflectance of all the pixels on it:

$$R(\lambda) = \frac{\sum R(\lambda, x, y)}{N} \quad (1)$$

where $R(\lambda, x, y)$, $R(\lambda)$ and N denote the measured spectral reflectance at pixel (x, y), the specified reflectance, and the number of pixels in the chosen area, respectively. Figure 2b shows the spectral reflectance of the 100 single yarn samples measured by ICM.

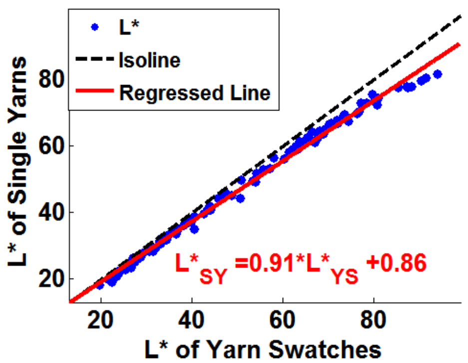
3. RESULTS AND DISCUSSION

3.1 Lightness Distribution

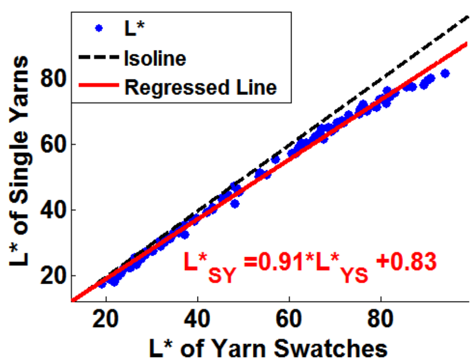
The first experiment analyzed lightness distribution (L*) of the single yarn and yarn swatch samples under CIE Standard Illuminants D65, F2, and A, as shown in Figure 3a-c. The black lines denote lightness values of single yarns acquired by the ICM are the same to those of corresponding yarn swatches measured by Datacolor 650. When a dot approaches to the black line, lightness of a single yarn is closer to that of corresponding yarn swatch. A dot above the black line represents lightness of a single yarn is larger than that of the corresponding yarn swatch, *vice versa*. The correlation (R) values between lightness values of the 100 pairs of single yarns and yarn swatches under D65, F2, and A are 0.997, which implies that dependence between lightness values of single yarns and yarn swatches are high. The least squares fitting method (Banerjee 2014) was applied to find the linear relationship between lightness of single yarns and yarn swatches, which are shown as red lines in Figure 3a-c. The coefficient of determination (R^2) is 0.994. Note that slopes of the regressed lines are 0.910, 0.910, and 0.900 for D65, F2, and A, which means that if yarn swatches with lightness as measured by Datacolor 650 is 1.0, lightness values of single yarns acquired by ICM are 0.910, 0.910, and 0.900 for D65, F2, and A. Therefore, it can be concluded that lightness of a single yarn measured by ICM is smaller than that of corresponding yarn swatch measured by Datacolor 650.

3.2 Hue Distribution

The second experiment analyzed hue distribution (a* and b*) of the yarn swatch and single yarn samples measured by Datacolor 650 and ICM, as shown in Figure 3d-i. The meaning of black and red lines is the same as in Figure 3a-c. The coefficients of R and R^2 are (0.991, 0.991, 0.992) and (0.981, 0.982, 0.984) for a* values of yarn swatches and single yarns under D65, F2, and A. For b* values, R and R^2 are (0.996, 0.996, 0.996) and (0.992, 0.992, 0.991). Note that slopes of the regressed lines are (0.88, 0.88, 0.88) and (0.91, 0.91, 0.90) for a* and b* distributions of yarn swatches and single yarns under the three CIE Illuminants. It can be concluded that a* and b* values of a single yarn measured by ICM is smaller than those of corresponding yarn swatch measured by Datacolor 650.



(a)



(b)

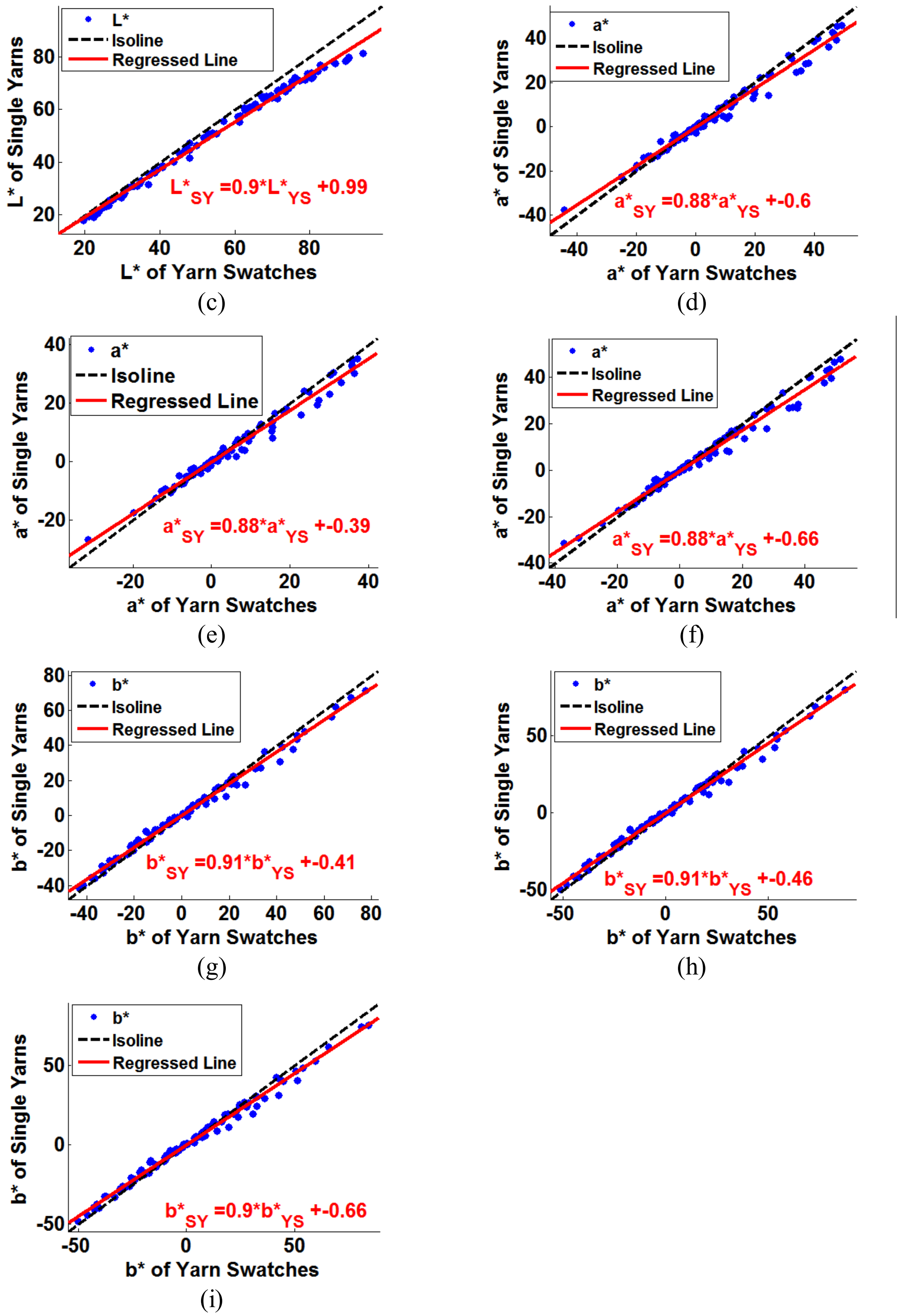


Figure 3: Lightness and hue distributions of single yarn(SY) and yarn swatch(YS) samples under D65, F2, and illuminant A. (a-c), lightness distributions under D65, F2, and A; (d-f), a distributions under D65, F2, and A; (g-i), b* distributions under D65, F2, and A.*

The coefficients of R, R^2, and slope between the 100 pairs of single yarns and yarn swatches under D65, F2, and A are summarized in Table 1. It can be concluded from Figure 3 and Table 1 that lightness (L*) and hue (a* and b*) values of single yarns measured by ICM are approximately 0.91, 0.88, and 0.91 times those of yarn swathes measured by Datacolor 650.

Table 1. Summary of the relationship between colors of yarn swatches and single yarns measured by Datacolor 650 and ICM.

	L*			a*			b*		
	D65	F2	A	D65	F2	A	D65	F2	A
R	0.997	0.997	0.997	0.991	0.991	0.992	0.996	0.996	0.996
R^2	0.994	0.994	0.994	0.981	0.982	0.984	0.992	0.992	0.991
Slope	0.910	0.910	0.900	0.880	0.880	0.880	0.910	0.910	0.900

3.3 Color Difference

The final experiment analyzed color difference between the 100 pairs of single yarns and yarn swatches under 9 CIE Standard Illuminants (A, C, D50, D55, D65, D75, F2, F7, and F11). The CMC(2:1) formula was applied to calculating the color difference (ΔE). Table 2 illustrates the statistics of color difference between the 100 pairs of single yarns and yarn swatch samples. The average color difference is 2.79 CMC(2:1) units with the standard deviation 1.55 CMC(2:1) units. The large color difference implies that color of a yarn swatch acquired by a spectrophotometer is different from that of corresponding single yarn measured by a multispectral imaging system. It can be concluded from Figure 3, Table 1, and Table 2 that the large color difference between single yarns and yarn swatches stems from that CIELAB values of single yarns measured by a multispectral imaging system are smaller than those of corresponding yarn swatches acquired by a spectrophotometer.

Table 2.Color difference between the 100 pairs of single yarns and yarn swatches under 9 CIE Standard Illuminants.

Statistics	A	C	D50	D55	D65	D75	F2	F7	F11	Average
Mean	2.83	2.80	2.82	2.82	2.81	2.81	2.67	2.77	2.80	2.79
Median	2.34	2.34	2.34	2.35	2.34	2.36	2.23	2.36	2.28	2.33
Std.	1.60	1.55	1.59	1.58	1.57	1.56	1.42	1.52	1.55	1.55
Max.	7.34	7.08	7.26	7.22	7.14	7.07	6.89	6.82	7.02	7.09
90th	5.45	5.07	5.21	5.16	5.09	5.06	4.73	4.97	5.09	5.09

4. CONCLUSIONS

Colors of single yarns and corresponding yarn swatches acquired by a multispectral imaging system and a spectrophotometer are compared in this paper, using 100 pairs of single yarns and yarn swatch samples. The colors of these samples were measured by a spectrophotometer Datacolor 650 and a multispectral imaging system, namely Imaging Colour Measurement (ICM). Lightness distribution (L*), hue distribution (a* and b*), and color difference between single yarn and yarn swatch samples were analyzed in detail. Experimental results show that lightness (L*) and hue (a* and b*) values of single yarns measured by ICM are approximately 0.91, 0.88, and 0.91 times those of yarn swathes measured by Datacolor 650. The average color difference between single yarns and yarn swatches is 2.79 CMC(2:1) units.

While these results demonstrate that colors of single yarns acquired by a multispectral imaging system are different from those of yarn swatches measured by a spectrophotometer, there is still much work to be done. First, the fundamental principle of color difference between single yarns and yarn swatches needs to be explored. Second, quantitative relationship between colors of single yarns and corresponding yarn swatches needs to be established. Together, these efforts should facilitate development of color measurement from fabric to single yarn in textile.

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New color rendering index based on color discriminability and its application to evaluate comfortability of illuminants

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ABSTRACT

We proposed a new way of evaluating color rendering property of illuminants based on color discriminability. From the experimental data collected from extended Munsell 100 hue test, in that number of hue is increased to 180, we found that maximum error of color discrimination task under various illuminants are correlated to a minimum color difference among 8 TCSs (Test Color Samples used for the CIE CRI evaluation) when they are plotted on the CIELUV uniform color space under each illuminant. We called this index CDC (Color Discriminability Criterion) as color discriminability is improved as CDC increases. There was a tendency that illuminants having lager CDC seem more comfortable because color chips appear more colorful under such illuminants, but some of illuminants having large CDC seem uncomfortable because red colors appear too prominent. Spectra of such illuminants are unbalanced as some spectrum region is too low and another region is too high. To evaluate the balance of a spectral irradiance distribution, we introduced another index, that is the minimum lightness (L*) value among 8 TCSs under the test illuminant. The index is called CL (Critical Lightness) because lack of energy in certain spectrum region can be improved by making CL larger. We found that one feels more comfortable under such illuminants that have lager CDC and lager CL.

1. INTRODUCTION

Color rendering is one of the important properties of illuminants. CIE CRI (Color Rendering Index) is widely used to evaluate this property. Recently, white LED light sources begin to spread as new illuminant, but the CIE CRI sometimes fails to describe its visual impression (Bodrogi et al. 2004). So, the higher CIE CRI is not necessarily means better visual impression of the illuminant. One of the problems of the CIE CRI is that it is a relative evaluation of a test illuminant compare to the standard illuminant that has the same correlated color temperature as the test illuminant. One can say if visual impression of the test illuminant is close to the standard illuminant, but cannot say if it is good or bad.

To overcome this disadvantage of the CIE CRI, we first tried to evaluate color rendering property of illuminants based on performance on color discrimination task. We conducted the experiment similar to Munsell 100 hue test, and performed color discrimination task under illuminants having various spectra. Assumption here is that errors of color order will be smaller under such illuminants having better color rendering property. By analyzing data from this experiment we found a new index correlated to the performance of color discrimination task. We called this index CDC (Color Discriminability Criterion).

Then, we investigated if this index could be used as an index for visual comfortability of illuminants. We conducted the second experiment to evaluate visual impression of illuminants using semantic differential method. In this paper, we describe above two experiments in detail and discuss about how we can construct a new method of evaluating color rendering property for wide variety of illuminants based on visual comfortability.

2. METHOD

2.1 Experiment 1: Munsell 180 Hue Test

To increase the number of color chips of Munsell 100 Hue Test (Macbeth Farnsworth-Munsell 100 Hue Test) from 85 to 180, we first measured spectral reflectances of the 85 real color chips using the spectrophotometer (GretagMacbeth Spectrolino). Then, the principal components of the 85 spectral refrectances were calculated to interpolate spectral reflectance of a color having an arbitray chromaticity coordinates. CIELAB uniform color space was used to interpolate 85 color chips, and 180 chromaticity coordinates were selected along interpolated locus in every 2^{O} hue angle, then spectral refrectance functions were synthesized using the 4 principal components obtained above. Munsell color test was performed on the calibrated CRT display (Mitsubishi RDF19S) by simulating tristimulus values of the color chips under given spectral irradiance of the test illuminants.

Tests were conducted under fifteen illuminants having different CDC values as shown in Table 1. Spctral irradiance distribution functions were synthesized mathematically using 7 Gaussian functions peaked at 430, 470, 510, 550, 590, 630, 670 nm. Band width of each Gaussian function was 30 nm. The illuminants in gray cells in Table 1 were standard illuminants for each CCT (Correlated Color Temperature). Two subjects participated in this experiment.

Table 1. CDC values of the test illuminants used in Experiment 1.

CCT	4200K					5000K					7500K				
CDC	14.8	19.1	27.2	31.5	25.3	13.9	19.3	30.4	36.0	26.1	11.2	18.3	33.0	39.8	24.5

2.2 Experiment 2: Absolute Evaluation of Visual Impression of Illuminants

Images taken by the multi-spectral camera were displaied on the calibrated CRT display (Sony GDM-2000TC) to simulate tristimulus values of every pixel in the image under given spectral irruminance of the test illuminants (Nakano et al. 2005). Subjects observed displaied image in the dark room and asked to grade visual impression using fifteen adjective pairs.

Test images were rendered using 30 illuminants synthesized in the same way as previous experiment. CDC values of each illuminants were shown in Table 2. Gray cells are for standard illuminants. Four subjects participated in this experiment.

Table 2. CDC values of the test illuminants used in Experiment 2.

CCT	CDC									
4200K	14.8	16.0	17.0	17.8	19.1	19.2	25.8	27.8	28.8	25.3
5000K	16.8	17.1	18.2	18.7	23.4	23.7	30.4	31.1	33.0	26.1
7500K	13.1	15.0	15.8	19.1	26.7	34.5	36.1	38.5	39.8	24.5

3. RESULTS AND DISCUSSION

Figure 1 shows three examples of the results in Experiment 1. Top panels show spectral irradiance distribution functions of the test illuminants. Middle panels show chromaticity coordimantes of 8 TCSs for CIE CRI under each test illuminant plotted in CIELUV uniform color space. CDC is defined as smallest color difference among 8 TCSs as shown in each panel. Bottom panels show error score plots for Munsell 180 Hue Test. Results of two subjects were averaged because tendency was the same between them. Dotted lines show original score data and thick solid lines show moving average among 9 neighboring data to smooth original data.

Clear tendency was observed that maximum error score increases as CDC value decreases. Correlation coefficient between CDC and maximum error score was -0.82. This means that we can evaluate color rendering property of test illuminants in terms of color discriminability performance using CDC.

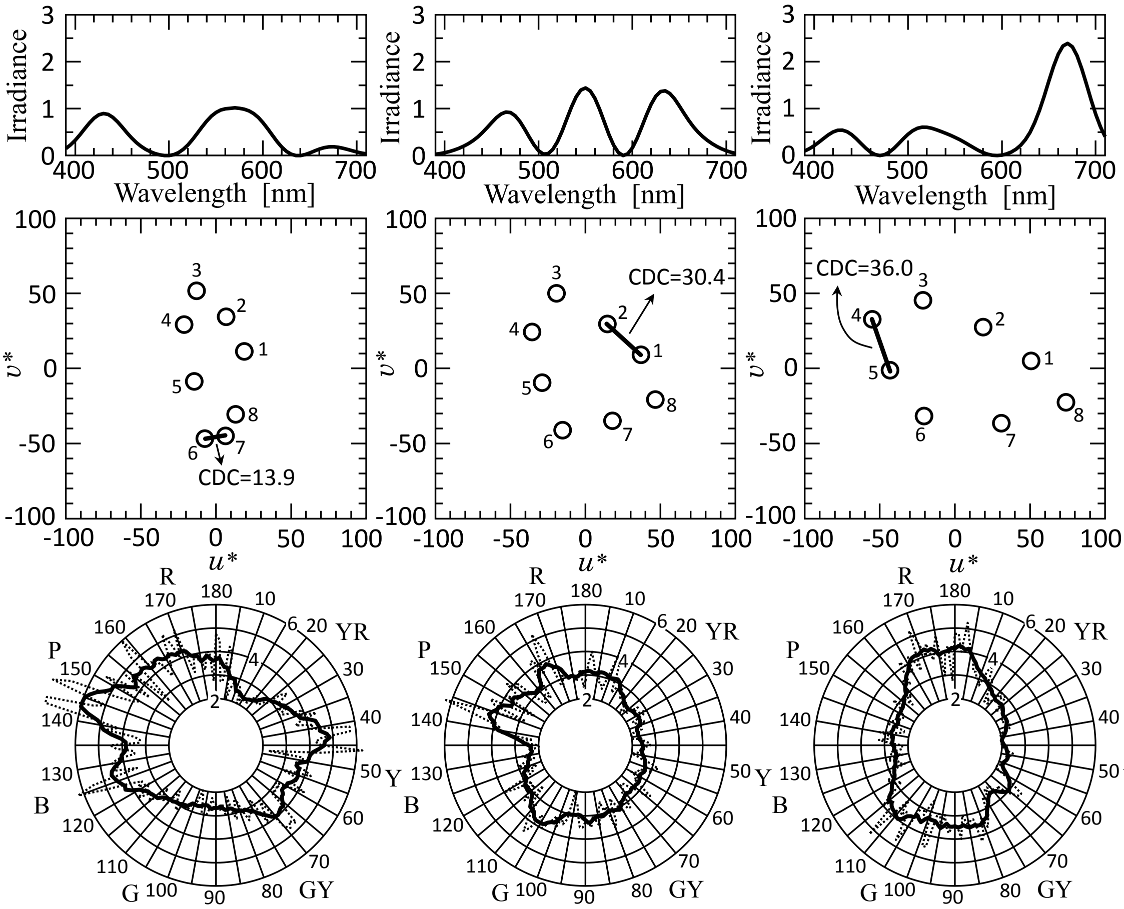

Figure 1: Examples of the results in Experiment 1 selected from 5000K illuminants.

While doing this experiment, we noticed that color chips became more colorful as CDC values increases, and felt comfortable for such illuminants that have lager CDC values. As the results of the next experiment show, however, correlation between CDC and comfortability is not necessarily high. Right hand illuminant in Figure 1, for example, has largest CDC value among 5000K illuminants, and color discrimination performance is good, but it is not necessarily comfortable because red colors are too prominent.

Figure 2 shows the results of Experiment 2. Left panel shows first two principal component vectors derived from score matrix of 15 adjective pairs (rows) for 30 illuminants (column). Scores were averaged for 4 subjects because the tendency was the same among them. Third vector and beyond were neglected because contribution rates were small. First vector is likely to relate to "colorfulness" impression of illuminant, because components of adjectives related to colorfulness show higher values compare to other components. Second vector is likely to relate to "fidelity/comfortability" impression of illuminants. Right panel shows score plot of 30 illuminants, in that, abscissa indicates score of "colorfulness" impression, and ordinate indicates that of "fidelity/comfortability" impression. Size of each symbol was set according to the score of "comfortable-unpleasant" adjective pair. Larger the size, the illuminant was evaluated as more comfortable. From these results, we can say that visual impression of color rendering arose by any illuminant can be evaluated using two factors, "colofulness" and "fidelity/comfortability", and comfortability become higher when both factors show higher score.

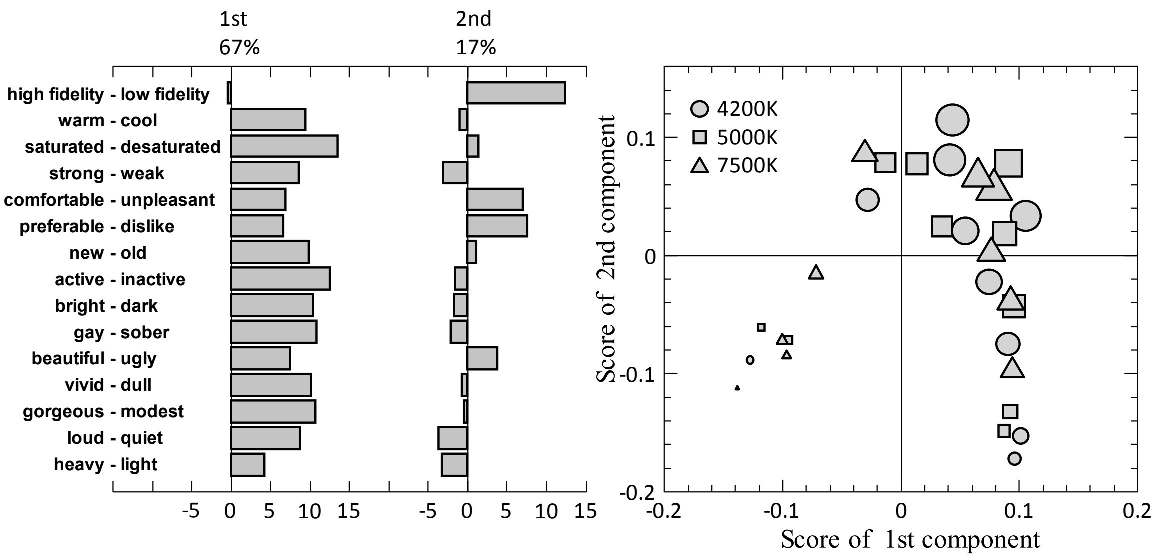

Figure 2: Principal component vectors derived from score matrix of 15 adjective pairs for 30 illuminants (left panel), and score plot for30 illuminants (right panel).

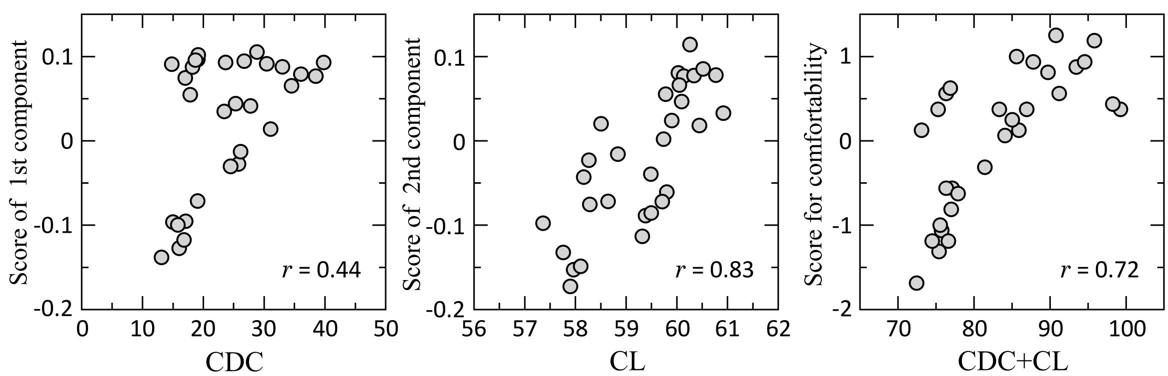

Figure 3: Correlations between scores and CDC, CL or CDC+CL.

It is convenient if we can evaluate these two scores just by using spectral irradiance distribution function of illuminant in practical situations. It is easy to imagine that CDC might be related to the score of first component, but we need another index to evaluate the score of second component. We introduced a new index, that is the minimum lightness (L*) value among 8 TCSs under the test illuminant. We called this index as CL (Critical Lightness), and the purpose of the index is to evaluate the balance of the spectral irradiance distribution of the illuminant. If energy in middle wavelength region is lacking in spectral irradiance distribution, for example, lightness of greenish test color sample will be lower. By increasing CL, such energy lack problem can be prevented, hence the balance of the spectral irradiance distribution is preserved.

Figure 3 shows correlations between CDC and score of first component (left panel), between CL and score of second component (middle panel), and between CDC+CL and score of "comfortable-unpleasant" adjective pair (right panel). Though, some of correlation coefficients are not so high, we can see that CDC is related to "colorfulness" impression, and that CL is related to "fidelity/comfortability" impression. If that is the case, we can expect that the illuminant having larger CDC and larger CL values will be more comfortable. This is confirmed by plotting the correlation between CDC+CL and "comfortability" score as shown in right panel in Figure 3.

4. CONCLUSIONS

CDC (Color Discriminability Criterion), that is defined as smallest color difference among 8 TCSs used for CIE CRI, can be used to evaluate color rendering property of illuminant in terms of color discriminability performance. By adding another index CL, that is defined as minimum lightness (L*) value among 8 TCSs, we can also evaluate visual impression of color rendering in terms of "comfortability". These indices will be useful when designing and evaluating spectral power distribution of new light sources such as LED and EL.

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Color monitoring method under high temperature during oven cooking

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ABSTRACT

The oven is one of the most popular appliances used for food processing tasks such as heating and baking, both in industry and domestic households. In general, the temperature of the oven chamber is monitored and regulated automatically during the baking process, and automated baking is performed using programmatic control. In this case, the only parameters used are those of time and temperature, without reference to color information. In contrast, when food is cooked manually (i.e. using a frying pan), we intuitively monitor the appearance of food visually, judging whether it is ready or not by its color, without measuring the time and temperature. This is because appearance monitoring in real-time, that is, in-situ color measurement, allows an optimization of the appearance of food, and provides a result that can be aesthetically appealing. Appearance is in fact one of the most important factors for food consumers. For these reasons, we have developed color-monitoring equipment, together with a method for baking in the oven. In our previous study, we reported on an in-situ color monitoring method that comprised a halogen light, an optical fiber and a spectrometer, used as a light source and a measuring instrument, respectively. Sliced white bread was used as the sample material. In this study, we investigated this real-time monitoring method using a charge-coupled device (CCD) camera for color detection. We constructed a small oven for our experiments using a conventional home oven as a basis, and examined the monitoring method at a temperature of approximately 200°C. The cooking and previously reported prediction expressions were also used. As we were considering practical usage in the home, infrared heaters installed in a commercially available oven (100V-600W-2200K) were used as the light source. The experimental results demonstrate their applicability for this purpose. Suitable methods for automatically determining the optimal conditions of the monitoring system, allowing for the preferences of users, are also proposed.

1. INTRODUCTION

The oven is one of the most popular items of cooking equipment in the home. Normally, oven users are able to control two crucial parameters of the heating environment, temperature and time. The latter is mostly determined by visual observation during heating. However, as it is not possible to observe the oven constantly during the heating process, it is difficult to know when the contents are ready, even if the oven temperature is regulated automatically and a timer has been installed. Therefore oven-cooked food is sometimes overcooked and so unsuitable for consumption. In addition, accidents may occur due to the abnormal expansion of food on a tray in the oven. For these reasons, color-monitoring equipment, has been developed, together with a method for oven cooking (Iyota *et al*. 2013, Matsumoto *et al*. 2014). It was also necessary to develop a food monitoring method that could remain inside the oven at high temperatures. Here a charge-coupled device

(CCD) camera was used to replace the role of visual monitoring, in order to improve the automatic control function. In this paper, we investigated a color monitoring method to be used during cooking at high temperatures, using a CCD camera and comparing the measured lightness, L*, using a spectrometer. An electric near-infrared radiant heater was used as the light source, and placed on the upper side of a commercially available oven suitable for home use.

2. METHOD

2.1 Experimental Apparatus

The experimental apparatus employed in this study is given in Figure 1. A conventional oven, suitable for use in the home, has been modified for use in these experiments. The fan and the convection heater (3) (with a power of 1360 W) were placed at the innermost side of the oven chamber, as shown in Figure 1. The oven chamber temperature was regulated automatically by a temperature controller. In addition, there was an electric radiant heater (2) (with a power of 600 W) placed at the top of the chamber, in order to bake food by a process of radiative heat transfer. The voltage supplied to this heater was controlled using a variable transformer. The color temperature of the heater at a power of 100 V was 2200 K, in the visible to near-infrared wavelength range. This heater was also used as a light source in the study. The CCD camera (4) (Imaging Source, DFK41AU02, 1/2 inch, 1280 × 960 pixels) and lens (5) were used to observe the food from the viewing hole composed of heat-resistance glass provided on the upper surface of the oven. At a lens focal distance of 8 mm, images of the bottom side of the chamber in a circle of approximately 100 mm diameter, were recorded using a personal computer, connected via USB. For comparison, spectroscopic measurements obtained using a spectrometer connected to the oven through an optical fiber were taken simultaneously.

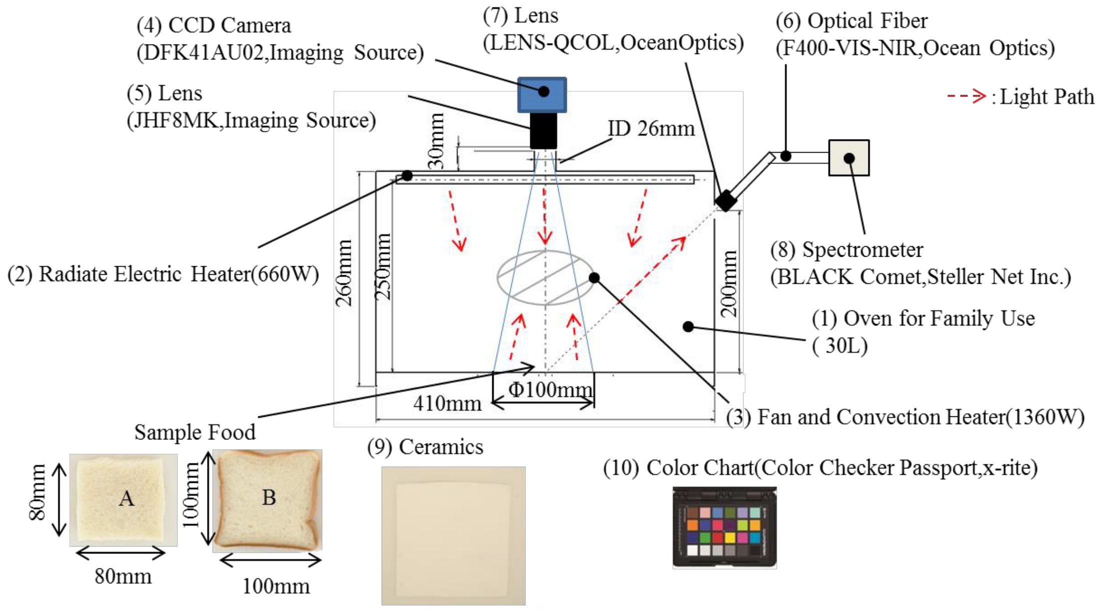

Figure 1. Experimental apparatus for the real-time color monitoring method (1-8) and the materials used for color and grayscale correction (9-10).

Two sizes of sliced white bread, with a thickness of 17 mm, were used as the food samples. The dimensions of sample A were 80 mm × 80 mm, with the surrounding crust removed, while the dimensions of sample B were 100 mm × 100 mm, including a brown crust. The oven temperature was maintained at 200 ± 5 ℃. We measured the voltage and the current of the radiation heater during heating, and confirmed that the electric resistant of the radiant heater, the heater temperature and the power remained constant (the change in the current value was less than 0.04 A).

After preheating the oven, the image of a white porous ceramics plate (9) was recorded for white balance correction. The plate was composed of a silicate compound (Miyagawa Kasei Industry Co.), with a reflectance of 0.88 in the 380-780 nm wavelength range. In terms of the total color (R, G, and B) light-receiving gain of the CCD sensor, the R and B gains were adjusted separately to equal 80% of the upper limit for each color. Values of the total color = 460, red = 18, and blue = 69 were used, together with a shutter speed of 1 / 2000 s. Next, the image of a 24-color chart (10) (Color Checker Passport, X-rite Co.) was recorded for the grayscale correction. Finally, after quickly placing the food sample (slice of bread) in the oven and closing the oven door, a continuous measurement of the sample color change was obtained. Images from the CCD camera and spectral data from the attached spectrometer were recorded by the personal computer approximately every 60 seconds, using the time stamp information.

2.2 Image analysis

The food images obtained were reduced from their original size of 1280 × 960 pixels to 800 × 600 pixel images. These images were then processed as follows:

(1) White balance correction:

Every pixel of the images was corrected using the white balance image data (taken from the white porous ceramic plate). The spatial distributions of the illumination, the color temperature, and the peripheral light of the lens were collected by performing this white balance correction.

(2) Grayscale correction:

An achromatic set of six colors in the color chart at position (10) in Fig. 1 was used for the grayscale correction. First, we determined the regression equation for converting the lightness of the corresponding portion in the color chart image, after applying a white balance correction to the standard values in the color chart. After determining the lightness of an image sample using the white balance correction, the image lightness was used to correct the values in this equation. The spectral data obtained using the spectrometer was also simultaneously used to determine the lightness, and the results compared with the values measured using the CCD camera.

3. RESULTS AND DISCUSSION

3.1 Determining measurement accuracy

Table 1 shows the variation with color of the standard lightness value, L^*_{std}, on the color chart, the value $L^*_{(1)}$ after the white balance correction, the value $L^*_{(1)(2)}$ after the additional grayscale correction, and the absolute value $|L^*_{std}-L^*_{(1)(2)}|$ of the error between L^*_{std} and $L^*_{(1)(2)}$.”

The maximum error obtained was 5.71 (No.15, red). Lightness was obtained from the RGB values with the greatest proportion arising from the G component. The standard G value for No.15 red is the second smallest among the 24 colors of the color chart. Therefore, the error in the measurement becomes large compared to that of the other colors. It is considered to exhibit the maximum measured error. The average error was found to be 2.32. This value was obtained for a CCD camera, giving the L^* measurement accuracy for current color measurement.

Table 1. The difference between the lightness of 24 colors. Measured L values are given for comparison with standard color chart values.*

No.	ColorChecker color name	L^*_{std}	$L^*_{(1)}$	$L^*_{(1)(2)}$	$\lvert \Delta L^* \rvert$
1	dark skin	38.02	11.61	36.37	1.65
2	light skin	65.67	38.42	65.62	0.05
3	blue sky	50.63	20.89	47.57	3.06
4	foliage	43.00	13.79	39.10	3.90
5	blue flower	55.68	27.15	54.48	1.20
6	bluish green	71.00	44.67	71.08	0.08
7	orange	61.13	38.05	65.28	4.15
8	purplish blue	41.12	15.28	40.94	0.18
9	moderate red	51.33	27.36	54.70	3.37
10	purple	31.10	8.57	32.46	1.36
11	yellow green	71.90	46.99	72.97	1.08
12	orange yellow	71.04	49.15	74.67	3.63
13	blue	30.35	8.42	32.26	1.90
14	green	55.03	25.73	52.95	2.08
15	red	41.34	20.44	47.05	5.71
16	yellow	80.70	61.15	82.99	2.29
17	magenta	51.14	28.97	56.39	5.25
18	cyan	51.15	22.84	49.78	1.37
19	white	95.82	87.61	94.61	1.20
20	neutral 8	80.60	61.37	83.12	2.52
21	neutral 6.5	65.87	39.40	66.51	0.65
22	neutral 5	51.19	21.24	47.97	3.22
23	neutral 3.5	36.15	9.66	33.88	2.27
24	black	21.70	3.14	25.16	3.46

3.2 Lightness change in baking food

The change in lightness given by baking two samples of different sizes, samples A and B, is shown in Figure 2. A difference in the color changes exhibited by samples A and B was observed. This result shows the importance of real-time color measurement for automatic oven operation.

The difference between color change, L^*_{fs}, in the baking process that was obtained using the optical fiber and spectrometer, and the color change resulting from the baking, $L^*_{(1)(2)}$, obtained using the CCD camera, were in agreement within ± 5. These results indicate that it is possible to monitor the lightness change of food during baking using a CCD camera with an electric radiative heater as the low color temperature light source.

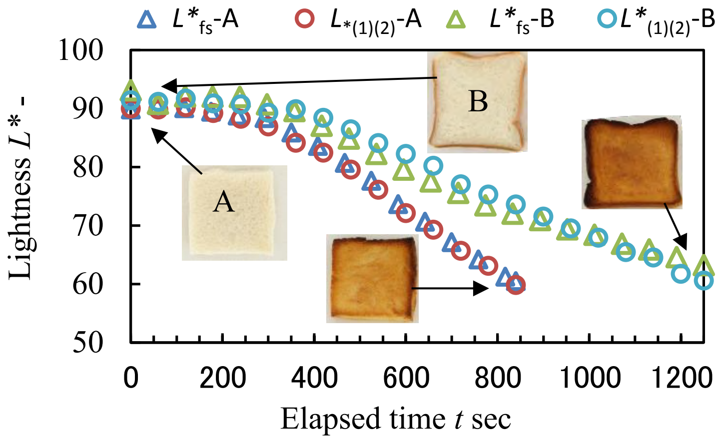

Figure 2. Lightness, L, obtained during the baking process using a CCD camera and a spectrometer vs. elapsed time.*

4. CONCLUSIONS

In this study, we monitored only the L* changes for images of food samples that changed from white to brown, captured using a CCD camera. We are examining the use of other types of food samples, in order to develop a user-friendly and safe automatic oven control.

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Woodblock printing as a means for 2.5D and 3D surface evaluation

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ABSTRACT

Inspired by the traditional Chiaroscuro woodblock printing techniques of the 16th century, we have explored the use of producing relief print impressions as a means to evaluate the surface rendered with 2.5D and 3D printing technologies. By transferring the surface characteristics of 3D or 2.5D down to 2D, we benefit from the availability of classic quality measurements.

As a benchmark of our idea, we employed different methods to control the modulation of a surface by either carving (laser cutting, CNC engraving) from an existing material (acrylic, wood, model board) or building relief using additive fabrication (Makerbot, Océ 2.5D printer prototype). For print analysis we created a set of two targets to test spatial resolution and edge detail. Following traditional printmaking processes the plates were inked, and subjected to a high level of downward pressure in a press to create impressions (i.e. the surface is embossed by the physical force). All of the plates were inked and printed in the same way. Instead of evaluating the quality of the relief plates created with each of the processes directly, we perform the evaluation on the impressions made with the plates. Each of the testing plates was adapted from optical frequency test patterns in order to access spatial resolution and edge detail in print. The Modulation Transfer Function (MTF), describing the print accuracy for different frequencies in horizontal, vertical and diagonal directions, was obtained for each of the methods based on the impressions.

In this paper, we discuss the results of our relief surface evaluation method with several technologies and the possible extension of our solution for the evaluation of more complex features.

1. INTRODUCTION

Although there exists an increasing interest in printing techniques possessing the ability to control the surface topology of the printout, there is limited focus on the evaluation of quality in the resulting prints. Due to limitations and instabilities of the printing process, the print will probably be distorted in shape and surface texture. Polzin et al. (2013: 37-43) designed a test target for 3D printing systems to evaluate such limitations, as the resolution and characteristics such as object strength and surface roughness. These results can be used to assess the accuracy and limits of a 3D printer and the feasibility of reproducing different shapes. Lui et al. (2014: 90180) proposed several measurements of 3D printed test charts for the evaluation of 3D printing systems, which also required measurements of the print surface topology. Although topography and micro-imaging methods can be used to measure surfaces, perceptual quality evaluation from surfaces rendered by additive printing methods is still a challenge, as discussed in a previous work by Baar et al. (2013: 1-6). In this paper, we propose to evaluate the print systems based on impressions produced with corresponding relief prints, as a means to evaluate the surface rendered with 2.5D and 3D printing technologies, thereby reducing from 3D or 2.5D down to two dimensions.

Traditionally, relief prints are created through the combination of a raised printing surface and the surface qualities of the printing woodblock (end-grain hardwood, chipboard, linoleum, acrylic), which is then inked and printed under great downward pressure. The woodblock surface is manipulated by engraving, cutting and abrasion (traditional tools include sharp V shape or U shaped chisels). In order to obtain a high quality printed image, the inked plate needs to produce well defined lines and solid areas with uniform colour.

Similar to traditional relief printing, we created plates by wood carving methods, using a laser cutter and a CNC engraving machine. Additionally, we introduced the use of two additional printing systems to generate printing plates. In the following section the target images used for assessment are described, as well as a description of each of the processes. Following this, we describe the results of our print quality assessment for each of the processes, based on the obtained relief prints.

2. TEST TARGETS FOR RELIEF PLATES

Each of the techniques used to modulate the surface texture carries advantages and disadvantages, both in terms of costs and creation time, and also in their ability to create small details and large smooth surfaces accurately. We used two resolution targets to assess the performance of the surface modulation processes.

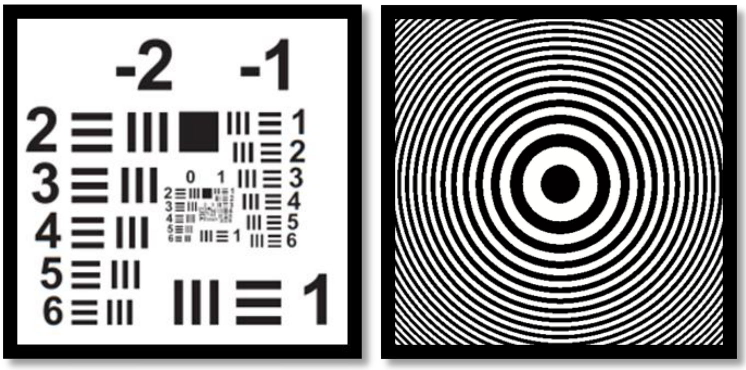


Figure 1: Test targets to assess resolution limitations of each of the relief plates. Black corresponds to high relief and white to a lower (carved out) surface.

The first sample is the USAF resolution test chart (1951), shown on the left of Figure 1, where a set (*element*) of three horizontal and vertical lines is depicted for different dimensions. Six elements together form a *group,* identified by the larger number on top. In accordance with the standard, this target is printed such that the first element of *group* -2 is 10mm long. By determining the element that corresponds to the smallest set of lines that are still distinguishable, the corresponding maximum representable resolution is calculated by:

$$Resolution = 25.4 \cdot 2^{group+\frac{element-1}{6}} \quad cycles/inch \tag{1}$$

For the second target we used a Zone plate ring pattern with a spatial frequency that increases from 5 up to 50 cycles per inch at the border, as shown on the right of Figure 1. A Modulation Transfer Function (MTF) could then be obtained from the printed target, describing the reproduction accuracy of the print for different frequencies in horizontal, vertical and diagonal direction, as described by Park, Schowengerdt and Kaczynski (1984: 2572-2582).

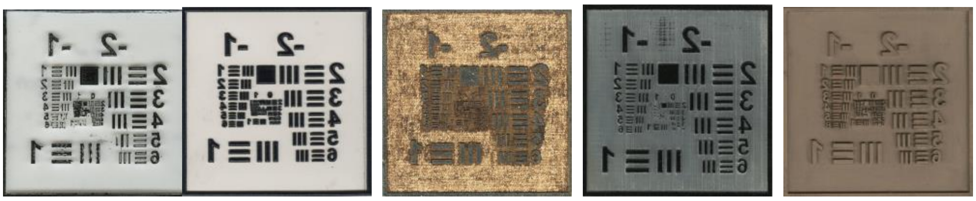
3. EVALUATION OF RELIEF PLATES AND IMPRESSIONS

We used five different processes for the creation of our test target printing plates. Relief was built up using additive (printing) fabrication, with both a commercially available Makerbot 3D printing system (using PLA filament to build 3D objects) and an Océ 2.5D digital printer prototype (where several layers of ink are superimposed to modulate the surface texture). Other relief plates were obtained by carving from an existing material, including wood and acrylic. Here, the non-printing areas were cut from these materials using a laser or CNC engraving machine.

3.1 Comparing Relief Plates

The two relief plates have been created using each of the technologies previously described. For each process, the target was input as a raster greyscale image (e.g. Tiff or Jpg file format), with the proper resolution used for each individual process. Each plate was made to have identical dimensions, including a depth in between 1.5 and 2mm (maximum distance between low and high parts of the plate). The time needed to create the plates varied from 20 minutes for the laser cutter to 46 hours using the CNC engraving. By observation of the relief plate, the maximum plate resolution was determined using the USAF resolution target and finding the smallest (textured) line pairs that could still be distinguished, from which a resolution limitation could be calculated following equation 1.

Table 1. Comparing relief prints from different processes.



relief plate process:	MakerBot 3D	Océ 2.5D	Laser cut wood	Laser cut acrylic	CNC engraving
input resolution:	253dpi	450dpi	300dpi	300dpi	600dpi
depth:	2mm	2mm	1.5mm	1.5	2mm
creation time:	2 hours	3 hours	20 minutes	20 minutes	46 hours
max. plate resolution:	g: -1 e: 4 18 cy/inch	g: 1 e: 2 57 cy/inch	g: 1 e: 1 51 cy/inch	g: 0 e: 4 36 cy/inch	g: 0 e: 5 40 cy/inch

The 3D printer showed the poorest reproduction ability, as it was unable to exceed a resolution of 18 cycles per inch. Artefacts for resolutions higher than 10 cycles per inch were observed with the frequency test, mainly caused by the filament traces left on unintended areas. The laser cutter failed to fully remove all the wooden and acrylic material, which led to some variation in the depth of the low parts of the printing plate. Furthermore, due to laser temperature, the material curves and edges are oddly sharp because of the material melting on the edges of the relief, forming unexpected textures. It should be noted that the wooden relief plates (made using the laser cutter and CNC engraving) require additional surface treatment. The resin ‘shellac’ was used to prepare the surface in these two cases. In comparison, the Océ 2.5D plate presented the highest achievable relief frequency and it did not require any additional cleaning or treatment following its production method. However, the OCE 2.5 plate exhibits one of the highest production times. It should be noted that the technique of using a printing system to build the relief showed the artefact of soft edges, less sharp than the plates created with the carving methods.

3.2 Comparing the Impressions of Relief Plates

Following a traditional printmaking process, the plates were inked and printed on an Albion press. Instead of evaluating the quality of the surface rendered by each of the methods directly, we performed the evaluation on the impressions made with the plates, accessing various aspects, such as density of ink, uniformity of the surfaces, sharpness of the edges and spatial resolution at different angles. Similarly to Table 1, Table 2 shows the maximum achievable resolutions based on the relief prints created with each of the processes. Compared to the resolution of the printing plates, the resolutions of the relief prints were found to be lower. Out of the tested processes, the highest achievable frequency was found for the plates made with the Océ 2.5D printer and CNC engraving machine.

Table 2. Comparing impression of USAF test target for different relief print processes

relief plate process:	MakerBot 3D	Océ 2.5D	Laser cut wood	Laser cut acrylic	CNC engraving
maximum resolution:	g: -1 e: 4 18 cy/inch	g: 0 e: 4 35 cy/inch	g: 0 e: 2 29 cy/inch	g: 0 e: 1 25 cy/inch	g: 0 e: 2 29 cy/inch

As previously introduced, the Zone plate was used as second target to analyse the print accuracy for different frequencies. For evaluation of print quality, the final prints from each of the relief plates were scanned, as shown in Figure 2. The first row of Figure 2 shows the input, a horizontal section of the Zone Plate from the centre to the right border, where the frequency increases from 5 to 50 cycles per inch. The next row is the result after printing, using the plate created with the MakerBot 3D printer, where resolutions over 25 cycles per inch could not be achieved. The following couple of rows show the resulting relief print for each of the other processes. For each relief printed image a section in horizontal direction is shown on top of a (rotated) section in the vertical direction. The horizontal direction is here referred to as the direction in which the print-head/laser/cutting tool moves.

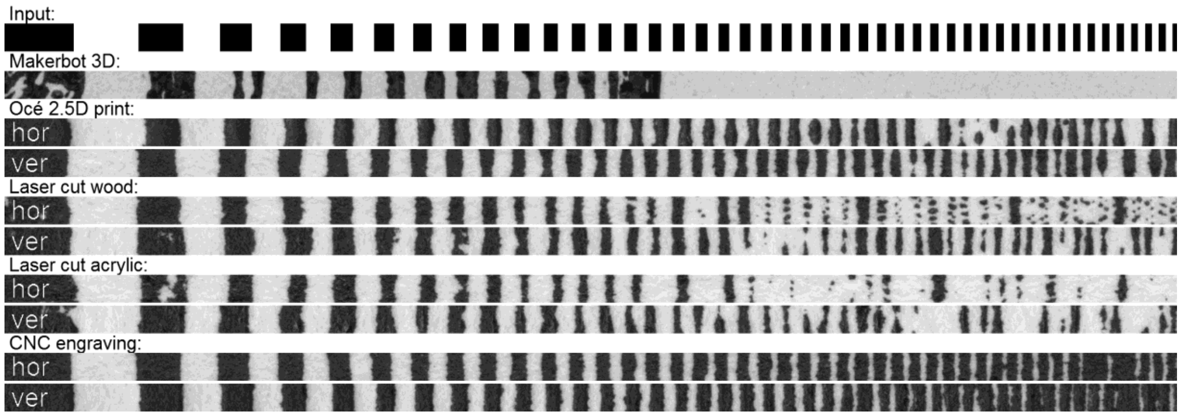


Figure 2: Scan of impression of Zone Plate for each of the processes. Only a selection is shown from the centre of the Zone Plate to the border, increasing from 5 up to 50 cycles per inch, both in the horizontal and vertical direction.

Although conclusions on the accuracy of printing different resolutions could subjectively be drawn from Figure 2, an objective measure is obtained by determining a Modulation Transfer Function for each of the printed outputs. The MTF is defined as the ratio of the modulation of the input signal and the output signal,

$$MTF = \frac{Modulation(output)}{Modulation(input)}. \tag{2}$$

Similar resolution targets are mainly used to assess the frequency response of optical measurement instruments where problems like aliasing do not occur and therefore the modulation can be simply determined based on minimum and maximum response values per frequency. In the case of the impressions shown in Figure 2, this would lead to an incorrect assessment of the performance, because the higher frequencies are not obtained but minimum and maximum values are still present in the calculation. We therefore determine the modulation via the Fourier domain:

$$Modulation(f) = \frac{F(f)}{F(0)} \tag{3}$$

Using equations 2 and 3 the MTF's are determined for each of the processes and shown in Figure 3, indicating how well several frequencies are reproduced. An important observation is the dependency on the direction of the output, as presented in the left graph of Figure 3. Here it can be seen that in the vertical direction (orthogonal to the direction of the laser and print head movement) a higher resolution can be obtained.

The MTF of the Océ 2.5D and CNC engraving process presented the highest achievable resolution, while the laser cut with the acrylic material shows the worst performance. These results are in agreement with the observations made earlier and indicated in Table 2. Based on the USAF test target, critical frequencies appear to occur at the 80% point of the MTF. An interesting observation was made from Figure 2 and 3 where the frequency response of the Océ 2.5D relief plate shows a peak at 45 cycles per inch, exactly around one tenth of the printer resolution. Although the impression of the CNC relief plate on the print (Figure 2) is nicely inked on the high frequencies, the inked lines are a bit thicker compared to the white spaces in between, which results in a low frequency response as shown in the MTF plot of Figure 3.

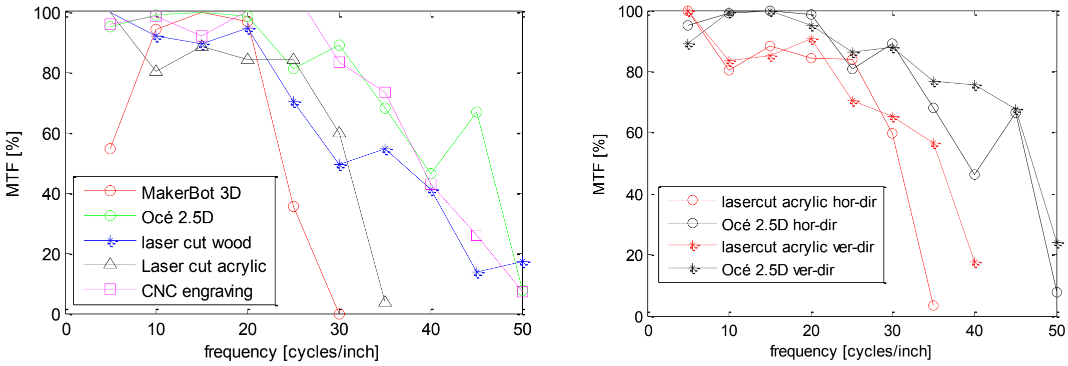


Figure 3: Modulation Transfer Functions based on the relief prints, comparing the different processes (left) and showing the direction dependency (right).

5. CONCLUSIONS

We have shown how several techniques can be used to create printing plates for the relief printing process. Imitating the Chiaroscuro woodcuts prints, we used two methods of carving printing plates out of wood and acrylic, along with two 3D printers, where plates were created by superimposing several layers of ink to modulate the surface texture.

Impressions of the relief plates were obtained through a relief printing process, from which limitations of reproducible frequencies were determined. In our investigation we found that spatial frequencies above 45 cycles per inch were poorly reproduced. The Océ 2.5D printing technique achieved the highest accuracy, preforming slightly better than the CNC engraving machine and laser cutting process. On the other hand we observed the effect of rounded edges in relief plates that were printed, while carving methods appeared sharper.

Current experiments have focussed on surface structures generated from raster images as input. Future work will be undertaken to investigate the performance differences using a vector format, which should result in more clearly defined cut lines. This would be more directly related to the creation of hand-carved woodblocks which could be included as a ground-truth comparison.

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The Relationships between Colors of Neck, Cheek, and Shaded Face Line Affects Beauty of Made-up Face

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ABSTRACT

The color choice of make-up foundation is one of the most important step to make a beautiful finish of made-up face, and a difficult problem for many users. For these users, there are many advices in markets. Such as “You should look for a nearest matching color to the color of your face line”. However, there have been several questions. 1) Where is the best region of a face (or neck) for the color matching? 2) Is color matching to a certain region the best way to make a beautiful finish? In this study, visual evaluation tasks were conducted using images of Japanese female faces applied make-up foundations having various colors. As results, the index value indicated the relationship between colors of several regions had a strong negative correlation with scores of beauty evaluated by these tasks. In detail, these results suggested that participants used the coincidence of 2 color directions from the color of shaded face line to the color of cheek or neck in L*a*b* color space, to evaluate the positive feeling about the color choice of make-up foundation.

1. INTRODUCTION

Make-up foundation is one of the basic make-up items. This item is usually applied to a whole face, and this finish is shown as a skin tone. Therefore, if the color of this item was far from the natural skin color, the finish is certainly not beautiful. This fact means that the best color of this item to make a beautiful finish is different for each users, because natural skin colors of each user are different. For this reason, the color choice of make-up foundation has been difficult problem for many users. For these users, there are many advices in markets. Such as “You should look for a nearest matching color to the color of your face line”. And there are several systems that could give these advices automatically using image analysis (e.g. Jain, et al, 2008: 331). However, several different regions have been recommended as the region for color matching in these advices, and it has not been clarified where the best region is. Furthermore, it has not been verified whether the color matching to a certain region is the best way to make a beautiful finish. There is a contradictory common opinion that many Japanese females want to make them face brightened. Considering each positions of these regions, cheek is usually applied region, and neck is usually non-applied region. Thus, we could observe the relationship between colors of applied region and non-applied region in neck and cheek. And then, it is predicted that the positive feeling about that color choice could be evaluated by using this color difference. However, the boundary is usually not clear, and there is the region of shaded face line. It is generally known that an existence of boundary regions or shades interfere to percept of a color difference between both sides. Furthermore, the color factor effected by shading of human skin is not only brightness but hue and saturation, because of the complex reflection structure of human skin. In other words, human skin has character about the shading color direction that is from the color of shaded region to the color of brightened region in L*a*b* color space. Therefore, we guessed that the main factor of the positive feeling about that color choice is not the color difference between cheek (applied region) and neck (non-applied region), but the coincidence of 2 color directions from the color of shaded face line to the color of cheek, or neck.

2. METHOD

The index value was developed as evaluating the positive feeling about the color choice of a make-up foundation. It was calculated from images of faces applied a make-up foundation using image analysis, and based on our hypothesis about the main factor of that positive feeling. And then, 2 visual evaluation tasks were conducted to verify this index value.

2.1 Index value

Calculating method of the index value is shown as follows. Firstly, each regions were defined. Figure 1(a) shows the line from neck to cheek was set up arbitrary in the image of face. And the darkest pixel in the line was defined as the region of shaded face line. Then, L*a*b* values of these 3 regions were gotten from each pixel value of the smoothed image. Figure 1(b) shows the 3D angle of 2 color directions from the color of shaded face line to the color of cheek or neck. The index value was defined the logarithm of this 3D angle. This value became lower when these directions were coincided, and became higher when these directions were divorced.

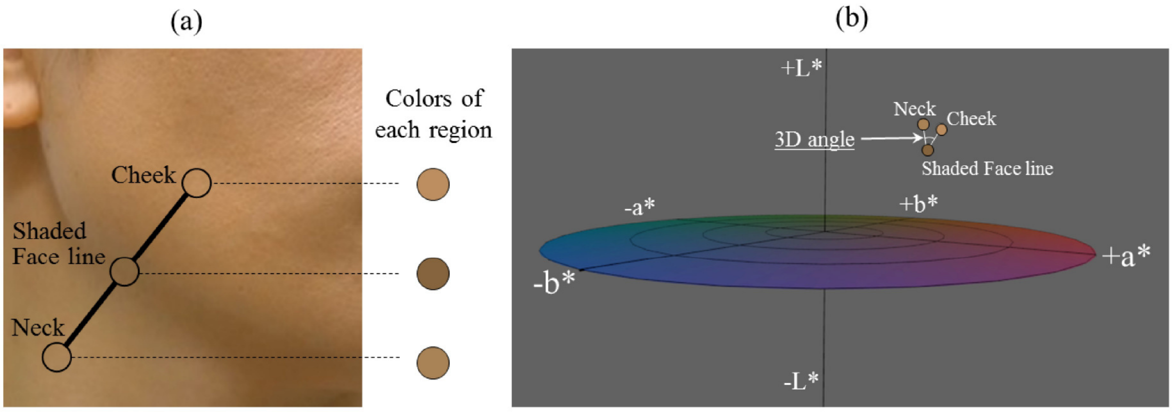

*Figure 1: (a) shows each regions in the image of face. (b) shows the 3D angle of 2 color directions in L*a*b* color space.*

2.2 Visual Evaluation Tasks

The first task were used 40 images of 4 Japanese female faces applied 10 make-up foundations having various colors. Figure 2(a) shows some images of them. 34 participants observed these images and replied scores (1: beautiful, -1: not beautiful, 0: not either) about these color choices. In the second task, simulated images were used. For the simulation, 12 original images of the first task were selected as the group having a mid-range index value. And then, 108 simulated images were made from these original images to 9 conditions (2 parameters, 3 steps) as shown in Figure 2(b). The parameter of horizontal axis was the color of neck, and to change the angle of the color direction from the color of shaded face line to the color of neck. Therefore, this parameter changed that coincidence of color directions, without to change the color of face and the color difference between neck and shaded face line. The comparison parameter of vertical axis was the the color of face, and to change the color difference from the color of shaded face line to the color of whole face. Therefore, this parameter changed the brightness of face without to change the color of neck and the coincidence of these color directions. Participants of the second task were 6, and other regulations of the second task were followed the first task.

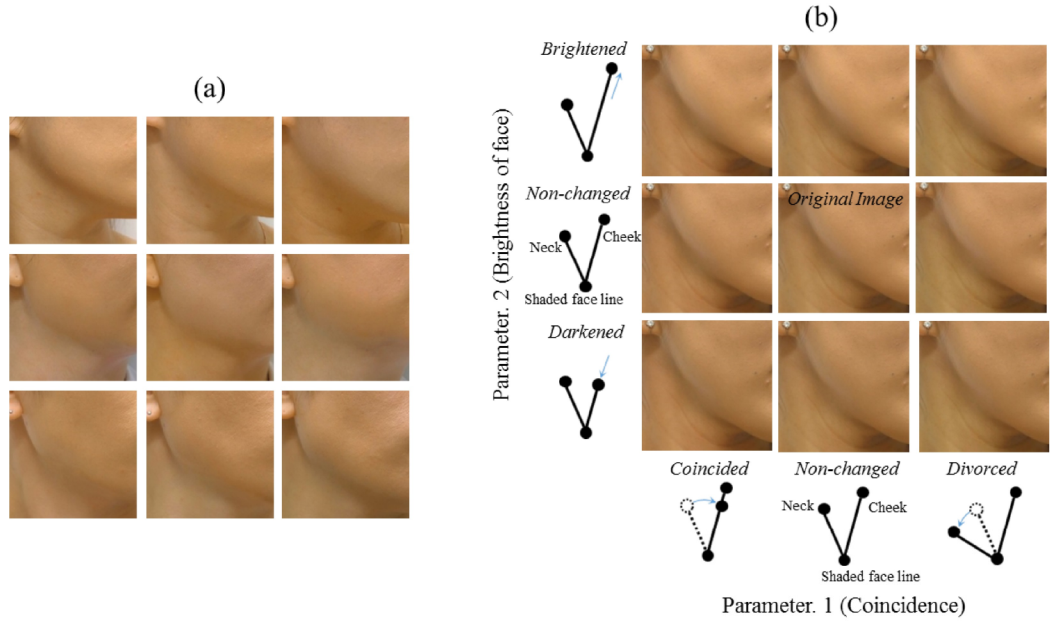

Figure 2: (a) shows faces applied make-up foundations having various colors for the first task. (b) shows faces simulated to control an index value or a brightness of face for the second task.

3. RESULTS AND DISCUSSION

As shown in Figure 3(a), the index value had a strong negative correlation with scores of the first task. This correlation coefficient was 0.73. The other hand, the correlation coefficient of the logarithm of ΔE (the color difference between colors of neck and cheek) versus these scores was 0.57 and significantly lower ($p<.05$). This reason was that shading degrees of neck and cheek were partialy different in these images, and this difference caused large ΔE. Our proposed index value was based on the consideration about this difference of shading degrees. Because this difference is usually shown in natural scenes.

Figure 3(b) shows results of the second task. Values of the vertical axis in this figure are differences of the average scores of each row groups as shown in Figure 2(b) against the score of original image. Therefore, these values indicate the effect of these 2 parameters which are the coincidence of color directions and the brightness of face. These p values were caluculated by using *Student's T-test* versus the average score of non-changed images of each parameter. One of the knowledge verified from these results is that the positive feeling of that color choices does not depend on the single color of any certain region, but depend on relationships between colors of several regions. Because these parameters were not related one either color of neck or face, and if it depended on a color of any single region without any relationships, either one of these parameters could not effect these scores. As the effect of brightness of face, the effect of darkned was significantly shown, but the effect of brightened was not significantly shown. For this reason, it is considered that the effect of brightness of face is little when the brightness is over a certain level. On the other hand, The effect of coinsidence of color directions was shown more significantly about either coinsided or divorced. For these reasons, it was verified that the coincidence of that color directions was important for the positive feeling of that.

Considering L*a*b* values of each regions in natural schenes, the color of shaded face line has usually lower value of L* and higher values of a* and b* than the color of non-shaded face line. This phenomenon affects the relationship between colors of these regions strongly. For this reason, we concluded that the color value of shaded face line in natural scenes is more importart than the color value of non-shaded face line, such as the value measured by a color difference meter or any other tools having the function of avoiding the influence of shades.

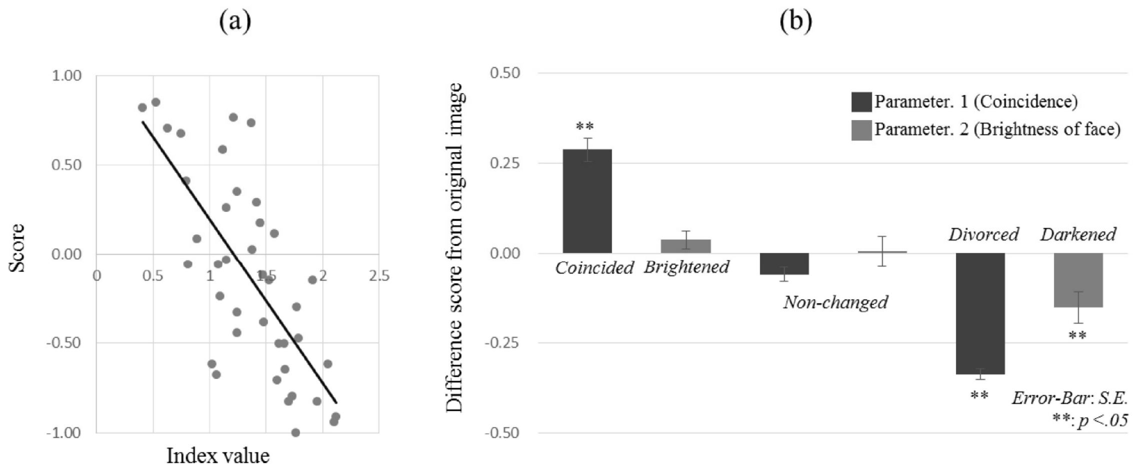

Figure 3: (a) shows results of the first task. (b) shows results of the second task.

4. CONCLUSIONS

It was suggested that the main factor of positive feeling about the color choice of make-up foundation is the coincidence of 2 color directions from the color of shaded face line to the color of cheek or neck in L*a*b* color space.

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Experimental Method Suggested for Optical Observation of Anisotropic Scattering

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ABSTRACT

Experimantal methods are suggested for observation of scattering considered with spatially anisotropic distribution. Applying "transferring surface" which has controled curvature and orientation can achieve easy and rapid observation of emmision or radiation from a sample set at an unique point; emmision (such as emitted or scattered light from the irradiated sample) with spatial anisotropy is projected or reflected on "transferring surface" and transfered intensity is detected as two-dimensional images veiwed with observing instruments. In this report, we adopted parabollic curved surface as "transferring surface". Such indirect observation can provide experimental merits as rapid and wide-range measurements with high resolution, and (observed) transferred intensity can be also revised through estimation of reflecting property on "transferring surface"; in the case of passively irradiated materials, it means effective experiments for bidirectional reflectance distribution function (BRDF). The method can be appliable for vairous scattering: both spontaneous light source and irradiated materials, discrete scattering and gradated (or diffused) one, observation of spatial distribution and color dispersion, and more. Measurements using straight light beams as incidence and "transfering surface" suggested analysis of distribution of light scattered by jewels (diamonds) and sheeny cloths (silk textiles).

1. INTRODUCTION

There are some genres for viewing estimation of commercial products where objective standards hardly exist or convictive explanations are not enough scientifically discussed. Estimation for jewels represented by diamonds is such typical operation which may be often regarded dubiously because the products are occasionally expensive; amateurs or customers have to trust judgments given by professionals or sellers.

On the other hand, as estimation for jewels, chemical analysis for the samples or measurement for their geometrical shapes may be objective.(Schumann, 1977: 68) However, conclusion indicated by such procedures are independent from optical process or viewing impression. Or, some instruments appeal results given by optical measurements but scientific explanations as physics are not sufficiently indicated.

Even for either spontaneous light source or materials irradiated by external light, visual effects and functionality are determined by spatial distribution of light from the objects. Viewing illuminated materials that do not emit light spontaneously, perception for the viewed objects depends on spatial distribution of scattered light: distribution for intensity, wavelength dispersion, solid angle width, orientation of scattered light direction, etc.

However, it is sure that all scattered light should be originated with external light incidence though their directions are unknown and do not have to be known, generally. In this sense, *"isotropic"* lighting or illumination, which is regarded as general and natural environments recommended for visual estimation, can be approximated by summation of *straight* incident beams with many enough direction.

Authors have been investigating objective and convictive estimation for viewing diamonds and jewels, which are recommended to be judged with isotropic lighting environment such as orthodoxy "through a north window, on a fine day". As mentioned above, however, such isotropic lighting can be approximated by straight light beam(s) and, then, optical property can be discussed as physical light scattering. Furthermore, suggested methods are generally applicable for estimation of other materials showing anisotropic light scattering.

2. METHOD

2.1 Samples

As a jewel sample, a diamond cut as "round brilliant cut" design was prepared: weight c.a. 0.2 ct., cut grade "very good (VG)", girdle diameter c.a. 3mm.(Figure 1) As sheeny textiles, three kinds of silk textile (Japanese "Nishijin-Ori") sheets were investigated. (A: white, B:pink , C: light blue, in Figure 1)

Figure 1: Jewel and Textile samples.

2.2 Optical Instruments and Layout: Mechanics and Fundamentality

As light source, laser beam (red) and LED (white) were used. Since each beam was collimated as straight incidence of 8 mm in diameter, which is larger enough than the jewel sample, they covered whole volume of the jewel sample. Beams were alternately introduced to the sample on the same path using a half mirror and the incident beam can move in angle range of Θ = 0-90 deg. and Φ = 0-270 deg. (Figure 2)

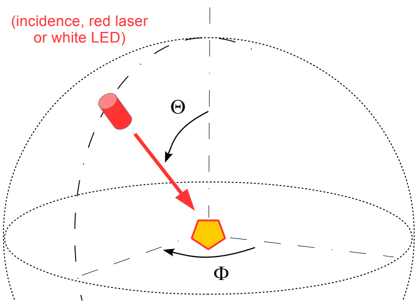

Figure 2: Orientation of light source; meridian coordination, Θ, and horizontal one, Φ.

Then, the sample position was a centre of light source running on a circle track with a rotating table; it was always irradiated by the incidence for all range of (Θ, Φ). Additionally, the position is also designed as a focus of following “parabolic surface”.

The beams emmited from the sample were observed through “transfering surface”, which can be available as plane surfaces or curved ones generally. Presently, we adopted parabollic curved surface which was coated by white powder (MgO) and was a circle of A = 200 mm in diameter with a slit of 10 mm width to introduce incident beams; emmission from the sample was observed as images projected on “transfering surface” as a curved screen. (Figure 3a)

When the sample position coincides with the focus of the parabollic curve (“origin” in Figure 3b), beams emitted from the focus point (“red lines” in Figure 3b) are transferred to parallel beams (“orange lines” in Figure 3b); emitted direction, (θ, ϕ) is transferred to observing coordination, (r, ϕ): $r = r(\theta) = A(1\text{-}\cos\theta)/\sin\theta$ or $\cos\theta = (A^2\text{-}r^2)/(A^2+r^2)$. And, intensity scattered form the sample, $I(\theta, \phi)$, is also transferred to $I_{obs}(\theta, \phi) \approx I(\theta, \phi)\rho_s(\theta/2)/D^2$, $D = A/(1+\cos\theta)$, ρ_s: reflectivity on transfering surface. Scattered beams projected on parabolic “transfering surface” were observed from a CCD camera at a point along the axis of the parabolic surface with sufficiently far distance, c.a.900 mm. (camera: Lumenera Lc370c, 3M-pixel; lens: Kowa LM25JC5M, f = 50mm) Actual surface (white area in Figure 3a) was manufactured applying part of parabollic curve, y > 0, and screen diameter, A, corresponds to x = -2 ~ +2, in Figure 3b.

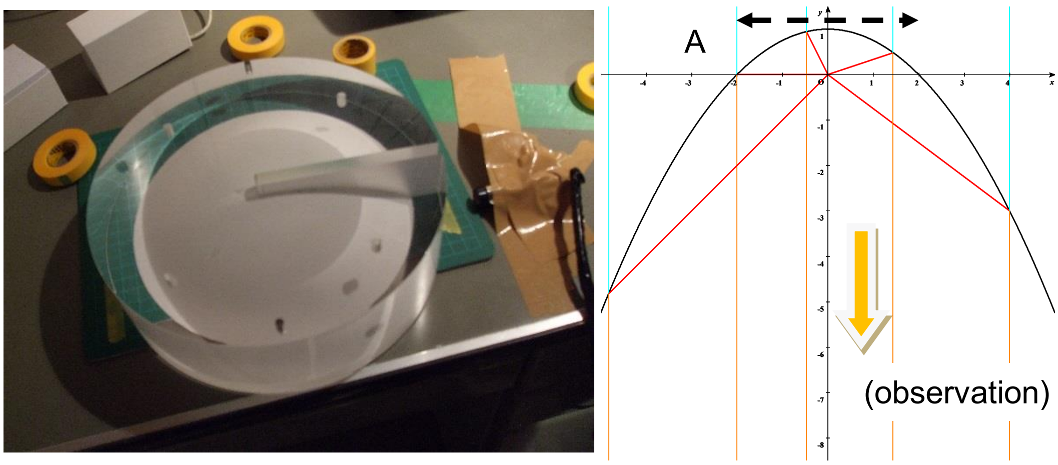

Figure 3: (a, left) Parabolic surface (behind acrylic pillar) and (b, right) its fundamentality.

2.3 Analysis for Scattered Beams from Jewel.

As light source, red laser beam was used for investigation of the jewel sample. The sample was set at the sample position with tweezers owing three wires, and its “table facet” which was the top and largest plane of the design was (almost) oriented to Θ=0 direction. Scattered beams emitted from the sample projected as “light spots” on the parabolic screen, and the view observed from the CCD camera was saved as image datum in a PC. Moving orientation of the light source (Θ, Φ) as 82 positions and controlling sensitivity of the camera (low and high), taken 82 shots were converted to “two-value (zero-one)” images to estimate statistical distribution of size of “light spots”.

For statistical analysis from the images, image analysing software, “WinROOF (Mitani

Corporation)", was applied. Distribution of size of "light spots" was summed for all (82) directions and was averaged for per one shot.

2.4 Observation for Silky Textiles.

For observation of silk textiles, white LED was used as light source moving in range of Θ = 0-75 deg. and Φ = 0-90 deg. Each textile samples was set at the sample position with a double-coated tape on the top of a flat-head pillar; normal plane of the textiles was oriented to Θ=0 direction. Quantitative analysis for the textile samples was not considered in present work because of inaccuracy of reflectivity on the "transfering surface".

3. RESULTS AND DISCUSSION

3.1 Emitted Beams from Diamond: Scattering by "Round Brilliant Cut" Design.

For a "round brilliant cut" diamond, which has 58 facets generally, one incident beam was scattered as number of $10^3 \sim 10^5$ (or much more, actually) emitted beams projected as "light spots". And such corelation of orientation between the *straight* incidence and each spot should be correctly indicating corelation between illuminating light (unknown and just before going into the jewels) and observation of the jewels as brilliancy or glare. If so, estimation for distribution of solid angle width of emitted beams (or size of "light spot") is fully meaningful since it is discussion of probability that each emitted beam can detected by an observer's eye.

Then, considering statistical tendency of distribution of size of "light spot", histogram plot is indicated; $\ln\{N(\Omega)+1\}$ vs. Ω, where Ω is a solid angle value (steradian) for each spot, $N(\Omega)$ is number of data contained in interval sections and "+1" term is introduced to avoid errors in logarithm function. As a typical result, statistical distribution of solid angle distribution of emitted beams is indicated in Figure 4.

Both plots for high sensitivity of camera and low one show existence of region applicable with "linear approximation" in low Ω range (emphasized with red dotted ovals in Figure 4); it means that, in low Ω range (as tendency of small or tiny "light spots"), statistical distribution of $N(\Omega)$ follows an exponential rule, $N(\Omega) \sim \exp\{-\lambda\Omega\}$ ($\lambda > 0$).

On the other hand, even if number of tiny "light spots" is much large, bigger sized "light spots" which volume is relatively small may be more effective or more impressive

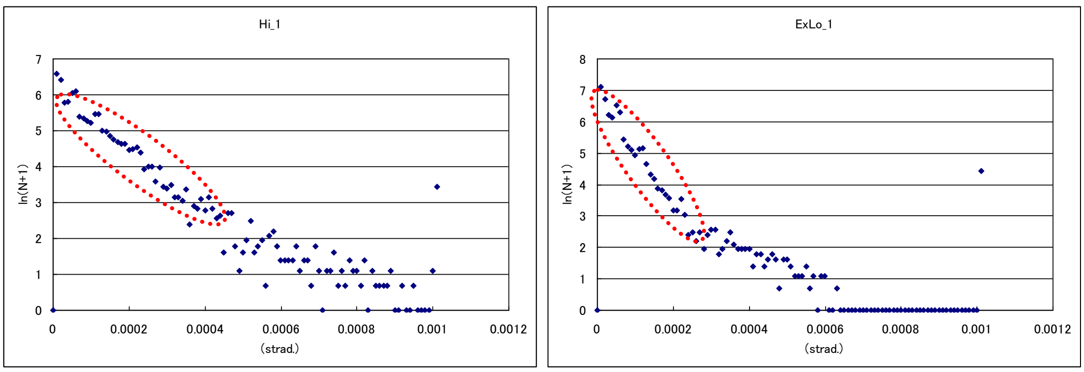

Figure 4: Histogram plots, $\ln\{N(\Omega)+1\}$ vs. Ω, and "linear region" in low Ω range; interval step is 1×10^{-5} strad., alternating camera sensitivity high (left) and low (right).

when customers actually look the jewels. Above “exponential distribution in low Ω range” is expected to clarify scientific objectivity for effective impression of jewels.

Furthermore, though directions of the emitted beams are innumerable, the suggested method can provide data for spatial bias about their orientation and wave distribution. Such factors are expected to be efficiency on observers’ impression.

Unfortunately, though above statistical distribution of size or solid angle can provide scientific grounds for facts of brilliancy of jewels, we have not yet arrived at relationship between the experimental data and professional jewelers’ judgment. Considering intensity distribution of the “light spots”, correspondence between statistical distribution of Ω and estimation judged by jewelers have to be discussed and concluded in near future.

3.2 Anisotropic Diffuse Scattering by Silk Textiles.

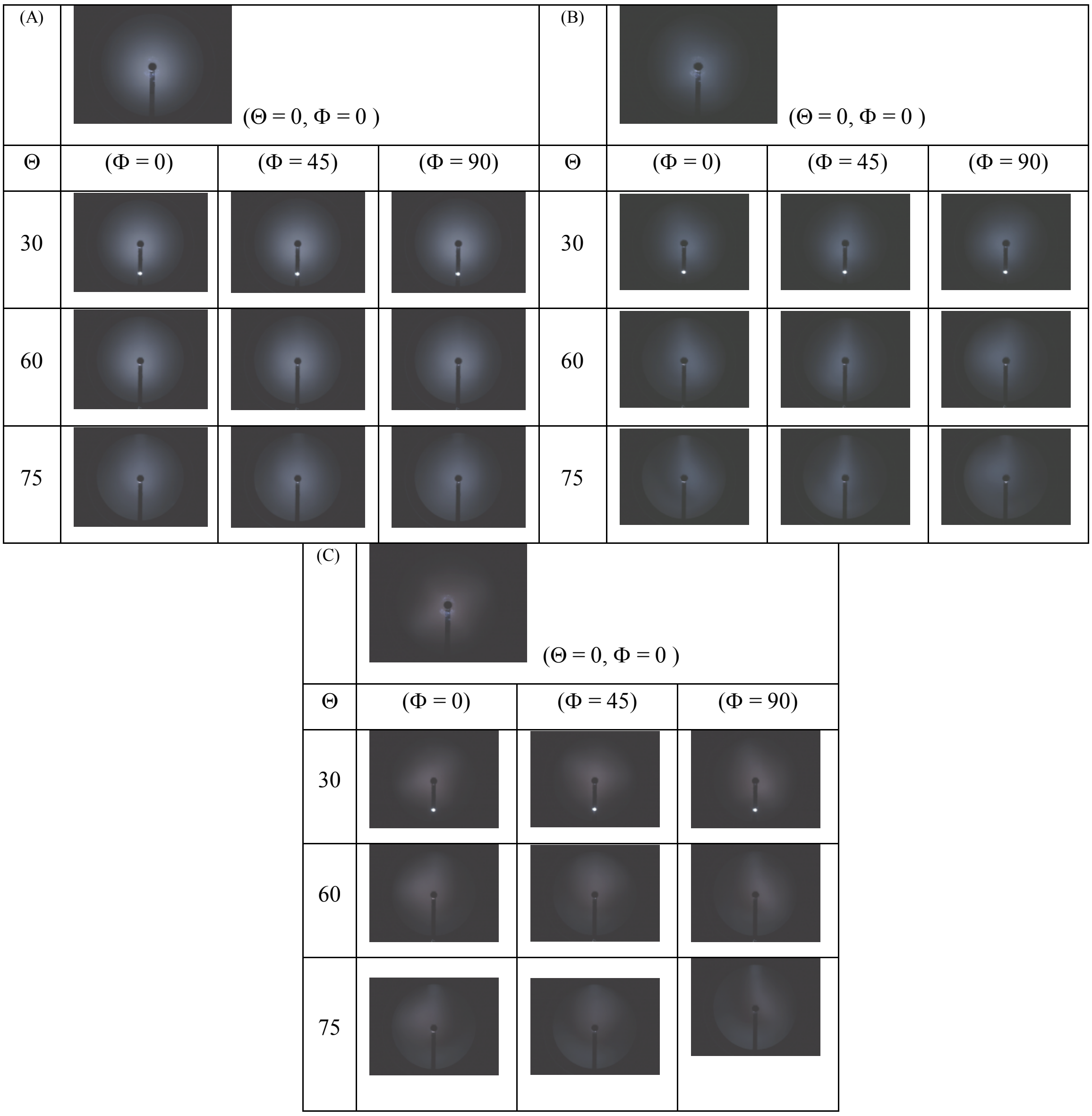

Figure 5: Scattered light distribution observed as 2-dim images for three silk textiles irradiated with white LED incidence; “black band” viewed on center is a slit for incidence.

Applying the method and instruments for observation of scattering as "light spots" from jewel samples, we can observe anisotropic light scattering from glossy materials such as silk textiles. However, since reflectivity function, $\rho_s(\phi)$ (ϕ: reflective angle at each point on the "tranfering surface"), has not tuned correctly and quantitatively, the present image data are estimated or discussed qualitatively.

Observation results for three silky textiles (A/B/C) irradiated with a white LED beam alternating incident orientation: $\Theta = 0, 30, 60, 75$ deg. and $\Phi = 0, 45, 90$ deg. Obviously, both dependency on colours of each sample and anisotropy of intensity, $I_{obs}(\Theta, \Phi; \theta, \phi)$ which is function for orientation of the light source (Θ, Φ) and direction of scattered light (θ, ϕ) or $(r(\theta), \phi)$, were recognized in the images. (Figure 5) It is noticeable that anisotropy in intensity of scattered light was frequently observed in area missing "incidence plane", which corresponds with plane parallel to "black band (slit)" in Figure 5; these figures are two dimensional detection of bidirectional reflectance distribution function (BRDF) for the silk textiles.

In measuring orientation of scattered or emitted intensity, usual orthodox experiments use a point-detector (a single camera) on a goniometer which catches intensity for some direction. Such direct detection is the most accurate procedure to estimate intensity or dispersion. However, it also has demerits: antinomy, "scanning range" or "resolution" vs. "measuring time", or insufficiency in observation for irregular bias or distribution under gradation. Indirect method of observation with "transferring surface" can introduce consistence between measuring time and resolution requiring standardization of 2-dim image and reflectivity of "transferring surface".

4. CONCLUSIONS

Indirect observation of light scattered from objects applying "transferring surface" has potential advantages to estimate irregularity or anisotropy in light scattering. When jewel samples such as cut diamonds are irradiated with a single straight incidence, scattered beams are emitted as "light spots" for innumerable direction. Since correlation between insidence and emitted beams is approximation of recognization, statistical and orientaional analysis are expected to provide objectivity for human's judgments. Presently, "exponential distribution", $N(\Omega) \sim \exp\{-\lambda\Omega\}$ $(\lambda > 0)$, is found for distribution of low range of solid angle (Ω) as statistical tendency. And, under standardization of 2-dim image and reflectivity of "transferring surface" and experimental devices, acquiring two dimensional distribution, (θ, ϕ) or $(r(\theta), \phi)$, for scattered light as image data can provide more effective observation for objective estimation of glossy samples. .

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Color measurement of meat in cooking under LED lightings with different spectral distributions

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ABSTRACT

We measured the colors of meat during cooking under the standard illuminant D65 and several LED lighting conditions which differ in the spectral power distribution. First, we prepared three kinds of minced meat, beef, chicken and pork, which were shaped into 2 cm cubes. Each cubes of the minced meats was baked with an oven at the temperature of 200 degrees Celsius. We made a spherical dome for measuring average chromaticity values of an object in the condition of no shadow. The dome equipped fluorescent lamps of the standard illuminant D65 and two kinds of LED lamps: RGB LED lamps and white LED lamps. We measured the average chromaticity of the top surface of minced meat cubes at a raw stage and 22 cooking stages using a two-dimensional luminance colorimeter under eight lighting conditions in the spherical dome. According to the results, the chromaticity values gradually decreased with the increases cooking time under all lighting conditions. It was also shown that the color appearance while the beef has been cooked depends on the lighting conditions.

1. INTRODUCTION

Color appearance is a powerful indicator of food quality (Hutchings 2010). When we cook meat, it is needed to be adequately heated to prevent food-poisoning among other aspects of safety and good hygiene. Therefore, the color appearance of cooked meat is important in order to confirm how it has been cooked. Color appearance depends on the lighting condition such as the illuminance and the spectral power distribution. It has been reported that the color appearance of food is different under the following three kinds of light sources: LED light, Halogen incandescent and compact fluorescent lamp (Ixtaina et al. 2010). In addition, the colors of meat during storage under fluorescent lamps with different spectral power distributions (Saenz et al. 2005) and the color appearance of food in cooking process under D65 fluorescent lamp were measured (Sakai and Iyota 2013). This study aims to clarify quantitatively the color changes of meat during cooking under LED lighting conditions. We conducted measurements of the color of meat during cooking under several LED lightings with different spectral power distribution.

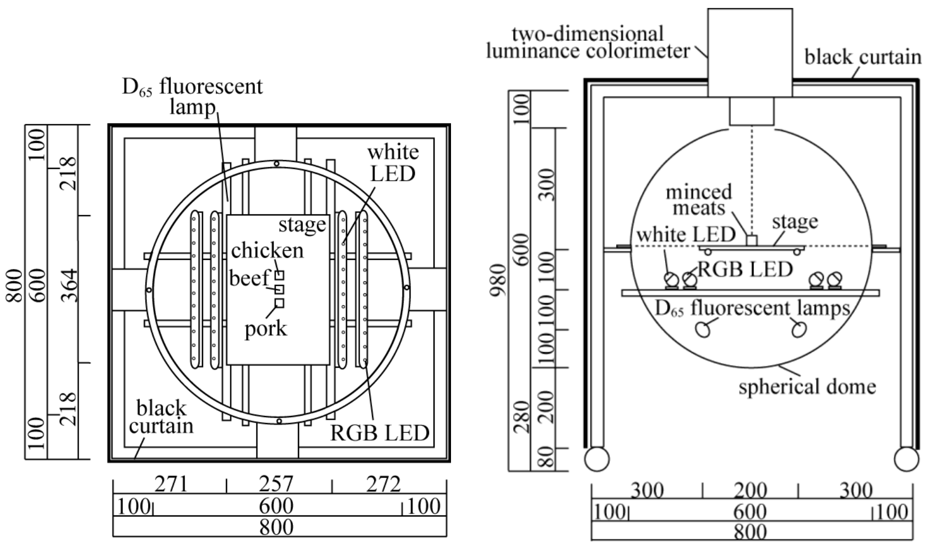
2. METHOD

2.1 Measured objects

We prepared three kinds of minced meat: beef, chicken and pork. We shaped these minced meats into a cube, 2 cm on a side. Each cube of the minced meat was baked with an electric oven [NE-M156-W, Panasonic] at the temperature of 200 degrees Celsius. We set 22 stages of the cooking time; in 30 seconds intervals till 5 minutes, 1 minute intervals from 5 till 10 minutes, 2 minutes intervals from 10 till 20 minutes and 5 minutes intervals from 20 till 30 minutes.

2.2 Apparatus

We made a spherical dome for measuring the chromaticity values of an object with no shadow. Figure 1 shows the apparatus for color measurement of the minced meat. The inner wall of the dome was painted white, L^*=93.59, a^*=-0.38 and b^*=2.40, measured with a spectrophotometer [CM-700d, KONICA-MINOLTA] in the setting of a D65 light source. The dome is equipped with two RGB LED lamps [iColor Cove MX Powercore, Philips Color Kinetics] and two white LED lamps [iW CoveMX Powercore, Philips Color Kinetics] with three kinds of LED chips with different correlated color temperature. It also had two fluorescent lamps of a standard illuminant D65 [FL20S D-EDL-D65, TOSHIBA]. These lamps were placed below the stage. The cubes of minced meat were put on the stage in the middle of the spherical dome. The top surface of the minced meat cube was measured by using a two-dimensional luminance colorimeter [UA-1000A, TOPCON Co. Ltd.] from the above.



a) Plan *b) Section*

Figure 1: Apparatus for color measurement

2.3 Lighting conditions

We set eight kinds of lighting conditions: seven kinds of LED lighting conditions and the standard illuminant D65. Table 1 shows the lighting conditions. Figure 2 illustrates spectral power distributions of the eight lighting conditions.

Table 1. Lighting conditions

Lighting conditions	CCT (K)	Ra	u'	v'	duv
LED-1	2894	82	0.255	0.523	0.00
LED-2	4134	59	0.229	0.486	-0.01
LED-3	4137	91	0.221	0.502	0.00
LED-4	4164	82	0.221	0.502	0.00
LED-5	6272	74	0.196	0.474	0.01
LED-6	6286	94	0.201	0.468	0.00
LED-7	6296	83	0.201	0.468	0.00
D65	5760	99	0.200	0.480	0.01

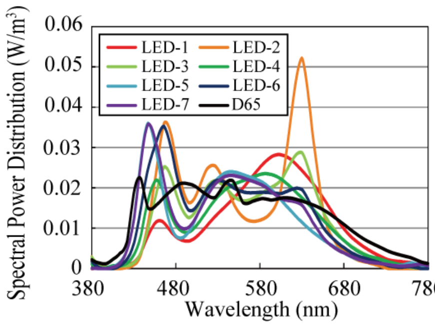


Figure 2: The SPDs of the eight lighting conditions.

3. RESULTS AND DISCUSSION

Figure 3 shows the mean values of chromaticity (L^*,u^* and v^*) of the top surface of minced beef at 23 cooking stages under each lighting condition. It was shown that the L^*, u^* and v^* values gradually decreased with increasing cooking time under all lighting conditions. The color appearance of the minced beef was different by the lighting condition as shown in Figure 4. The beef looked reddish under the lighting condition of LED-1 though the beef had been sufficiently cooked. On the other hand, under the lighting condition of LED-5, the beef looked dusty-red at each cooking stage. Therefore, the color appearance of the beef during cooking depends on the lighting condition.

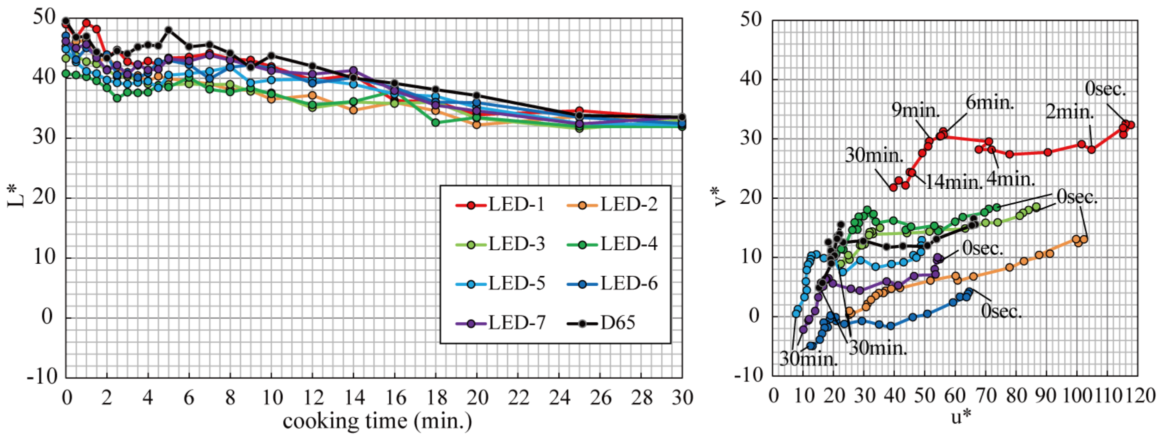


Figure 3 : The values of the average chromaticity of minced beef

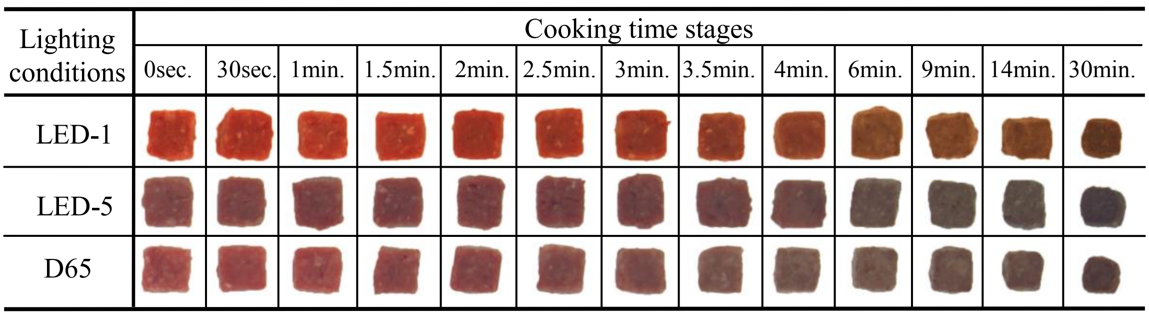


Figure 4 : The digital image of minced beef under the conditions of LED-1, LED-5 and D65

Table 2 shows the color differences (ΔE^*_{uv}) of the measured chromaticity under all lighting conditions. The color differences were obtained in the calculation as below (Equation 1).

$\Delta E^*_{uv} = | L^*u^*v^*_{\text{LED-}i} - L^*u^*v^*_{D65} |$ Equation 1

$L^*u^*v^*_{\text{LED-}i}$: chromaticity value under i-th LED lighting condition

$L^*u^*v^*_{D65}$: chromaticity value under the standard illuminant D65

It was shown that the color difference values greatly differed among the LED lighting conditions. In particular, the color difference was large at the raw stage (0 second).

Table 2. The color difference (ΔE^*_{uv}) of the measured chromaticity under LED lighting conditions and those under D65 lighting condition

Lighting conditions	LED-1	LED-2	LED-3	LED-4	LED-5	LED-6	LED-7
0 second	54.06	34.95	21.58	11.78	18.04	12.65	14.32
8 minutes	39.26	20.65	15.16	11.57	9.15	13.97	9.17
14 minutes	37.15	15.44	11.04	9.39	8.15	11.20	5.60
20 minutes	27.85	11.53	7.05	5.44	10.68	13.46	12.49
30 minutes	28.32	10.03	9.65	5.93	10.22	11.39	7.55

4. CONCLUSIONS

We measured the color change of minced meat during cooking under various LED lighting conditions and compared their color appearance with those under the standard D65 lighting. It was clarified that the chromaticity values gradually decreased with increasing cooking time under all lighting conditions and that the color appearance of beef during cooking depends on lighting conditions.

ACKNOWLEDGEMENTS

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Color temperature and Illuminance of Main Streets with Day and Night Illumination in the Center of Osaka, Japan

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ABSTRACT

There are many topics on the beauty of the scenery concerning color planning. The author considers it is very important to designate lighting planning[1] for urban color planning. This paper includes a survey concerning lighting atmospheres of the urban districts and questionnaire survey in Osaka City. As a result of the survey, the mean value of illuminance was considerably similar between each street at night-time but not at daytime, on the other hand, that of chromaticities did not show significant difference between night-time and daytime. The questionnaire survey indicated the street lighting was effective in making people feel bright and safe.

1. INTRODUCTION

Nowadays with an aim of creating comfortable, delightful and interesting urban environment, various factors in the actual environment[2),3)] are used to promote attractive plans. In color planning, not only the surface color but also lighting planning are very important. The author obtained data from two main sources: 1) measurement data on daylight and night illumination, and 2) questionnaire survey obtained from young people in Osaka. Firstly two areas were selected as survey sites, one northern and the other southern areas in the center of Osaka City. Five streets were picked up in each area. In every measuring point, the horizontal and vertical Illuminance, as well as the horizontal and vertical color temperature were measured both in daylight and night illumination for three days. Questionnaire survey was carried out to find any difference in psychological perceptions relating to lighting on these streets.

2. METHOD

The author investigated the illumination of Osaka city by using measurement data and the visual perception of those illuminations. This research includes data collected from two main sources: 1) measurement data in daylight and night illumination, and 2) questionnaire survey obtained from young people.

2.1 Measurement Data

10 survey locations were selected for this study as shown in Table 1. These streets were located in the center of Osaka city, Umeda, a northern area, and Namba, a southern area. Five streets, grouped into three district features, the shopping arcade, the downtown and the main street, were picked up from each area. For each street, we monitored 16 measurement points with 20 meter interval covering 300 meter length, total 160 measuring points. Data was recorded 6 times during the collection period between July to

November 2009, at daytime and at night-time for three days. We measured the values of horizontal and the vertical illuminance and the horizontal and vertical chrommaticities of daylight and night illumination. Data were recorded in daytime (10:00 to 16:00) and at night-time (18:00 to 22:00). Thus each points had total of 24 measurement values. MINOLTA-CL-200 was used to identify the illuminance and the relative color temperature. At the same time the author also evaluated the visual perceptions of the lighting circumstances at these monitoring points. There were 11 items that the author considered; brightness, confusion, beauty, warmth, exoticism, nature, calm, plane, ordinary, harmony

Place	Shopping Acade		Downtown	Avenue	
Umeda	Higashi Dori	Ohatsutennjin Dori	Cyayamachi	North Nishiumeda	South Nishiumeda
Namba	Shinsaibashi	Sennichimae	Doutonbori	North Midou	South Midou

and pleasant for psychological evaluations.

Table 1 Survey Locations

2.2 Questionnaire Survey

Questionnaire survey was carried out to find any difference in psychological perceptions relating to lighting on these streets in Osaka city November 2009 by e-mail. 100 subjects were asked to give their visual perception of the street lightings. They were all students in their twenties and had visited those streets both at daytime and night-time.

3. Results and Discussion

3. 1 **Shopping Arcade**

These streets have an arcade, shops facing each other and the road 7m in width.

1) Illuminance

The horizontal illuminance data of daytime at Higashidori is shown in Fig.1. The mean value of the horizontal illuminance at each point ranges from 800lx to 3,700lx. The higher illuminance 20,000lx is observed at the 160m point on the street as there is an intersection on that point. The vertical illuminance of this street ranges from 300lx to 2,000lx as shown in Fig. 3. To compare with measurement data of other street, the mean value of three days are used to evaluate the illumination of each street. At night, the horizontal illuminance ranges from 250lx to 900lx and the verticl illuminance from 40lx to160lx,

2) Relative Color Temperature

Figure 2 and 3 shows the results of the relative color temperature versus the horizontal illuminance and the vertical illuminance, respectively. The relative color temperature ranges from 4,700K to 5,800K for the horizontal illuminance and from 4,600K to 5,300K for the vertical illuminance. In the daytime, the color of the light source is blue or whitish blue. These illuminance data shows some difference, but little difference for the visual perception according to the paper described by the authors, within the measured environment..At night, the relative color temperature ranges from 4,400K to 4,900K for the horizontal illuminance and from 3,600K to 4,800K for the vertical illuminance. The colors of the light source is reddish .

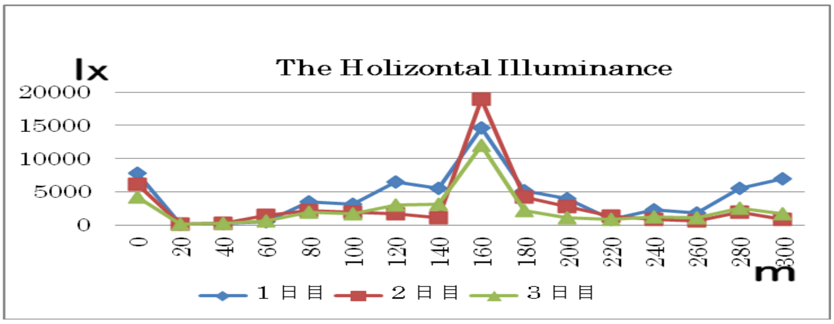

Fig.1 The horizontal illuminance from daylight at Higashidori shopping arcade

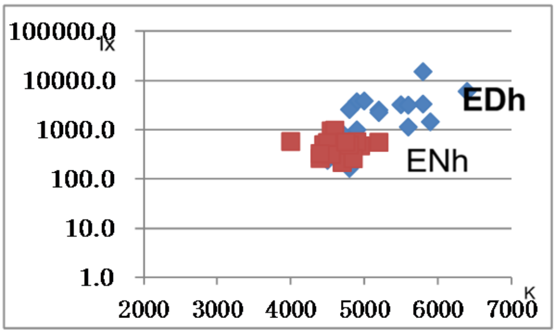

Fig.2 The relationship between horizontal Illuminance and relative color temperature at day and night (Higashidori)

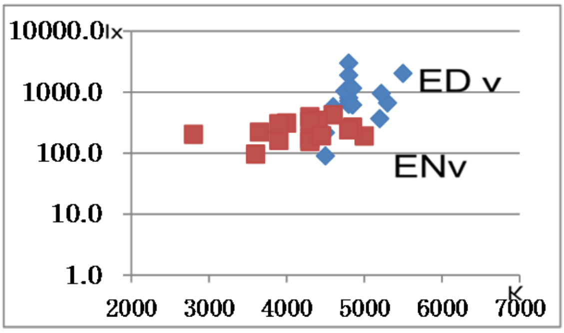

Fig3 The relationship between vertical illuminance and relative color temperature at day and night(Higashidori)

3.2the downtown

These streets have roads 7m wide in north area and 14m wide in south area, respectively and open to sky. Shops are facing each other and are around 15m in height.

1) Illuminance

In daytime at Cyayamachi Street, the horizontal illuminance ranges from 13,400lx to 22,000lx and the vertical illuminance from 3,800lx to 7,300lx. At night, the horizontal illuminance ranges from 20lx to 80lx and vertical illuminance from 10lx to 50lx. These values are quite low as compared with those of shopping arcade.

2) Relative Color Temperature

The relative color temperature ranges from 5,900K to 6,100K for the horizontal illuminance and from 5,700K to 6,000K for the vertical illuminance in the daytime. The color of these light sources is whitish blue. At night, the relative color temperature ranges from 2,500K to 3,300K for the horizontal illuminance and from 2,600K to 3,200K for the vertical illuminance. The colors of the light sources are reddish and orange. In daytime, these data are similar to those observed in shopping arcades, but different at night-time.

3.3 Main Street

The roads of these streets are 15m wide in north area and 45m wide in south area, and open to sky. The buildings are around 30m in height and most of shops are located on the first or second floor.

1) **Illuminance**

In daytime at North Street of Nishiumeda, the horizontal illuminance ranges from 100lx to 5,700lx and the vertical illuminance from 500lx to 2200lx. At night, the horizontal illuminance ranges from 8ix to 44lx and the vertical illuminance from 5lx to 25lx, These night data at night are quite low as compare with those of shopping arcade at night.

2) Relative Color Temperature

The relative color temperature ranges from 5,800K to 6,300K for the horizontal illuminance and from 5,500K to 5,800K for the vertical illuminance during the daytime and the colors of these light sources is whitish blue. At night, the relative color temperature ranges from 2,400K to 3,900K for the horizontal illuminance and from 2,600K to 3,200K for the vertical illuminance. The colors of the light sources are reddish and orange. These data are similar to those of downtowns at daytime and night- time.

3.4 Questionnaire Survey

Questionnaire surveys were carried out to find any difference from visual perceptions relating to lighting on these streets, the author got the street lighting was effective in making people feel bright and safe, but not clear to find delightful and interesting lightings.

4. CONCLUSIONS

The illuminance of daylight at the shopping arcade area is about 1/2 as compared with two other area, but it is more than 5 times higher than those of two other areas at night. The color of the light source from daylight at the shopping arcade is whitish and that of other areas is whitish blue, .and from nightlight the former is reddish, the latter are reddish and orange, Although the data obtained in this research may not be enough to indicate clear conclusion, however the author can recommended how to improve illumination on the street and how to change them to achieve a better visual impact and perception.

ACKNOWLEDGEMENTS

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Changes of Color Names and Coloring Materials in Japan

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ABSTRACT

It is necessary to organize the historical changes in the Japanese colors. The color of Japan had several changes historically, and at least three changes exist. The first change is introduction of the color notion in 6th century. Around the 6th century, by trade with the China (such as the Tang dynasty) and the countries of Korean Peninsula, "Saishiki(coloring)", the manufacture of pigments, the notion of color like “Goshiki(5 colors)” were conveyed to Japan. After that, various color names appeared in Japan. The second change took place in Heian period. After 10th century, enhancement of the Japanese culture led to the development of literature, dresses and their ornaments at salon culture in the Court. In this time, new color "Kasane" was created in dresses. It describes the colors which layered or put in order and likened the color to the plants or the natural phenomenon. From this time, some colors even if they were made of another color materials had been called as the same color names.The third change is change to the new coloring materials. In Europe, synthetic dyes was developed in the 19th century, and the "painting" changed. In Japan, at the Meiji Restoration, "Westernization" was called for. Then the inflow of techniques and materials of oil painting and watercolor painting took place. Simultaneously, the color theories developed in Europe were also brought to Japan. The color mixing and the three primary colors were studied immediately in Japan. After passing through such changes, some “new” colors were come to be called by color names of “old” materials. Since the situation of such multistory changes are not researched, this research organize the historical change of “the color of Japan”, and it clarifies the multi-layered color names of Japan.

1. INTRODUCTION

It is difficult to define "The color of Japan", because has a various color names and color materials. Therefore, it is necessary to organize the historical changes in the Japanese colors. If you look at the historical change of color names, materials and theories, you would recognize three major changes. In order to organize complex color names and materials about "The color of Japan", I would like to arrange the historical changes of colors in Japan.

2. THE FIRST CHANGE

The first change is introduction of the color notion in 6th century. Before that, a few natural dyes and mineral pigments were already used in Japan. Because of the lack of the historical materials, the actual circumstance of formation and classification about color names are not clear. There were also few coloring materials used as pigments. Around the 6th century, by trade with the China (such as the Tang dynasty) and the countries of Korean Peninsula, "Saishiki(coloring)", the manufacture of pigments, the notion of color like

“Goshiki(5 colors)” were conveyed to Japan. After that, various color names appeared in Japan. "Goshiki" is five colors about "red", "blue", "black", "white", "yellow". Goshiki is a concept that was associated with the five elements (Wu Xing), and is also a systematic color classification (Figure 1). Wood represents green which include blue. Fire represents red. Earth represents yellow. Metal represents white. And Water represents black. In China, the five colors is important as a formal color. Before the five colors introduced into Japan, red color of Aka-Tsuchi(赤土 minerals of red clay), and blue green color of Yama-Ai(山藍 plants of Mercurialis leiocarpa) were familiar colors in Japan. The first Japanese colors were considered to be those colors.

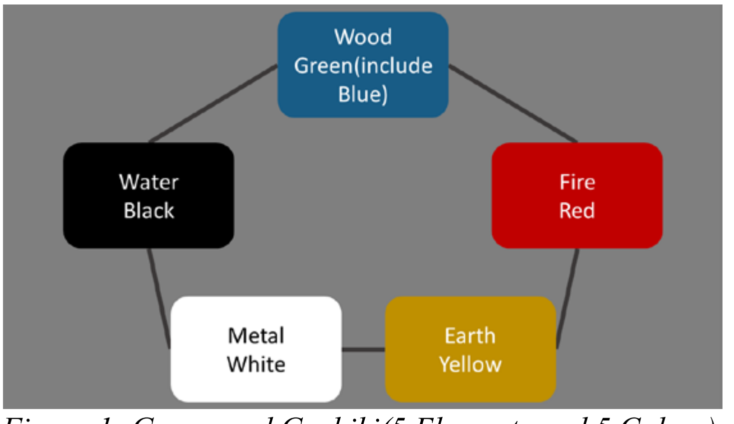

Figure 1: Gogyo and Goshiki(5 Elements and 5 Colors).

Berlin and Kay pointed out establishment order of color terms. It is white and black is first established, and then the red, yellow, and green is followed[1]. Satake Akihiro consider the "Aka(red)", "Kuro(black)", "Shiro(white)", "Ao(Blue)" has been established from the representation on the initial literature of Japan. He thought that Aka comes from Akarui(bright), Kuro comes from Kurai(dark) , white comes from is Shiroi(clearly), Ao comes from Aoi(vague) (Figure 2). However after introducing of the five colors to Japan, due to strong influence by the culture of Chinese characters, the Japanese idea of the color comes the five colors as it base.

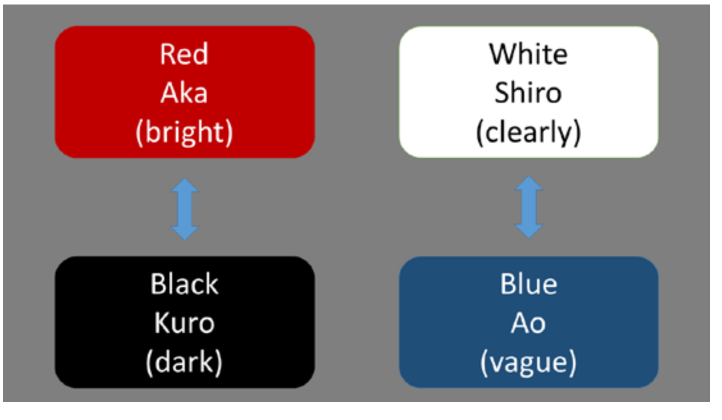

Figure 2: Appearance of Japanese Color Names.

[1] Brent Berlin, Paul Kay 1969(1999).*Basic Color Terms: Their Universality and Evolution.*University of Chicago press 1999 14-25.

3. THE SECOND CHANGE

The second change took place in Heian period. The abolition of official envoys to Tang dynasty, and the imitation of the Chinese Tang culture were over at the end of 9th century.The pigments of pictures and sculptures like "Syusa(朱砂)", "Konjyo(金青)" and etc were scribed in manuscripts "Shosoin-Monjyo" of the 8th century. At that era, various pigments were obviously classified and were used.Color name of material derived have been written many in "Shoku-Nihongi" and "Shosoin-Monjyo" of the 8th century.By construction of Todai-ji Temple has been made as a national business, Buddhist art was developed. And production of paintings and sculptures has been actively produced. The many kinds of coloring materials inscribed on the historical materials indicates that the understanding and arrangement of the color materials and color names were made. However at 894 AD, Japanese missions to Tang dynasty were abolished, and the era of imitation of the China's Tang culture was finished. After 10th century, enhancement of the Japanese culture led to the development of literature, dresses and their ornaments at salon culture in the Court. In this time, new color "Kasane" was created in dresses (Figure 3). It describes the colors which layered or put in order and likened the color to the plants or the natural phenomenon(Figure 4). While new many colors appeared as Kasane, the discovery and development of new color materials weren't made. However, increasing of rich color expression in conjunction with development of the literature had represented the extension and understanding of Japanese color cultural development.

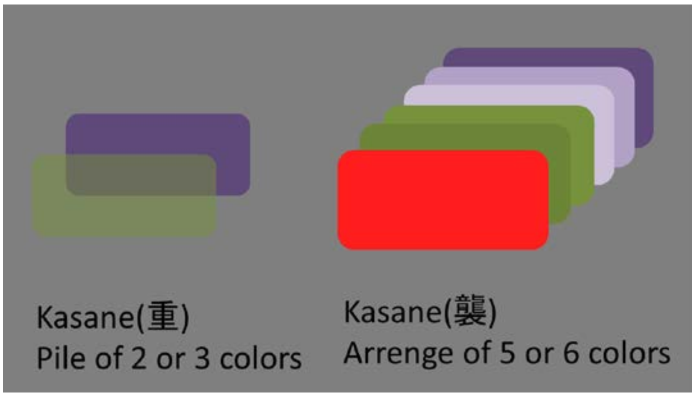

Figure 3: Images of Kasane colors.

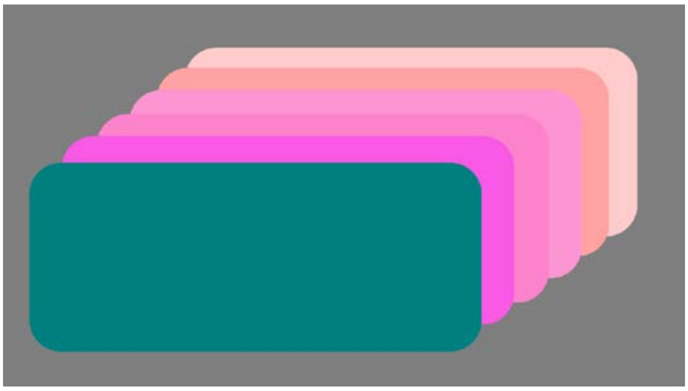

Figure 4:Mood of Kobai（紅梅 Japanese apricot, Prunus mume）color, from "Masasuke Syozoku-syo" Historical Material of Heian period.

Before introducing of 5 colors to Japan, the color name had been represented by the materials. However, the skill and knowledge of the dye plant cultivation which continued from Asuka and Nara period had begun to be lost gradually. From around this time, some colors even if they were made of another color materials had been called as the same old color names. Because of that, the Japanese color names have such overlapping complexity. And, the establishment of this multi-layered color names was not limited to the Heian period, and was occured gradually.

4. THE THIRD CHANGE

The third change is change to the new coloring materials. In Europe, synthetic dyes were developed in the 19th century, and the "painting" had changed. In Japan, through the Meiji Restoration, "Westernization" was called for. In either politics, economy, industry or culture, Japanese people were willing to learn the knowledge and technology of the West. This circumstance was same in the arts. Then the inflow of techniques and materials of oil painting and watercolor painting took place. Furthermore it brought about change of the coloring materials of Japanese fine arts and traditional handicrafts. In the Meiji era, imported European coloring materials had to be called in more than one color name which called the color names from European pronunciation and Japanese color names. In addition, assigned Japanese color names to imported materials were meant sometimes another color material. Simultaneously, the color theories developed in Europe were also brought to Japan. The color mixing and the three primary colors were introduced and studied as soon also in Japan. Theories of George Field (1777–1854), David Brewster (1781–1868), Hermann von Helmholtz (1821–1894), James Clerk Maxwell (1831–1879) et al were introduced. As the expansion of color science in Japan, there was "Shikisai-Gaku (Color Science)" by Michiya Yano to introduce a lot of knowledge about color science of Europe, and there was remarkable teaching at the field of art education by Shirahama Akira. In addition, "Shikisai Shin-Ron" of Beisaku Taguchi was the first Japanese color theory. "Beni(紅 red of safflower)","Yellow (Yellow)","Ai (藍 Blue of Indigo)" had written as the three primary colors in that book. It was remarkable that “Beni(red)" and "Ai(blue) had been written as color classification.

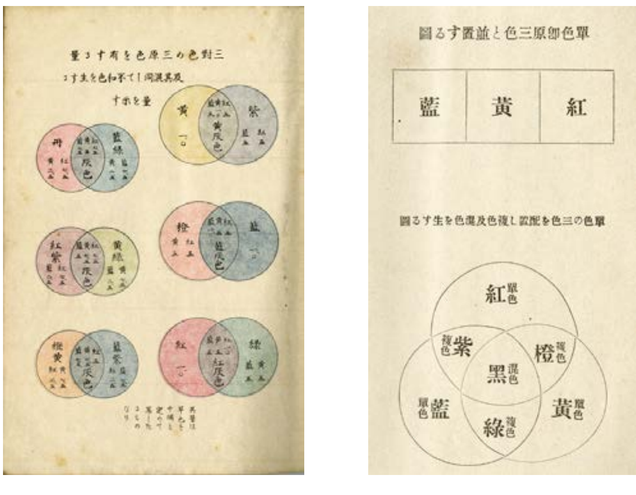

Figure 5: Beisaku Taguchi,”Shikisai-Shinron”

5. CONCLUSIONS

Thus, after three major changes of colors, Japanese color has been established. Currently, some "new" colors may be referred as the color name of "old" materials. For example, the color with a name such as "Roku-Syo(緑青 Malachite)" and "Gun-Jyo(群青 Azurite)" originally refers to the color material by the natural pigment from around the 8th century. "Dosabi(Patina or Verdigris)" and one of "Shin-Iwa-Enogu(新岩絵具. Colored glass powder which are made from spraying the synthetic dyes) " are called as "Roku-Syo" today.

In the history of Japanese color culture, there have not been studied about major changes as described above. In this paper, I summarized the major changes of Japanese color. Because of such changes of color, there appeared the multi-layered color names. In addition, it was also pointed out emerging about the color of the same color names while different color materials. Then, I pointed out reason for further complicatedness of Japanese color that caused by flowing of European culture to Modern Japan. In order to explore the peculiarities of color materials and color names in Japan, I would challenge deeper investigation and research about the color names and color materials of a turning point of changes of colors in the future.

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"DIFFERENCES IN THE DRAWINGS AND THE COLOR OF THE VIOLENCE IN CHILDREN FROM THREE DIFFERENT CULTURES."

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Dra. Mabel López
Universidad de Buenos Aires, GAC

ABSTRACT

The violence is a social phenomenon, that, although it has been present in all the history of the human beings is not inherent to all the individuals, and it is known that the social environment contributes to its development.

The fear produced by the violence is intensified in the child population and that is why we considered important to know what the children think about the violence, how they perceive it and, if it is possible, how they feel it. We seek these answers through two media that are familiar and not dangerous for them: color and drawing. Both are privileged elements for the research of violence through a visual image, the color, informs about the emotional states through the analysis of the meanings and formation of chromatic patterns found in the drawings (Ortiz, 2011). That is why we can say that humans live in a symbolic world of color.

The research presented here in is oriented toward the investigation and the study of the way in which the children draw and color violent scenes, since their drawings will let us know their personal experiences.

Our objectives were:

-To know the influence of the native and urban cultures in the representation and use of colors of violence.

- To know the colors and the meanings that children from ten to twelve years use in their graphic representations of violence and not violence.

We used a qualitative method using rhetorical and semiotic analysis of the images for their interpretation**.**

Key words: Color; drawing; children; culture.

INTRODUCTION

Mexico is one of the countries where the violence has exceeded the criminal limits and it has become a part of the daily environment, in which the children are innocent participants since they live the violence, directly or indirectly in their familiar, academic, and social environments through the media and electronic games.

That is why, to study how children perceive their socio-cultural environment, we use drawings and its components. One of these components is color; through it, we can get information about the assessment of intelligence, mood, psycho-physical development, nature of conflicts and development potential (García González, 2000).

However, although there are common elements in their drawings, regardless their ethnicities, we can say that culture gives different nuances to the drawings according to their natural and social environment (Kellogg Rhoda, 2007). Regarding color, we must remember that it is a communicating element that must be decoded by following the rules of the culture in which it develops, as it is based on meanings of signs and symbols (Ortiz 2010).

Moreover, color is related to emotions (Ortiz, 2011), and they reinforce another kind of expressions like drawing, i.e. they make rhetoric from the graphic expression (López, 2014).

OBJECTIVE

To know, through pictorial manifestations and the use of color, how the culture of their place of origin and development influence the children in their perception of violence.

METHOD

Two traditional methods were used for the analysis of the graphic expressions: the quantitative and qualitative, because there are no general or specific parameters for their study.

The drawings obtained in three different samples will be presented: Nayarit (Lindavista), Guerrero (Chilpancingo de los Bravos, Apaxtla, San Marcos) and Mexico City, the latter in order to point to local differences.

Population and sample

The sample application in Nayarit and Guerrero was discretionary; while in Mexico City sample it was probabilistic. These three samples were different according to the possibilities of the interviewers; the smallest one was from the state of Guerrero, where only 15 children were interviewed. The other two samples were randomly matched with this number, so a total of 45 drawings will be analyzed.

RESULTS

General data

The population was composed by 45 respondents of elementary school students from 5^{th} and 6^{th} grade. Their age range from 10 to 12 years old with a mean value of 11.00 and a standard deviation of 0.7385; 20 (44.4%) were girls and 25 (55.6%) were boys.

Violence

To find out if the respondents were subjected to violence, they answer several questions ranging from family violence to violence perceived in videogames. The results were the following:

- The boys suffer more violent acts (56%) compared to the girls (40%).

- The girls of Guerrero suffer less violence (29%) compared to boys (50%); this situation was opposite in the sample from Mexico City.
- Most of the violence was physical and it was received from a family member, especially in the case of girls (50%). In contrast, the sources of the violence for boys were their friends and schoolfellows (20%), one or both parents (20%) and another family member (20%).
- The places where the violence took place vary according to their gender; for girls it was their own homes and for males the school and the streets.

In the school environment we observed that:

- In almost all the cases, the violence came from the students (42.9% for girls and 50% for boys).
- The sample from Mexico City had the highest percentage of affirmative answers, both in girls (58.3%) and boys (63.6%).

It was also inquired whether the children had suffered any violent situation in the street:

- 80% of the girls and 60% of the boys gave a positive answer.
- The main act of violence suffered by them was physical aggressions.
- 58.8% of the girls had suffered physical aggressions compared to 40% of the boys.

The results of the analysis by entities were:

- Nayarit:
    - 42.9% of the girls suffer physical aggressions.
    - 60% of the boys did not specify what kind of abuse they suffer.
- Guerrero
    - The boys did not explain the situation.
    - The girls preferred not to answer.
- Mexico City
    - The most recurrent act of violence for both, girls (66.7%) and boys (80%), was physical aggressions.

Drawings

By analyzing the drawings of the three different populations, similarities and differences were found.

- The number of characters in the drawings range from 1 to 26
- The statistical mode was 2
- The mean value was 3.68 human figures per drawing.

Some of the similarities found were:

- Most human figures depicted were figurative with different complementary elements such as clothes, decorations and, in some of them, movement.
- Regarding size, in most of them, the aggressors were bigger than the victims.
- The aggressors depicted were mainly men, so it is not surprising that the aggressions were committed mainly against women or children.

The most relevant differences found were:

Nayarit

- For the children in this sample, the violence is an attack on the property of others and, especially, against nature. The main causes are the roads; in them, they draw cars without windows, cars running over pedestrians, or cars transporting people with guns. In one of the drawings, one truck carrying bread is assaulted; this drawing can be an indicator whether of much poverty and hunger or of a very high criminal activity.
- Most of the aggressors cannot be identified because they faces are hidden by masks or bandanas; some of them have empty faces or just have eyes, but their gender can be recognized through other features of the body. Most of them are men.
- In the drawings in which the aggressors have faces, they show happiness or anger when they committed an act of violence. Some of the victims are smiling when they suffer the act of violence.
- The range of weapons used in the acts of violence is not as wide. They used mainly guns, rocks, and knives, drugs and physical strength.
- The acts of violence include blood and dead people.

Guerrero

- The violence against nature did not appear. The aggressions were between two persons, mainly carrying weapons.
- The acts of violence were located in different scenarios such as the house, the school or any place that promotes social relations.
- In this sample, a plurality of identifiable forms of violence (physical, verbal, psychological, gender) was found, mainly because the children drew different scenarios in one sheet.
- The representation of violence lies mainly in men and their faces did not show expressions.
- The blood is present as a characteristic element of physical violence.
- The faces of the victims did not show happiness unlike the sample from Nayarit.

Mexico City

- In this sample, the natural landscapes have completely disappeared and although there are scenes in the streets, most of the aggressions were located in the school environment.

- Fantastic aggressors such as monsters appear, so we can infer that the factor of the media influence is present. We can see this specially in one drawing where the aggressor can also be considered as a victim.
- Regarding the weapons, the guns are preferred as in the other samples.

Colors

As in the analysis of the drawings, similarities and differences between the uses of colors were found.

Some the similarities found in the three samples are:

- Most of the analyzed drawings do not have a background color so, the color of the paper (white) is the predominant one and it is where the drawing is created.
- Regarding the use of color:
    - most of the girls used soft colors while boys used strong shades;
    - the boys used fewer colors than girls;
    - Most participants did not illuminate the faces, so they were white, with the exception of the sample from Mexico City.

The results of the analysis by entities were:

Nayarit

- The most common colors were green, blue and brown. They are used mainly in natural landscapes such as mountains, rivers, trees and flowers.
- Most of the animals in the representations of violence lacked color.
- The colors used in the aggressors clothes, and in some cases in the victims, are darker (regularly black and brown).
- Most of the cars were blue; in contrast with the blue of the sky, they were drawn with darker tones. It is important to mention that they belong to the aggressors.
- The houses depicted showed a wider variety of colors compared to the other two samples, but the preferred color was blue, followed by black, white and yellow.
- Regarding the color of the aggressors, girls perceived it as black and brown.
- The color black was mainly used to hide the identity of the aggressor.
- Unlike girls, boys did not relate directly the color black with the aggressor but with the victim (usually in their pants) and they illuminate the aggressors with the colors red and dark blue.
- The color red represented blood.
- The victims appeared naked to their aggressors.
- The weapons were mainly guns and the most frequent colors in them were white and black.
- All the knives were totally white.
- We also found the use of rocks as weapons, they were mostly brown. We can infer that if they do not have access to “advanced” weapons, they can use things in their immediate context to exert power over others. In one drawing we can see a somber scene abut funerals and cemeteries, where the dark colors are related to emotions of sadness but we can also see a social coexistence of people unlike the scenes of violence that are much more individualized.

Guerrero

It is important to note that this is the poorest group and that when they received the box of colors and they were informed that it was a gift for them, they were so happy that they kept it as something very precious without using it.

- The number of colors used in this sample was lower compared to the other two samples. We found a trend to draw only with the pencil without worrying about the use of color. This trend was observed more in boys than in girls. For this reason, the discussion of the use of color in this group is limited.
- The girls used a greater number of different objects for the characters and a greater number of colors. The trend is similar to the one from Nayarit; they used the colors brown, green and blue that are a true reflection of the things they saw daily in the natural world.
- We observed more frequently the figure of the sun (in the sample from Nayarit we only found one); it generally was yellow or red.
- The dark colors, like the black and brown, are representative of the aggressors for the boys, and for the girls it was the color green; the same color that represented mountains and trees before now represents violence.
- Regarding the victims, we found that both genders draw them with the colors white and red in their clothes.
- The clothes of the feminine characters usually corresponds with the feminine stereotype, thus the color pink was used in them.
- The color red, used for the presence of blood, was found in the aggressors and not in the injured or dead people.
- The tendency to draw colorless faces is still present, but we can observe colors such as pink or yellow in the faces, especially in the victims.
- In the case of the viewers of violence (new characters drawn), we found that they try to pass unnoticed because they are drawn only with a pencil stroke; in just one drawing the viewer has colors but, in this case, there is a house interposed between him and the act of violence.
- The most present weapons were, again, guns; they were drawn only with the pencil, so its color was grey; they were followed by white ties or belts for both genders.

Mexico City

- In this sample, the natural landscapes have completely disappeared.
- The factor of the media influence is present, especially in one drawing where the aggressor, which can also be seen as a victim, is a multicolor Godzilla type character; so, in this visual context we found a tendency to caricaturize the violence. The only color used that was used also in the other samples is the green and, again, it is used in the landscapes.
- The color blue is used more often in the sky than in the water, indiscriminately for both genders.
- The color of the aggressor (or the violence) is the white, this finding contradicts many of the researches which determine that the colors black and red represent this phenomenon; it is true that the color red is still one of the mostly found in all the samples in this research, but the color black is more related to the victims (except in girls where it is related to the aggressors) and the color white (in boys) is most related to the clothes of the aggressors.
- The color of the faces in this sample is more varied, the flesh color is more used and also the brown to represent brown skins, that in most drawings are from the aggressors, especially for the girls in both, Mexico City and Guerrero samples.

- Regarding the weapons, the guns, the preferred weapons along all the research, are represented more frequently with the colors white and black.

Comparatives

The results of the comparison of the three samples are the following:
BACKGROUND:

- The color of the space or the place represented mostly lacked color. In the few cases where the background has color we observe that the most used colors were brown and transparent and in second place green.
- Regarding the use of color by entity, the following chart indicates that the urban sample use the greater number of colors.

Color of the space									
	NAYARIT		**GUERRERO**		**MEXICO CITY**				
Garden					*transparent*	*orange/*	*blue*	*transparent/*	*green*
Street			*transparent*		*transparent/*	*blue*			
Countryside	*transparent*	*green*	*transparent*	*green*	*green/*	*blue*			
House	*transparent*								
Driveway	*transparent*								
Town	*transparent*	*green*							
No determined	*transparent*		*transparent*		*transparent*				

Characters:

- We found a maximum of 10 characters.
- By analyzing the color of the characters in the drawings of violence we found that:
  - Most of the girls did not illuminate the faces
  - The second more used color were flesh color.
- In the Nayarit sample we found that the aggressor used Balaclava helmets, so their faces were black.
- The faces of most of the characters that were not covered were colorless.

Color of the face			
Nayarit	*transparent*		
	flesh		
	black		
	brown		
Guerrero	*transparent*		
	yellow		
	blue		
Mexico City	*flesh*		
	pink		

	orange
	transparent
Total	*transparent*
	flesh
	pink
	brown

- Regarding the color of the accessories, we found that the most used was the black; again, it was the urban sample the one that used more colors.

Colors in accessories										
	NAYARIT					**GUERRERO**	**MEXICO CITY**			
Buttons							*red*	*green*		
Horns							*red*	*green*		
Hat/cap							*black*			
Hair accessories							*pink*	*orange*	*purple*	*black*
Belt	*green*	*black*	*yellow*	*blue*	*brown*	*transparent*				
Balaclava helmets	*green*	*black*				*black*				
Bracelets			*yellow*							

Weapons

The results regarding weapons were the following:

Colors in weapons											
	NAYARIT				**GUERRERO**			**MEXICO CITY**			
Guns	*grey/ pencil*	*transparent*	*purple*	*black*				*black*	*transparent*	*blood*	*transparent*
Machine guns	*transparent*							*black*			
Panque								*brown*			
Ball								*green*	*transparent /*	*black*	
Rifle with bayonet					*grey/ pencil*			*transparent*			
Hands/ fists	*transparent*	*grey/ pencil*			*brown*	*grey/ pencil*		*pink*	*orange*		
Knives	*transparent*	*grey/ pencil*			*transparent*						
Brick/ rocks	*brown*	*transparent*			*transparent*	*brown*	*grey/ pencil*				
Chainsaw	*transparent*	*grey/ pencil*									

Belt		*black*	
Stick		*transparent*	
Other		*transparent*	

The number of houses in the drawings was also recorded. The results were the following:

- We obtain a statistic mode of 1 and a mean value of 2.8 houses. Most of them were not lit. In most of the cases we found the use of the colors brown, brown and black, and blue.
- In Mexico City sample we found one case of a house painted with color blue.
- In Nayarit and Guerrero samples there was a trend of not using colors in most of the cases.

Colors in houses		
Nayarit	*Transparent*	
	brown/	*Black*
	blue/	*Purple*
	red/	*Orange*
	Green	
	Blue	
	Brown	
Mexico City	*Blue*	
Guerrero	*Transparent*	
	Brown	
	red/	*Yellow*

Curiously we only found land transports in the sample from Nayarit, because for them, the driveways and vehicles are signs of violence.

Colors in transports					
	NAYARIT				**MEXICO CITY**
Airplane					*Transparent*
Car	*pink*	*purple*	*black*	*orange*	
Van	*blue*				
Truck	*Transparent*				

Regarding another elements present in the drawings where color was used, we found the following:

- In most cases, they were colorless; however, we found the use of the colors brown and green followed by the filling with the pencil and the black.
- In Nayarit, the most used color in these objects was blue, followed by brown and green, related to nature.
- In Guerrero it was more common to let them colorless, but in second place was the use of the black, followed by red.
- In the sample from Mexico City, there was only one case of using of the color red.

Colors in another elements						
	NAYARIT					
Flowers	*green*	*red*	*orange*	*transparent*		
Lake	*blue*	*pencil*				
River	*blue*	*brown*	*transparent*	*green*	*green/ white*	*/red*
Rock	*brown*	*pencil*	*green*	*blue*		
Smoke	*pencil*	*brown*	*transparent*	*blue*	*black*	*orange*
Bag/briefcase with money	*green*					
Road/ driveway	*blue*	*brown*	*transparent*			
Cigar	*pencil*	*brown*	*transparent*	*black*	*blue*	*orange*
Balaclava helmet/mask	*black*					
Bushes	*green*	*orange*	*transparent*			
Flag	*green*	*blue*	*green/ white*	*red*		
Mountains	*blue*	*transparent*	*pencil*	*green*	*orange*	
Fence/wall	*brown*	*pencil*				
Grass	*green*	*blue*	*red*	*brown*	*Green/ white/*	*red*
Tomb	*blue*	*brown*	*transparent*			
Casket/coffin	*blue*	*brown*	*transparent*			

Colors in another elements				
	GUERRERO			
Flowers	*Red*	*transparent*	*brown*	
River	*Red*	*transparent*		
Smoke	*Black*	*transparent*		
Bag/briefcase with money	*Black*	*transparent*	*pencil*	*yellow*
Road/driveway	*transparent*			
Cigar	*Black*	*transparent*		
Balaclava helmet/mask	*Black*	*pencil*	*yellow*	*transparent*
Mountains	*Brown*	*red*	*transparent*	
Grass	*Green*			
Deer	*Red*	*transparent*		
Ball	*transparent*			
Rocks	*Brown*	*black*	*red*	*transparent*
Jewels/valuables	*Black*	*yellow*	*pencil*	*transparent*
Public lighting	*Black*	*yellow*	*pencil*	*transparent*

Colors in another elements	
	MEXICO CITY
Balloon	*Red*

CONCLUSIONS

When we analyzed the drawings we found that the respondents were in the first phase of the **intellectual realism** (Loquat, 1978) in which they draw the things they see and they try to copy the models represented as well as elements that are visible. Although in this phase, they also use items that should not be visible, this situation, in turn, causes the suppression of visual elements that are not important for them, so they recurred to the use of transparency, although, few cases were found in this report.

Other characteristics of this phase that we found in the analyzed drawings were the lack of perspective; this allowed them to put the maximum possible number of elements in certain form, so the quadrupeds, birds and fish are always in side face while the human figures are always frontwards.

Regarding our objective, we found that the differences are greater than the similarities. This confirms the hypothesis that the natural environment has an influence in the use of the perception of violence through drawings and colors in the drawings of violence.

Such differences were, among others, that in the sample from Nayarit, we can see a widespread concern for the natural environment manifested in the excessive presence of driveways. In this research, the brown or grey driveways were interpreted as violence to the natural environment, disappearance of nature for purposes of modernization / urbanization.

This situation was different in the sample from Guerrero, a place that, in the last few years, has been characterized by high levels of violence. This maybe the reason why the children visualize violence in their social environment and some of them included in different planes different scenes, that although they are related with the general subject their characters, scenarios and objects are not related with each other.

It is important to highlight that although the box of colors was a gift for all the participating children, the group from Guerrero chose to keep them instead of use them and that when they received it, they showed an expression of joy and surprise as if they had never had a gift like this.

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COLOR AND IMAGE OF THE CITY IN ENVIRONMENTAL DESIGN OF KAZIMIR MALEVICH

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ABSTRACT

The article is devoted to the description and the systematization of Malevich's strategies for color design in urban space. The article demonstrates the ideas of Malevich on how color functions as an important symbol in environmental design and how a new color 'edition' helps to change the impressions about the existing social structure of urban society, and also serves as a means of promotion of some quarters, districts and even whole towns. The text contains the description of the main results of Malevich's experimental research into the role of color in the built environment. These studies include the principles of color organization of the scenic architecture, Suprematism facade coloration, and architectural painting of Malevich, implemented in 1919 in Vitebsk. The principles of form and space organization in Malevich's projects are analyzed. The color structure, color constellations, and how they contribute to the creation of image and spatial illusion in the city are characterized. An important aim of the article is the examination of the impact of unique methods and ideas of Malevich on contemporary and subsequent architectural color usage. In particular, it reveals the link between the work of Malevich and Russian avantgarde projects, especially to abstract axonometric compositions of geometric solids such as the Prouns of El Lissitzky. It also shows the ways in which the ideas on environmental color design of Malevich continue to exist in the modern popular culture of the city.

1. INTRODUCTION

Kazimir Malevich is well known as a prominent painter. However, he also had a lot of interesting ideas about color environmental design, and his town-planning painting had a significant impact on the color development of cities.

2. METHOD

As the basic research method was used a complex (integrated) approach based on the appropriate methodological arsenal. An important means of this study was a comparative analysis and its methodology as well. A case study using such field methods of qualitative research as project analysis and historical documentation of color, content analysis, comparison of individual cases and a systematic qualitative data analysis was conducted by the description of the Malevich's scenic architecture, his Architectons and Planits, projects of spatial Suprematism, facade coloration, and architectural painting, implemented in 1919 in Vitebsk.

3. RESULTS AND DISCUSSION

The starting point of the research was the thesis that we have been using color to create idiosyncrasies in urban space as long as we have been living in cities. Color in a city is accessible to individual citizens or "actors" who desire a means of "self-expression" and "impression management" (Goffman 1959) they wish to make upon others. However, together with these individual actors in the color space of the city we find collective actors as well, and the influence of these actors on color characteristics of the city is much more essential. Having a great amount of resources, the collective actors "modify the city" by use of color. Collective actors can create color illusions implying that urban spaces have particular qualities that are not present in reality.

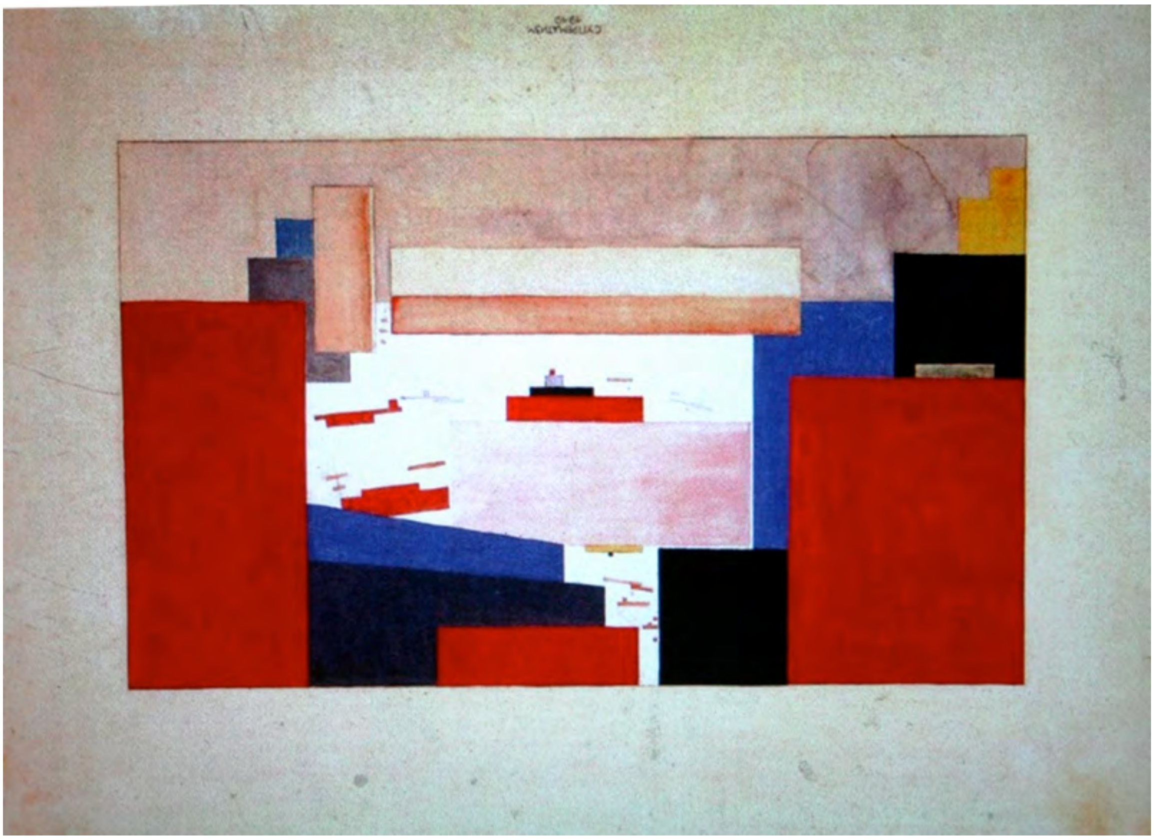

Figure 1: Kazimir Malevich. Study for a curtain (1919).
Source: cultobzor.ru

3.1 Philosophy of Malevich

The political power of color in the color design of urban space was extensively used in socialist societies. Architects were working at the creation of a visual environment that corresponded to the socialistic structure. A rather exact and idealized image was produced, which transformed the architecture itself.

Malevich obviously realized that socialism changed not only the political system but also the ideology of people. It created new conditions for the development of color planning and urban color design, forced new ways for the production and distribution of color images in urban culture. His idea was that architects could not get rid of the existing architecture; however, they were able to use that accumulated architectural material as a basis for expressing new ideas and creating a new image of the city by means of color.

Malevich considered color as an important symbol in environmental design. His idea was, that a new color "edition" can help to change the impressions about the existing social structure of urban society, and also can serve as a means of promotion of some quarters, districts and even whole towns.

3.2 Malevich's projects

The main results of Malevich's experimental research into the role of color in the built environment include the principles of color organization of the scenic architecture, the Architectons and Planits, the spatial Suprematism, facade coloration, and architectural painting of Malevich, implemented in 1919 in Vitebsk.

The scenic architecture of Malevich was his first experience of color design in three-dimensional space. As a stage designer of the Futurist opera "Victory over the Sun" premiered in 1913 in Saint-Petersburg he intended to underline parallels between literary text written in zaum[1] language by Alexei Kruchenykh, musical score written by Mikhail Matyushin, and the art of painting and the color (Figure 1).

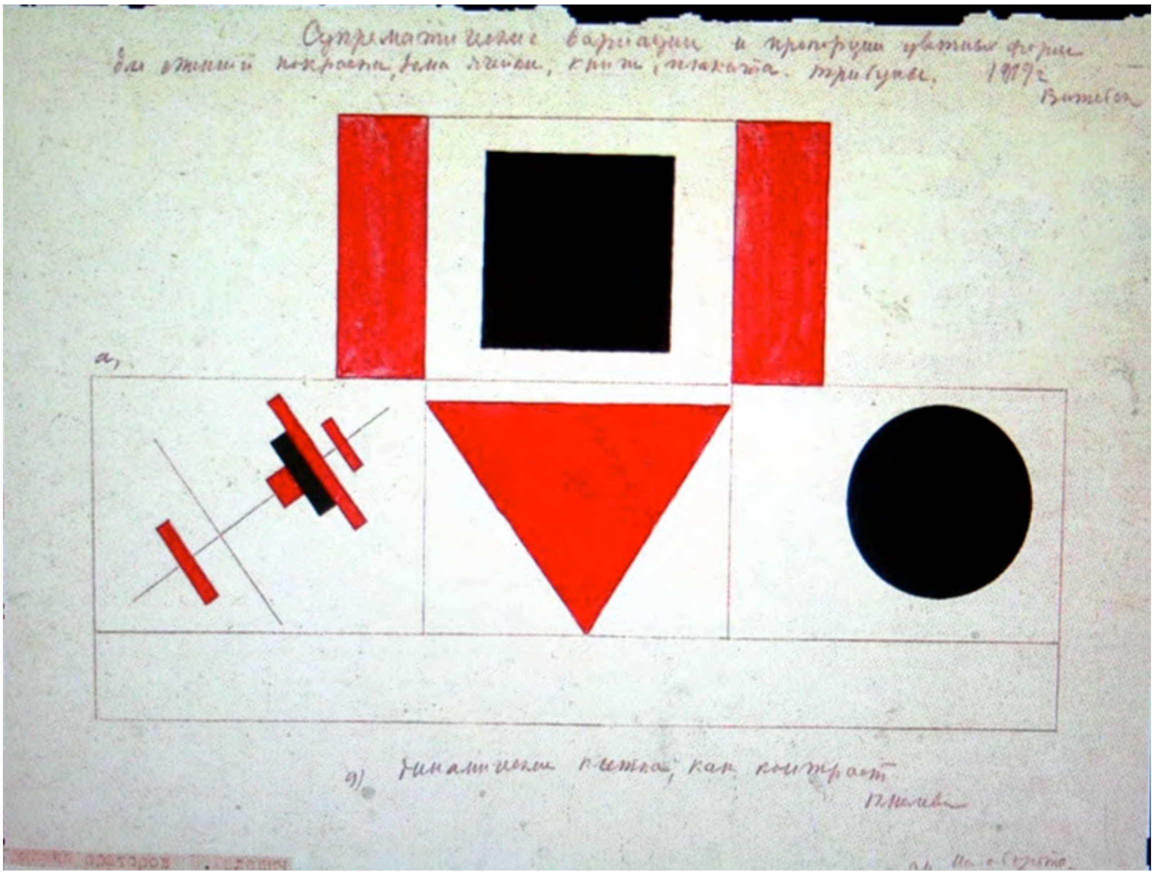

Figure 2: Kazimir Malevich. Design for the speaker's rostrum (1919).
Source: Arskaya et al. 2000

In 1919, during Malevich's tenure (1919–1922) in the Soviet town of Vitebsk, Malevich's spatial Suprematism confronted the real built environment. The Vitebsk experiment involved many different objects of urban space: Malevich and his disciples

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1 Zaum (Russian: зáумь) are the linguistic experiments in sound symbolism and language creation of Russian-empire Futurist poets such as Velimir Khlebnikov and Aleksei Kruchenykh.

created drawings for murals on buildings and interiors, signboards for the stores and shops, propaganda panels that decorated the sides of streetcars, speaker's rostrums (Figure 2), and even the decorations on the ration cards used during the period of War Communism, crockery, textiles.

The prominent filmmaker Sergey Eisenstein depicted his reception of the transformation of “sooty and cheerless” provincial city, typically “built of red brick” into a Suprematic one:

> But this city is especially strange. Here the red brick streets are covered with white paint, and green circles are scattered around this white background. There are orange squares. Blue rectangles. This is Vitebsk in 1920. Its brick walls have met the brush of Kazimir Malevich. And from these walls you can hear: ‘The streets are our palette!’ (Eisenstein 1963: 279).

3.3 The principles of form and space organization

The essential characteristic of space representation in the town-planning painting of Malevich was the "two-dimensionality" of the basic forms he used in the urban space decoration (Figure 3). All the compositions comprises the same repeated elements – squares, circles, crosses, triangles of various sizes and colors, vivid against the typical of Malevich’s Suprematism white ground. The white canva was for him a field of pure light, a means emboding infinite space with no gravity inside. Spread over the façade both horizontally and vertically, the dynamically distributed colored forms of various sizes were included in a series of smaller and more complex compositions. Dynamic positioning of shapes testified to Malevich’s desire to restructure the rigid solidity of the original building while creating a feeling of "non-objectiv" environment.

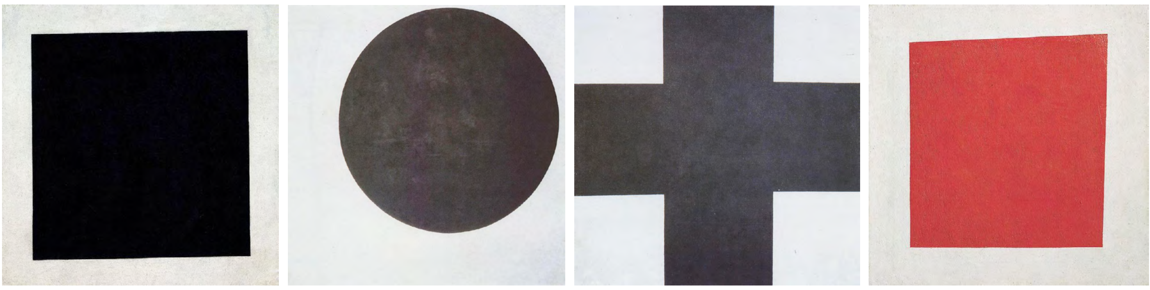

Figure 3: The basic Suprematism forms. The Black square (1923).The Black circle (1923). The Black cross (1923).The Red square (1915).
Source: Arskaya et al. 2000

3.4 The color structure

In urban space Malevich knowingly used a simplified coloration. The color system of the town-planning painting of the artist had a definite brief structure. Two main colors, the black and the white, were used in it. These two colors had quite clear and well-defined semantics. Malevich considered the black as "the most concentrated materiality" and "the sign of economy". The white was identified as "nonfigurative art", "renovation", "purity", "order", "high geometry of consciousness" (Malevich 2001: 80). All other colors did not have any expressed independent fixed symbolism in the art concept of Malevich. They were identified and semantically belonged to the third class. Only symbolism of the red was mentioned in some of his works as a "signal of revolution" (Malevich 2001: 80).

Thus, Malevich created the color dictionary of his town-planning painting, abandoning the symbolic meanings of a number of colors and shades, eliminating their cultural meanings. Similar "color blindness" was typical of the early stages of the color language evolution, the basic principles of which were affirmed in the works of Berlin and Kay (1969). In particular, just the same tendency was evident in the language of the African tribe Ndembu. Recurring one of the early stages of the color terms development, the color dictionary of the town-planning painting of Malevich was based on the three-termed classification. Such a parallel is not unique in the history of art and indicates that different types of color simplifications continue to exist in the artistic consciousness, repeating certain stages in the evolution of color language.

3.5 The impact of Malevich's ideas on architectural color usage

The unique methods of Malevich (the two-dimensionality of basic forms, color-structuring of space, etc.) and his architectural ideas on spatial Suprematism have the great impact on contemporary and subsequent architectural color usage. In particular, there is an evident link between the work of Malevich and Russian avant-garde projects, especially to spatial Suprematism and abstract axonometric compositions of geometric solids such as the Prouns of El Lissitzky (Figure 4). The ideas on environmental color design of Malevich continue to exist in the modern popular culture of the city, where they work rather as metaphors (Figure 5).

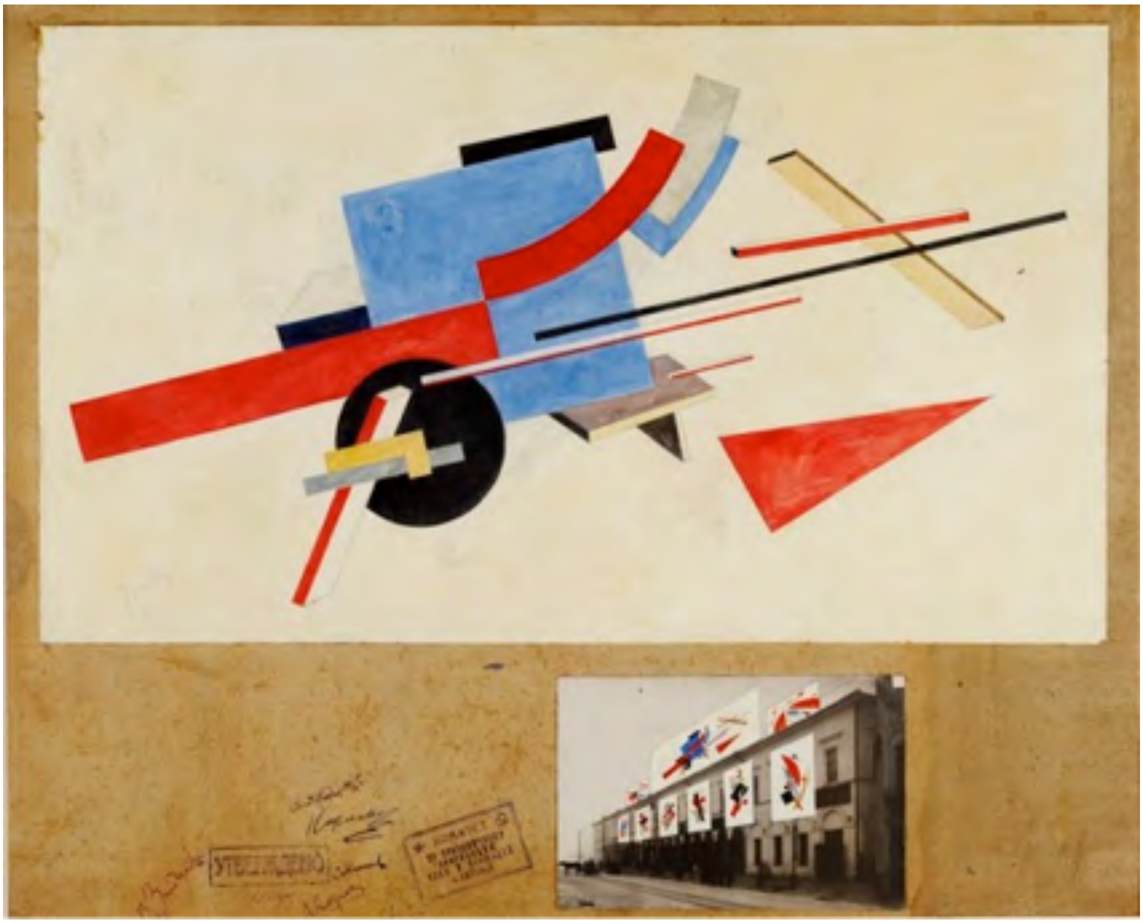

Figure 4: El Lissitzky. Study for a builging exterior in Vitebsk (1919). Source: designblog.rietveldacademie.nl

4. CONCLUSIONS

Malevich's ideas on urban color design have the great theoretical importance to the development of conceptual and methodological approaches toward the study of color phenomena in environmental design. The systematization of Malevich's strategies of color planning has not only theoretical but practical significance as well. This is a new chapter in color education, and will be used in the restoration and reclamation of monuments as well as in new construction and city image developement.

Figure 5: The residential area "Malevich" (Yekaterinburg, Russia)
Source: us-invest.ru

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Comparative Study about Preference Tendency to Spatial Color Based on Color Recognitions and Emotions among Nations: Focused on Korean and Malaysia

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ABSTRACT

Korea is changing rapidly from a single-raced nation into a multi-national due in part to the increasing number of Chinese and Southeast Asian immigrants. This gives rise to a multitude of social problems, one of them being the difficulties faced by children of the second generation multi-cultural families who enroll to elementary schools in Korea. This should be solved urgently as it is predicted to be an unavoidable problem in future. Only by understanding and accepting mutual cultural differences will the solution to these multi-cultural societal problems be remedied. This study aims to investigate the differences in preference tendencies among nations with respect to their recognition of colors and emotions within spatial color environments. The study's sample consisted of Korean and Malaysian design students, whose colour preferences and vocabulary appraisals of the environmental colors in Korean school health rooms were solicited. The collected data was analyzed to ensure the reliability and the results show strong support for comparison studies on colour preferences among nations.

1. INTRODUCTION

In South Korea today, foreign workers from China and Southeast Asia have been growing in numbers due to the economic shortcomings of their home countries. This increasing number of foreignen workers in South Korea is causing the number of multicultural families to increase, and consequently, results in cultural and social conflicts and problems. Due to this globalization, these second generation immigrants enroll into Korea elementary schools. As such, these younger generation begin to experience maladjustment and difficulties. Therefore there is an urgent need to solve the problem as soon as possible. Since 2003, the Ministry of Education of South Korea organized the "Health Room Modernization" program as a means to solve this problem. The result of this initiative is the design and development of elementary school health rooms. These elementary school health room should include health guidance, prevention education and counseling.

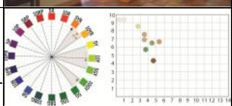
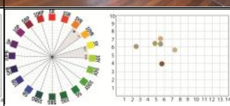
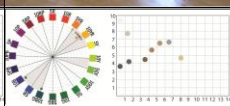
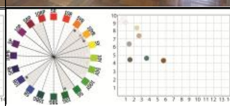
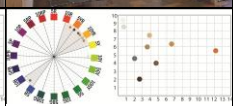
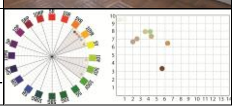
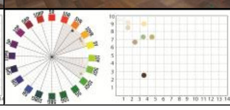
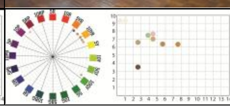
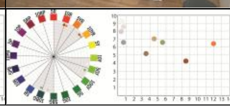
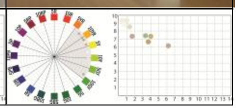
As the multi-cultural society continues to grow, there is a need to educate the younger generation to recognize and understand the color changes of the environments. This can be done through understanding the differences between cultural sensibilities, which, in turn, would help alleviate these cultural conflicts and problems. Limberg (2000) has claimed that color could influence the feelings and emotions of a human with a very strong impact, Schmitt(1995) concurs and states that color has a significant influence on people's feelings and emotions. Every color has different meaning depending on the person's culture, so it is important to understand the difference between perception and color preferences of each culture. Therefore, this study aims to identify the characteristics differences between two countries, Korea and Malaysia, and investigate their sensitivity in color perceptions and color preferences.

2. METHOD

2.1 Composition of health room color

The "Korean Government's Health Room Modernization Service" was conducted in 10 Elementary School health rooms (A-J) in Busan, South Korea. Our research team went to all 10 locations, using a spectroscopic to collect the color data, took some photographs and collected information about each school. Looking at the configuration of colors of each, only one main color was been applied to the floors YR(90%); for walls, there were two similar main colors with similar hues YR(43.6%), Y(41%); and for furnitures, a variety of colors was applied Y(32.5%), GY(32.5%), YR(20%), G(5%), B(5%). This was seen through all 10 schools observed. Table 1 shows the distribution of spatial colors in each of the health rooms.

Table 1. Distribution of health room's spatial color

School	A	B	C	D	E
Space Image					
색상 분포도					
School	F	G	H	I	J
Space Image					
색상 분포도					

Each health room used most of the nine colors, and YR, where the Y color was seen to be used as the main color. School B had less colors configurations, and thus presented the simplest color scheme. School I's health room had a total of 6 colors, and was the school with the most color scheme. Color YR was seen to be the color most often applied, approximately 3-4times. School A applied the most YR as its main color, whereas color Y was applied most frequently in school B. School C's Value and Chroma levels were both heavy and appeared to be have the least decent color scheme, where as School J had high Value but low Chroma levels, and appeared to have the color characteristics of softness. Schools E and I appeared to have the most contrasting colors, where its colours had high saturation levels, which resulted in strong color contrast characteristics in its the applied colors.

2.2 Survey

To investigate the differences between Korean and Malaysian preferences and emotional state towards these health room environments' colors, a survey was conducted on a sample of 160 students. These students were made up of Koreans (males = 26, females = 54) and Malaysians (males = 29, females = 51). They were asked to choose a color to symbolize their country, follow by their most preferred and least preferred color palette color among the 10 School health rooms. Following that, they were then give the emotional evaluation form, which would solicit their preferences with respect to the health rooms' color environment.

3. RESULTS AND DISCUSSION

3.1 Koreans and Malaysians Perception of National Color

In order to examine the cognitive aspects of color of each country (South Korea and Malaysia), students were asked to choose a color that they felt symbolized each country. As shown in Table 2, Korean subjects reported Red (55%) and White (31.3%) colors to symbolize their nation, due on part to the effect of both the uniform color of the Korean football team (Red Devil) as well as the notion of White representing the Korean traditional spirit. On the other hand, In contrast, Malaysian subjects reported White (37.5%), Red(26.3%), Blue(25%) to symbolize South Korea, mainly because of South Korea's national flag and their perception of South Korea as a clean and high-tech industry.

Table 2. Korean and Malaysian's perception of symbolic color for the two countries

	Korea's symbolizing color										Malaysia's symbolizing color									
Color	Red	Orange	yellow	Green	Blue	Purple	Brown	Black	White	Etc.	Red	Orange	yellow	Green	Blue	Purple	Brown	Black	White	Etc.
Korean (%)	55	2.5	1.3	0	10	0	0	0	31.3	0	10	27.5	16.3	31.3	3.8	1.3	8.8	0	1.3	0
Malay (%)	26.3	0	1.3	2.5	25	5	0	1.3	37.5	1.3	35	3.8	21.3	8.8	31.3	0	0	0	0	0

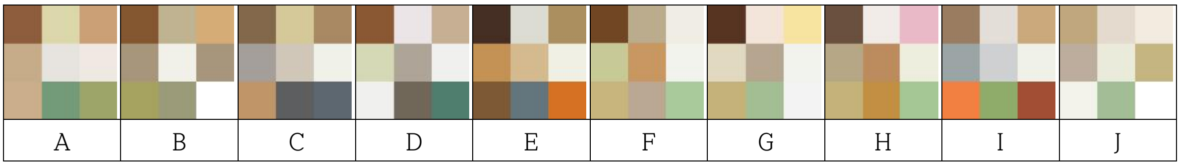
The Korean subject provided a variety of colors to symbolize the country Malaysia, with Green (31.3%), Orange (27.5%) being the colours with the highest percentages of students. The answer Green was chosen because of the green plants and fruits representive of the tropical climate of Malaysia, and the color Orange were chosen as of the color of Malaysians.

According to a study by Abdulrahman (2015), in Malaysia the color Green referred as the color that symbolizes danger and disease. The 31.3% of Koreans who answered that the color that symbolized Malaysia was Green will indicate shortage of recognition and may cause disrespect to the Malaysian culture, even if a small number of Malaysian answered Green, they appeared to be foreigners residing in Malaysia.

3.2 Environment Color Palette of Preferences and Sensibility Evaluation

Korean and Malaysian students were also asked to pick their three most preferred color palettes and their three least preferred color palettes, which were followed with an emotional assessment survey to elicit the reasons for their choices.

Table 3. Health room's color spatial palette



As can be seen in Table 3, the top three colors that Koreans preferred was A, B, and C. These three color palettes have similar low brightness (range: 6.3 - 6.8), and showed that they preferred calm and soft colors. As for the emotional assessment results, Koreans preferred Calm feeling (32.5%), Soft feeling (22.5%), however Clear feeling (12.5%), Breezy feeling (12.5%), and Natural feeling (12.5).

On the other hand, Malaysians was found to favour Natural color feel with high brightness color in palette A, H, J. As for the emotional assessment results, Malaysian students preferred palettes that were similar to the Korean students with highest ratio of Calm feeling (28.8%), follow by Happy feeling (20%), Soft feeling (17.5), Natural feeling (16.3). From Korean student's answers, Happy feeling was the lowest, but interestingly, was one of the highest chosen by Malaysian students. This result showed that Malaysians valued happiness more over Koreans. This is shown in Table 4 below.

Table 4.Emotional Assessment for preferred color palette

Vocabulary	Soft feeling	Clear feeling	Happy feeling	Breezy feeling	Calm feeling	Natural feeling	Others
Korean (%)	22.5	12.5	3.8	12.5	32.5	12.5	3.8
Malay (%)	17.5	7.5	20	7.5	28.8	16.3	2.5

As shown in Table 5, Korean students' least preferred color palette appeared to be E, H, I. Koreans did not prefer a color palette that had high saturation levels, because they felt that the color did not seem to be balanced. As for the emotional assessment results, Koreans did not prefer Muddy feeling (33.8%), Artificial feeling (28.8%). In contrast, Malaysians preferred color palette H, although the Koreans does not. This clearly shows that there is a difference in the color preferences between Malaysians and Koreans.

Malaysians' least preferred color was found in C, D, and E. Generally, Malaysians disliked muddy and dull feelings as shown in the result. Koreans preferred color palette C, although Malaysiana did not appear to like it. This proven even though the same color palette is chosen, people from different cultures can still have completely different emotion feelings towards it.

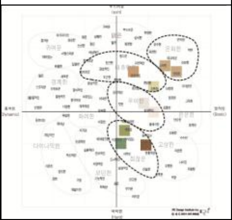
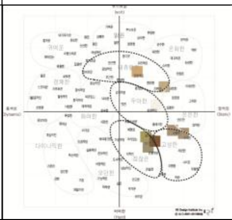
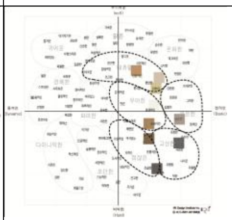
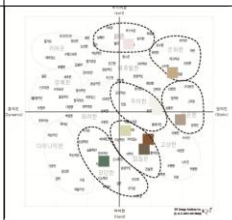
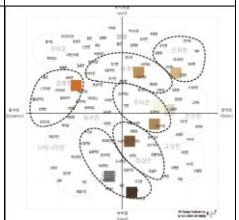
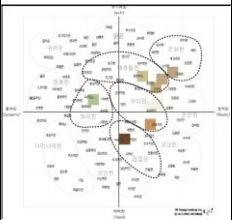
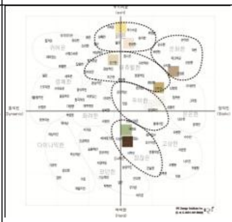
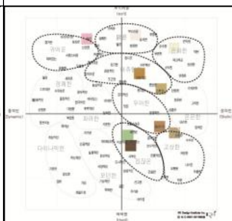
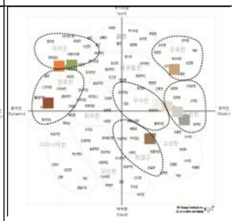
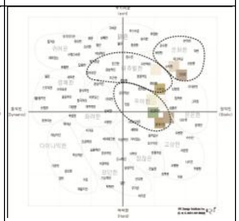
Table 5. Emotional Assessment for least preferred color palette

Vocabulary	Hard feeling	Muddy feeling	Sad feeling	Dull feeling	Active feeling	Artificial feeling	Others
Korean (%)	5	33.8	8.8	13.8	0	28.8	10
Malay (%)	11.3	21.3	3.8	37.5	13.8	8.8	3.8

3.3 Comparing the Emotional Evaluation on Color Palette and the Scale of Spatial Color Image

In addition, analysis and comparison between the evaluation assessment of color palette preferences and the actual spatial color image scale were conducted. As Table 6 shows, Korean students chose images A, B, C as their most preferred spatial color, because they preferred the Calm feeling, Soft feeling, Clear feeling, Breezy feeling, Natural feeling. This showed that Koreans equally prefer Naturally, Graceful, Decorous colors and partially towards the Elegant color. This result shows that the collected data of evaluation assessment of color palette preferences matches with the actual spatial color image scale.

Table 6 Spatial color image scale

School	A	B	C	D	E
Image Scale					
Voca.	Mildly, Naturally, Graceful, Decorous	Naturally, Graceful, Decorous, Elegant	Naturally, Graceful, Ambient, Decorous, Elegant	Clearly, Mildly, Ambient, Graceful, Decorous, Modernistic	Mildly, Graceful, Decorous, Modernistic, Breezy
School	F	G	H	I	J
Image Scale					
Voca	Mildly, Naturally, Graceful, Decorous, Glamorous	Clearly, Mildly, Naturally, Graceful, Decorous,	Lovely, Clearly, Mildly, Naturally, Graceful, Decorous, Elegant	Lovely, Breezy, Mildly, Ambient, Graceful, Decorous,	Mildly, Naturally, Graceful,

Malaysian students chose images A, H, J as their most prefer spatial color, because they preferred the Calm feeling, Soft feeling, Clear feeling, Breezy feeling, Natural feeling. Malaysians appear to prefer Naturally, Graceful, Decorous colors follow by Lovely and Mildly colors. By analysing the preferred color palette, the results showed that Malaysians preferred the Happy feeling, follow by Lovely feeling and Mildly feeling. This result shows that the collected data of evaluation assessment of color palette preferences matches the actual spatial color image scale.

4. CONCLUSIONS

There are several conclusions that can be drawn from this study's results. Firstly, when Korean and Malaysian subjects did the same survey of choosing the symbolic color for each country, their results showed that the colors in their national flags are higher in ratio. However, Malaysians reported that the color Green symbolized disease, whereas the sKorean thought Green symbolized Malaysia because of the the country's tropical climate, plants, and fruits. This results showed that people from different culture background have different points of view on the same color.

Secondly, Korean and Malaysian subjects were asked to choose their most preferred and least preferred spatial color images and evaluate their emotional sensitivities towards the 10 color palettes. Results show that Koreans preferred color palettes that have calm and gentle emotions feelings, whereas Malaysians favored color palettes that had happy and natural emotion feelings. In adition, Koreans did not prefer color palettes that were artificial and harmonious, and Malaysias dis not like the color palette that had dull and muddy feelings.

Thirdly and finally, comparing and analysing the emotional evaluation on color palettes and the scale of spatial color images, the results show to matche very well. This shows that the collected data were reliable, in future research will further this study by doing more comparison with other countries.

ACKNOWLEDGEMENTS

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The analysis of door color on the Traditional Palace of the Kingdom of Joseon

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ABSTRACT

This study is a part of the architectural element color analysis on the Traditional Palace(Gyeongbokguang,_Changdeokgung and Changgyeonggung) which belongs to Kingdom of Joseon. This study is based on main architectural element door analysis on the Traditional Palace of the Kingdom of Joseon. In this paper, we adopt Munsell Color System and NCS Color System to study color usage on the door of the Traditional Palace. The objective is find out the color distribution range and the character on the doors and analyze the results based on cultural tradition of Korea. This study includes by three steps. First was mainly of the study which is subjects information searching.The second step used the Munsell Color System and NCS Color System to analyze the study subjects to get the color distribution range and the character of distribution range. The third step was the analysis of the door color from step two and got the results like followings. Firstly, the range of door color distribution concentrated from 5R to 5YR by the Munsell Color System. And color adopted is low and middle value and chroma. Secondly, the color of door distributed in the range of 5 and 6. The character of the color in this area is dark, while the dark tones and dark tones correspond to nearly colorless. Lastly, it found out the relationship between color and culture. The major color of Korea architecture are used by asymmetrical balance with natural, and harmonious color.The color of the palace also has same character, the color impression is not serious and dignified sense. The impression is relaxed and stable integration of the nature feeling. Future research will analyze other architectrual element color on the Traditional Place of the Kingdom of Joseon.

1. INTRODUCTION

With the development of history, most of Asian like the lifestyle and culture of western Traditions lifestyle and cultural are gradually neglected. The culture of nations which once owned themselves also has been gradually forgotten. However, with the development of economy, the international status of Korea has been improved. People of the country pay attention to their own nation culture and lifestyle. People start to search for the source of nation culture.

This study is a part of the architectural element color analysis on the Traditional Palace(Gyeongbokguang, Changdeokgung and Changgyeonggung) of the Kingdom of Joseon. In this paper, we adopt Munsell Color System and NCS Color System to study color usage on the door of the Traditional Palace of the Kingdom of Joseon.The purpose of this study is find out the color distribution range and the character on the doors and analysis the results based on cultural tradition of Korea. This study was the base of the architectural element color analysis on the Traditional Palace between China and Korea. I did this study just for two reasons. The first reason was the past research had compared a long time. And the other reason was compared with other method such as photo analysis method in past resarch, this one raises precision and error was kept below 0.1. So I decided to do this study for researching color distribution range and the character on the Traditional Palace again.

2. METHOD

2.1 Sample Preparation

In this paper,three Traditional Palace were selected and founded in the Joseon Dynasty which is Gyeongbokguang,Changdeokguang and Changgyeongguang.The 3 research subjects were located in Seoul. This study aims are the color of the main building doors. (Figure 1).

Figure 1: Gyeongbokguang, Changdeokguang, Changgyeonggung

2.2 Experimental Procedure

To measure the color of doors,the current study used CM-2600d,_NCS COLOR SCAN 2.0 to measure physiological signals.CM-2600d used Munsell Color System to measurement the color of doors. NCS COLOR SCAN 2.0 used NCS Color System to measurement the color of doors. Before measuring the color of doors, I used my hand to wipe the surface of the door. After the measurement of color was done throgh the machine on the surface of the door. To minimize the mistake with the surface, extraneous substances were wiped off the surface of the door.

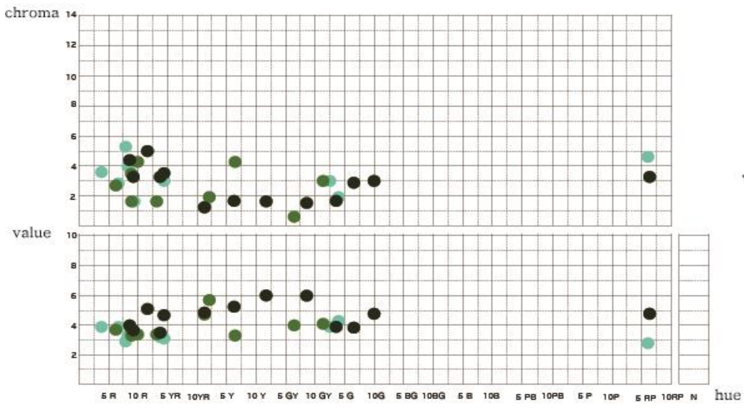
The measurement method used as follows. The subject was seated comfortably in the outside and the day had no strongly sunlight. I used my hand to wipe the surface of door.Next,two color measurement machines were taken for 10 seconds in the surface of the door. In order to reduce the error of result of measurement.I measured different positions just like red square region in the surface of door. And the other way to reduce the error of result of measurement, I used color measurement machines to measure the color of door for many times. At last, I took the average of the result of color measurement and recorded in the paper(Figure 2).

Figure 2: Measurement color used two color measurement machines.

3. RESULTS AND DISCUSSION

This study used the Munsell Color System and NCS Color System to analyze the study subjects to get the color distribution range and the character of distribution range. Munsell Color System, this system consists of three independent dimensions which can be respresented cylindrically in three dimensions as an irregular color solid: hue, measured by degrees around horizontal circles; chroma, measured radially outward from the neutral vertical axis; and value, measured vertically from 0 (black) to 10 (white). Munsell Color System determined the spacing of colors along these dimensions by taking measurements of human visual responses. NCS Color System is based on the color opponency description of color vision. The system is usually used for matching colors rather than mixing colors.

The result of color measurement can be classified into the two following groups. In the first group,CM-2600d used Munsell Color System to measurement the color of doors. The result of color measurement was shown as in Figure3 and Figure4.In the second group, NCS COLOR SCAN 2.0 used NCS Color System to measurement the color of doors. The result of color measurement was shown as in Figure 5.



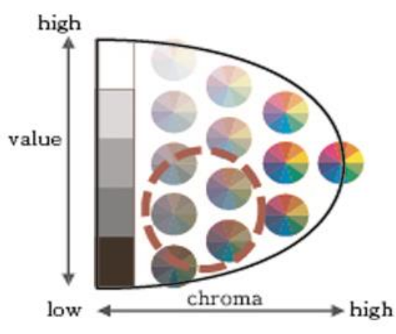


Figure 3: Measurement color by CM-2600d and Analysis by Munsell Color System

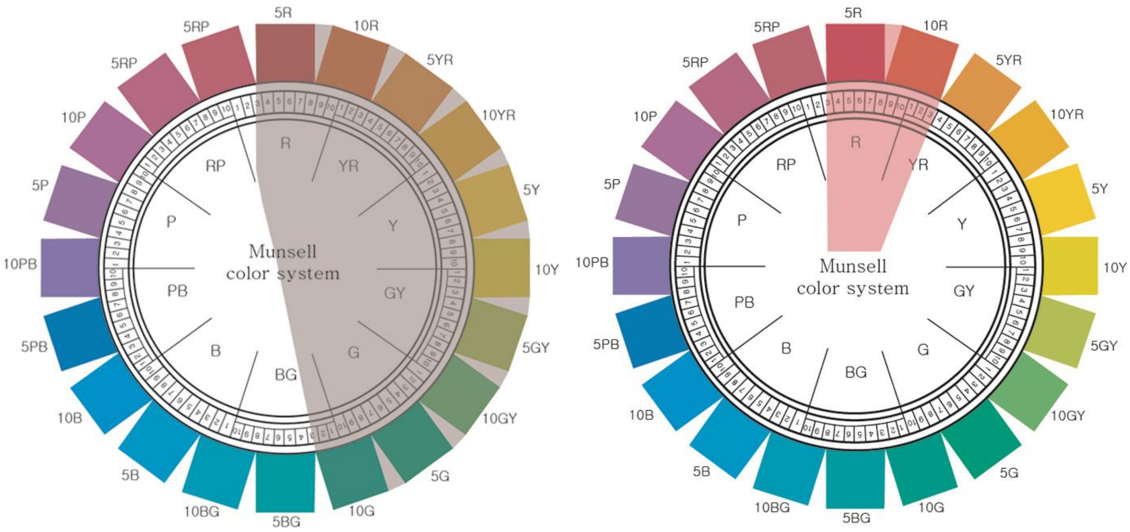


Figure 4: Measurement color by CM-2600d and Analysis by Munsell Color System

The result of the first group is anyalyzed by Munsell Color System.The range of door color distribution is from 1-5 in the direction of chroma.And the range of door color distribution concentrated from 2-5 in the direction of chroma.The range of door color distribution is from 3-6 in the direction of value. And the range of door color distribution is from 3-5 in the direction of value. And color adopted by door is low and middle value and chroma.The range of door color distribution is from 5R to 10G in the black shadow region.The range of door color distribution concentrated from 5R to 5YR in the red shaow region by Munsell Color System.

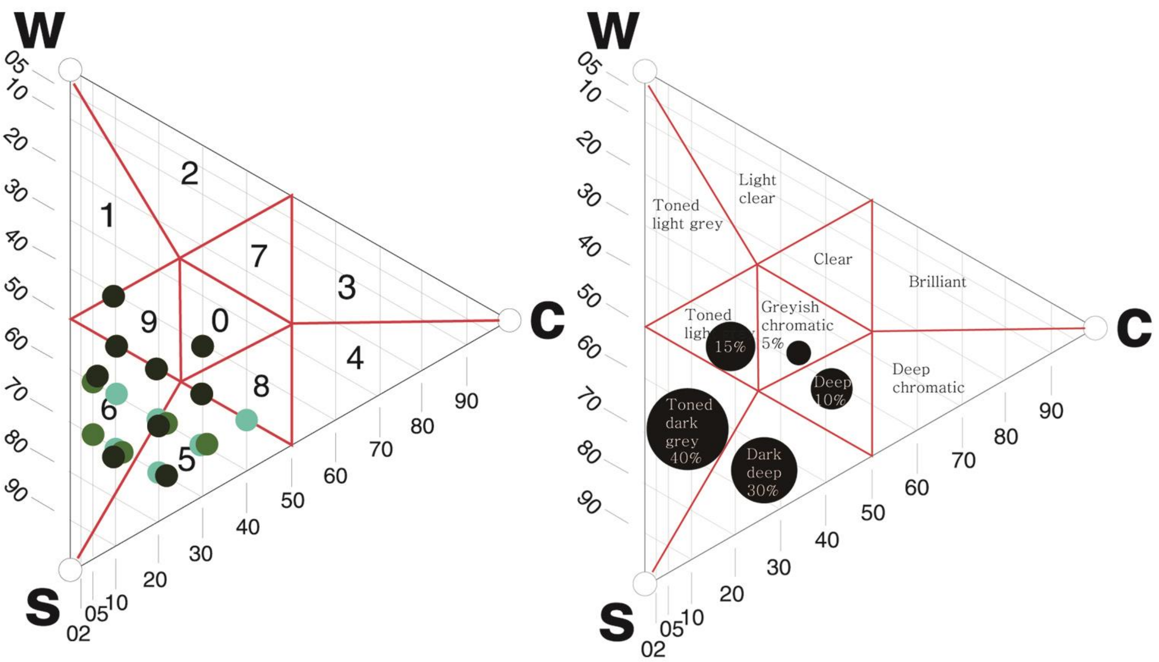


Figure 5: Measurement color by NCS COLOR SCAN 2.0 and Analysis by NCS Color System

The result of the second group is anyalyzed by NCS Color System.The color of door distributed in the range of 5, 6, 8 and 9. The color of door distributed concentrated 5 and 6. The character of the color in this idea is Toned dark grey and Dark deep tones correspond to nearly colorless.

4. CONCLUSIONS

The purpose of the current study was to analyze the door color on the Traditional Palace of the Kingdom of Joseon.Based on the result, the color adopdted by door is low and middle value and chroma by the Munsell Color System. And the color adopted by door is Toned dark grey and dark deep tones correspond to nearly colorless by the NCS Color System.

Following the result, the traditional palace color of the Kingdom is associated with traditional Korean culture. Korean traditional culture thinks that the relationship for person and nature should be a harmonious unity. Under the influence of this idea, people prefer to use the natural unity of color and materials. Even though Korea also has a hirerarchy society but not too fierce so that during the brightness design shows available, the colors are most unsophisticated which are put more attention in the spiritual feelings.The major color of Korea architecture are used by asymmetrical balance with natural, and harmonious color.The color of the palace also has same character, the color impression is not serious and dignified sense. The impression is relaxed and stable integration of the nature feeling. As such, future research will analyze other architectural element color on the Traditional Palace of the Kingdom of Joseon. And it will analyze architectural element color on the Traditional Palace of China. It will find out the same and different character between China and Korea.

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Comparison among three methods for Thai colour naming.

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ABSTRACT

We conducted experiments in colour naming and colour categorisation in Thai to facilitate colour communication within and across cultures. In this study, we compare the frequency and location of Thai basic colours terms (n=11+1) in three experimental methodologies - two conducted in controlled viewing conditions (classical and category) and one over the Internet. Although the frequencies of colour names across the methods were different, they produced ranks within each method that were only slightly different compared with the ranks obtained in the other 2 methods. In terms of hue and lightness the agreement was relatively good for most colour terms but we found large differences in chroma.

1. INTRODUCTION

There are five published studies about Thai colour naming. Three of them are made by linguists and were published in Thai language.

The first study was focused on colour names and on colour perception in Utaradit, north of Thailand (Witchurote, 1986). One hundred and twenty observers participated but only 33 colour names were verbally stated. More than 90 percent of observers could name white, red, yellow and green. Seventy percent could name black, pink, sky blue, and orange. The number of known colour names was significantly different among gender, age and profession. The colour names that could be identified with highest precision were white, black and yellow.

The second research was the comparative study of Zhuang on Thai colour terminologies (Prasithrathsint, 1988). Four observers, with ages between 30 and 40 years, living in 4 geographic regions: central (Bangkok), north (Chiang-mai), north east (Nakhon-ratchsima) and south (Nokorn-sri-thammarat), were interviewed and were randomly showed 217 printed colour samples one by one. The process was repeated twice. The colour samples were printed by Graf-G process inks from Dainippon Ink and Chemicals. Basic colour terms were defined on the criteria of Berlin and Kay, distinguishing the following 3 cases: 1. Identical 12 basic colour terms were identified using: a). observers from Bangkok; b). observers from Chiang-Mai; 2. Eleven basic colour terms were identified using observers from Nakhon-ratchsima; 3. Ten basic colour terms were identified using observers from Nokorn-sri-thammarat.

The 12 basic colour terms identified in the first case, are: white /*khaw*/, black /*dam*/, red /*dang*/, yellow /*leaung*/, green /*khiaw*/, sky blue /*fa*/, blue /*nam-ngen*/, brown /*nam-tan*/, grey /*thaw*/, purple /*muang*/, pink /*chom-pu*/ and orange /*som*/. In the second case, all former colour terms were identified but blue and sky blue were identified with the same colour term. In the last case, grey and brown were identified with the same colour term while pink could not be associated to any colour term, the rest of colour terms being as in case 1. Despite the subjectiveness of the observation procedure, useful data was collected and, based on it, further studies were developed.

In 2003, there was a third research, a comparative study of colour terms made for the Sukhotai period (13-15 A.D.) and for the present time (Engchuan, 2003). Thai colour names that were found in recorded documents originating in Sukhotai period were corroborated with colour samples and natural colour objects. The colour name identification process was carried out with 10 female and 10 male observers, having the age between 30 and 45 years. This study showed that there were 5 basic colour terms in Sukhotai period: white /*khaw*/, black /*dam*/, red /*dang*/, yellow /*leaung*/, green /*khiaw*/, and 12 in present time: white /*khaw*/, black /*dam*/, red /*dang*/, yellow /*leaung*/, green /*khiaw*/, sky blue /*fa*/, blue /*nam-ngen*/, brown /*nam-tan*/, grey /*thaw*/, purple /*muang*/, pink /*chom-pu*/ and orange /*som*/.

In addition to the 3 studies conducted by linguists, there were 2 more studies performed by colour scientists on traditional Thai colour names. The first study resulted in the subjective identification of 50 colour names and was published in a Thai local journal in 1988 (Siripant, 1988). The second study is based on an objective identification method first published in 2011 (Katemake et al., 2013), which was subsequently improved, resulting the first Traditional Thai Colour Name Dictionary that presents 147 traditional Thai colour names analysed, identified, quantitatively described, explained, transliterated and translated (Katemake and Preda, 2014). Most of the traditional Thai colour names take the names of specific objects from nature and environment to be part of their name in combination with basic colour terms.

In December 2013, we started collecting unconstrained colour names with their colour coordinates from hundreds of Thai speakers in an online colour naming experiment (Mylonas & MacDonald, 2010) with an aim to facilitate colour communication across cultures over the Internet. In this study, we attempt to validate our findings by comparing the frequency and the location of colour centroids in CIELAB, against two experimental methodologies conducted in controlled viewing conditions.

2. METHOD

Three experiments of colour namings: classical (CS), category (CT) and online (OL) were carried out. The method of online experiment is already publised (Mylonas & MacDonald 2010, Mylonas & MacDonald 2015), therefore we will only describe the principle.

2.1 Stimuli Preparation

One thousend three hundred matt Munsell sheets were used in both CS and CT experiments. Samples of 5 x 5 cm were cut from each Munsell sheet, were pasted on white cardboard and were framed with neutral grey for the classical experiment. For the CT experiment, cut samples of 2 x 2 cm size were pasted on white paper with magnetic sheet and marked with Munsell notation and barcode on the opposite side. In OL experiment, 600 Munsell codes were selected from the Munsell Renotation Dataset with an addition of neutral samples and were converted to sRGB colour coordinates in order to display the colours on a monitor against a neutral mid-grey backgroud. The chosen size for each displayed colour was 147 pixels width and 94 pixels height, which for a pixel density of 3.3 pixels per mm would be 4.5 x 3.0 cm, subtending an angle of 3.4 degrees at 50 cm viewing distance (Mylonas & MacDonald, 2015).

2.2 Subjects

In the CS experiment, 10 paid subjects participated (5 males and 5 females) with an averaged age of 26.9 years (σ=6.9). The subjects were undergraduates, graduates and lecturers, all having normal colour vision and half of them having basic knowledge of colour science. In the CT experiment, 8 paid subjects were involved (5 males and 3 females), undergraduates, graduates and lecturers, with an average age of 25.6 years (σ=7.7). In the OL experiment, 266 subjects participated but only the responses from 214 subjects (156 males and 58 females) could be used for analysis. Their education level ranged from primary school to Ph.D and their averaged age was 29 years (σ=9.8).

2.3 Apparatus and procedure

In the CS experiment, Munsell samples were placed in a viewing booth of 116x56x83 (WxLxD) with neutral grey interior walls. D65 fluorescent lamps, with the colour rendering index (CRI) of 98 and total illuminance of 1200 lux, were installed on the booth's ceiling. The viewing distance was 60 cm. This resulted in an approximately subtended angle of 4.8 degrees for the sample size of 5 x 5 cm. In the CT experiment, 1300 Munsell samples with magnetic base were randomly positioned on a 100x200x92 (WxLxH) cm iron-table with neutral grey background. The D65 fluorescent lamps, having the same CRI and illuminance as in the CS experiment, were installed on a white ceiling placed 90 cm far from the table surface. The ceiling was sustained by a framework outranging the experimental area in order to have no walls within the subjects' viewing range. The viewing distance depended on the height of subjects. For an average height of 160 cm, the viewing distance was approximately 74-78 cm. The subjects' variable sized top part of the body was another factor affecting the viewing distance. This gave an approximately subtended angle of 1.5 degrees for the sample size of 2 x 2 cm.

For the CS experiment, 2 samples were cut from each Munsell sheet, resulting 2600 samples. One set of 1300 samples, one sample for each Munsell colour, was randomly separated in 6 boxes. From the second set of 1300 Munsell samples, 200 samples were randomly selected and placed into a 7th box. The samples from the 6 boxes were shown to the subjects one at a time in random order in the viewing booth. The subjects were asked to say "open" when opening the grey cover for viewing each sample and they were asked to name each colour, as fast as possible, using basic colour terms or non-basic colour terms, without using foreign words. The time needed for each subject to name each colour was recorded as response time for the considered subject/colour pair. The 7th box with 200 samples was used for checking the consistency of the obtained data. The total observations were 15,000. In the CT experiment, 1300 Munsell samples were placed simultaneously on the iron-table. The samples were shown randomly to subjects who were asked to select and group colours according to each subject's opinion on colour similarities and based on each subject's choice for naming the colour-group. The colour names were written down for each resulted group and the colour samples from each group were placed separately into small boxes. The subjects were allowed to build colour-name groups simultaneously and/or sequentially. The total observations were 10,400. We measured each Munsell sample under the experiment lighting condition with Konica Minolta CS-1000 in the same angle and distance that subjects were seated.

The OL experiment (www.colournaming.com/th) consisted of six procedural stages: i) adjusting the display condition ii) giving display information iii) testing colour vision iv) naming colours of 20 randomly selected colours, v) giving cultural information and vi) summary of the results (Mylonas & MacDonald, 2010).

3. RESULTS AND DISCUSSION

In the laboratory experiments, the subjects were asked to name the colours in Thai language without using foreign descriptive terms or Thai words of foreign influence. More colour terms were obtained in the CS experiment, when one sample at a time was shown to the subjects, than in the CT experiment, when various samples were shown simultanously. The average ratio was 6 to 1. We analysed the data in terms of colourname frequencies and colour centroids. The colour names were divided into 3 groups: G1) basic colour names according to Berlin and Kay (Berlin and Kay 1969) definition plus *fa* (sky blue) G2) monolexemic terms and G3) colour names that include G1+identifier, G2+identifier, 2 colour-word and 2 colour-word + identifiers. The reason why we added *fa* (sky blue) to the basic colour names is that *fa* (sky blue) has been used to represent blue before the word *nam-ngen* (blue) was known. With CS and CT method, G1 were 23.03% and 61.90%, G2 were 1.34% and 2.88% and G3 were 75.25% and 35.22% respectively.

The frequencies of colournames grouped in G1 are shown in Figure 1. The colourname with the highest frequency obtained in the CS method was *thaw* (grey): 20.32%, because the matt Munsell samples within the first step of chroma, which is much higher than other steps, were mostly named *thaw* (grey) by subjects. However, when subjects were shown these samples along with other samples, the resulted frequency dropped to 9.38%. The colour names that had the top six highest frequencies were: 1) for CS: *thaw* (grey), *khiew* (green), *muang* (purple), *nam-tan* (brown), *chom-pu* (pink) and *fa* (sky blue); 2) for CT: *khiew* (green), *muang* (purple), *chom-pu* (pink), *fa* (sky blue), *nam-tan* (brown) and *thaw* (grey); 3) for OL: *muang* (purple), *chom-pu* (pink), *fa* (sky blue), *khiew* (green), *nam-ngen* (blue) and *nam-tan* (brown). This shows that *fa* (sky blue) is more frequent than *nam-ngen* (blue), which indicates that *fa* (sky blue) might be more appropriate to be considered in the Berlin and Kay 11 basic colour terms than *nam-ngen* (blue).

Colour centroids of G1 colourname-group (n=11+1) determined in all three experiments, are shown in Figure 2. The CIEDE2000 colour differences in CIELAB between CS and CT were relatively small (mean DE_{00}=3.26) because the same type and number of colour samples and the same type of illumination were used in both methods. The differences between CS and OL (mean DE_{00}=12.5) and between CT and OL (mean DE_{00}=12.5) were mainly observed in chroma. The largest hue difference was observed in *nam-ngen* (blue). The lightness difference was small across the samples, *dam* (black) being an exception. The colour centroids obtained for *thaw* (gray) in the 3 methods were close to each other.

The advantage of the CS over the CT method is that a greater number of non-basic, non-monolexemic colour names could be recorded. This method is similar to OL in terms of presenting samples sequentially to the subjects. The disadvantage of CS compared to CT relies in the time consuming procedures of colour naming and analysis.

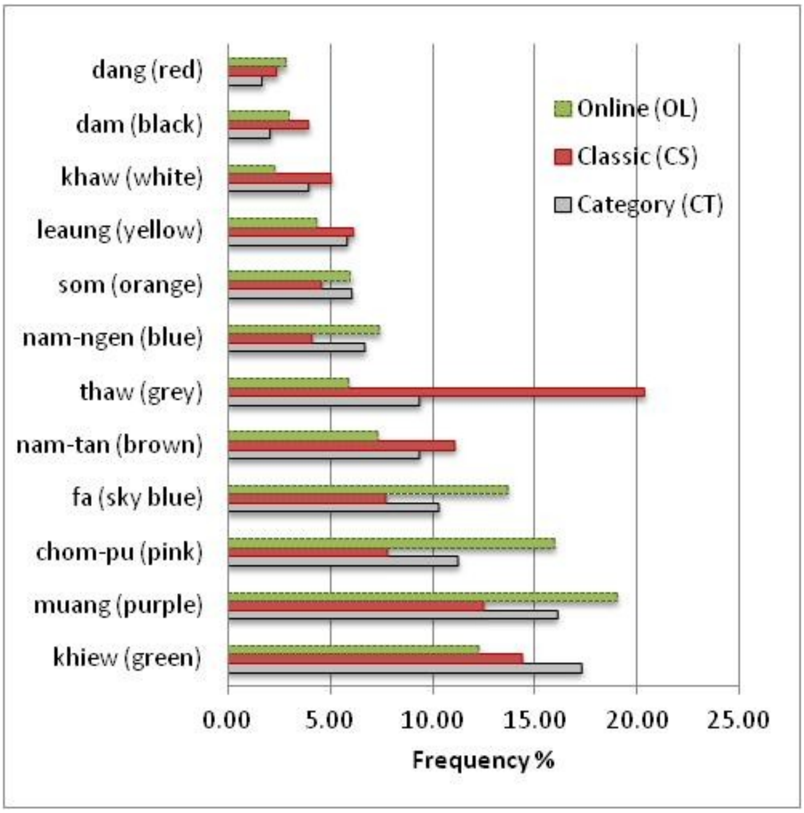

Figure 1: Frequencies of basic colour terms plus fa (sky blue).

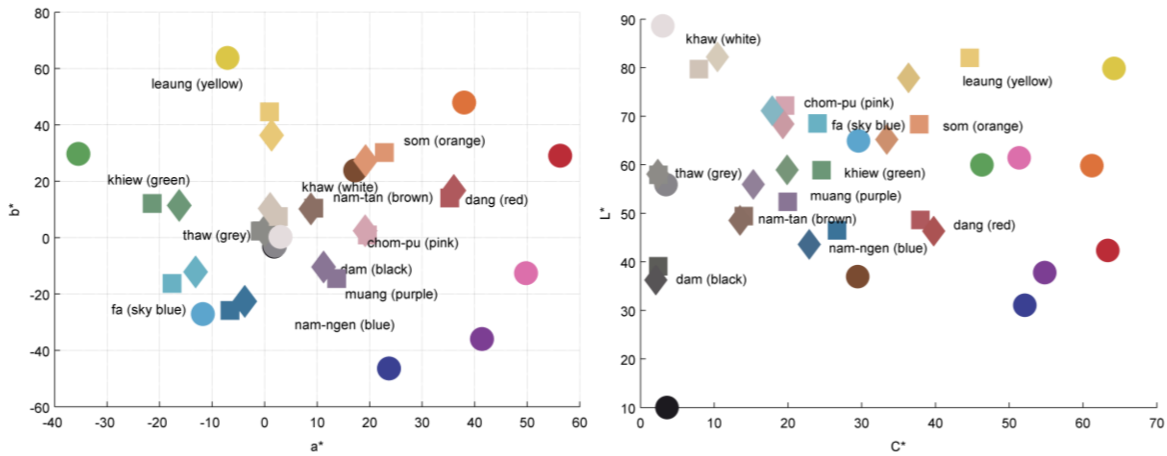

Figure 2. Colour centroids of basic colour terms plus fa (sky blue) obtained by CS (square), CT (diamond) and OL (circle) methods, D65/10°, left plot is CIE a b* showing hue and chroma differences and right plot is CIE L* C* showing lightness and chroma differences.*

4. CONCLUSIONS.

In this study, we presented a comparison of the frequency and location of basic colour terms in Thai among three experimental procedures. The small differences observed between the two laboratory procedures (CS vs. CT) might be due to the same type of colour samples and illumination used in both methods and the effect of size and surrounding. The relatively larger differences between online and laboratory (CS vs. OL and CT vs. OL) observed mainly in chroma might be the result of different sampling and different display medium and the constrain of subjects in the laboratory setting to use foreign influenced words. Our initial results are encouraging, but further work is still needed to develop a comprehensive colour naming model to facilitate colour communication across cultures including the analysis of basic and non-basic colour names and their response times.

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A Study on Elements Perceived as Traditional among Fabrics and Colors for Hanbok

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ABSTRACT

Recently, traditional Korean clothes Hanbok, being perceived as inconvenient and out of style, are evaded from young people and daily life. Thus, this study felt the need to develop colors and materials of Hanbok and sought to investigate which kinds of fabric and color the young generation might feel as traditional or modern. On the premise that the extent of people's perception as traditional might differ by color or fabric, the study arranged 100 color sample chips composed of various fabrics such as cotton, satin, chiffon, organdie and fabric for Hanbok, and conducted questionnaire survey among 15 women in their 20s and 30s. As a result, the study found that regardless of fabric types, colors with high lightness were dominantly perceived as modern, while those with low lightness as modern. And as the significant difference the study also found that while fabrics perceived as traditional had no big difference, chiffon and organdie-transparent and thin fabrics-were not perceived as modern. Based on these findings, this study expects that if fabric for Hanbok were used excepting fabrics such as chiffon and organdie, also along with colors with high lightness, it will contribute to modernization and popularization of Hanbok.

1. INTRODUCTION

As Korean people's overall lifestyle has been westernized since the modernization in the mid 19th Century, traditional Korean clothes Hanbok, being perceived as inconvenient and out of style, just maintains its status as a high-class formal dress to be worn in the events such as first birthday party and 70th birthday party. As for reasons for that phenomenon, Soo Ae Kweon, Jong Myoung Choi, Eun Kyung Lee (1998) attributed to 'inconvenience in activity', 'cumbersomeness' and 'difficulty of handling', while Kyung-Hee Hong(2007) attributed to 'inconvenience', don't like the image', and 'don't like to attract the attention of others' for the reason why traditional Hanbok is averted in daily life. This tells people's perception has not changed in the course of over 10 years time, highlighting the urgency of Hanbok's modernization .

Under the circumstances. this study, in an attempt to develop various colors and materials for Hanbok, sought to investigate which kinds of material and color the young generation might feel as traditional or modern, including modern material as well as material for Hanbok. If materials and colors of Hanbok were to be used in a modern style based on the findings of this study, the study expects, it will contribute to modernization and popularization of Hanbok.

2. METHOD

Prior to experimental design, the study established two hypotheses to identify how color is to be perceived as traditional depending on fabric - the purpose of this study. One is that same color may generate different feelings of being traditional depending on fabrics. Another is that same fabric may generate different feelings of being traditional depending on colors.

2.1 Collection of survey data

Building on these hypothesis, the study conducted a questionnaire survey by comparing fabrics actually used in Hanbok with those generally used in modern clothes. As the first step, the study collected recently-used samples of fabrics for Hanbok and then collected fabrics such as cotton, satin, chiffon and organdie largely used for modern clothing. It selected 100 samples in total by matching fabrics identical or similar with fabric for Hanbok.

2.1.1 Types and features of fabric

Looking at features by the fabric type used in this experiment, fabric for Hanbok has fine and precise structure as well as diverse textures and designs, whereas cotton has a bit rough surface due to relatively thick threads and its structure of plain weave. Satin, closely woven by thin threads, has soft surface and lustre. Unlike the above fabrics, chiffon and organdie have such a loosely woven structure as to be visible the other side, while they are distinct in that chiffon is soft and organdie is quite stiff.

2.2 Composition of questionnaire and analysis methods

100 random sample chips produced by the above method were distributed to the subjects of the survey. The questionnaire comprized three choices; they were supposed to choose 'traditional' and 'modern' if they found each sample to be so and 'neutral' if they found the sample didn't belong to any specific category. And the subjects were asked to check if each sample were perceived 'traditional' or not.

The survey was conducted among female graduate students in their 20s and 30s who were sensitive to colors, and based on the analysis of frequency of answered outcomes, the study analyzed the distribution of CIELAB values of the samples.

3. RESULTS AND DISCUSSION

The result of classifying totally 69 samples with distinct differences - those with the most votes and getting seven or more votes beyond the majority at the same time - showed that 31 samples were perceived as traditional, 17 were as modern, and 21 as neutral. However in an effort to investigate definite colors perceived either traditional or modern, the study excluded the samples that were answered as 'neutral' or didn't have clear distinction with one vote difference or the tie.

3.1 Analysis by the color

Looking at the distribution of CIELAB color coordinate of the samples consistently perceived as traditional or modern regardless of fabric types out of the samples with same color but different fabric, the samples perceived as modern were evenly distributed for their chroma but were mainly situated at high lightness, while the samples perceived as traditional were centered on low chroma and low lightness. And the colors perceived as traditional were mainly revealed as R group, RP group, B group. On the other hand, the colors perceived as modern were evenly distributed among R group, Y group, G group except B group <Figure 1>. <Table 1> shows the colors perceived as either traditional or modern regardless of fabric types.

Table 1. Color with consistent images

Traditional	Modern

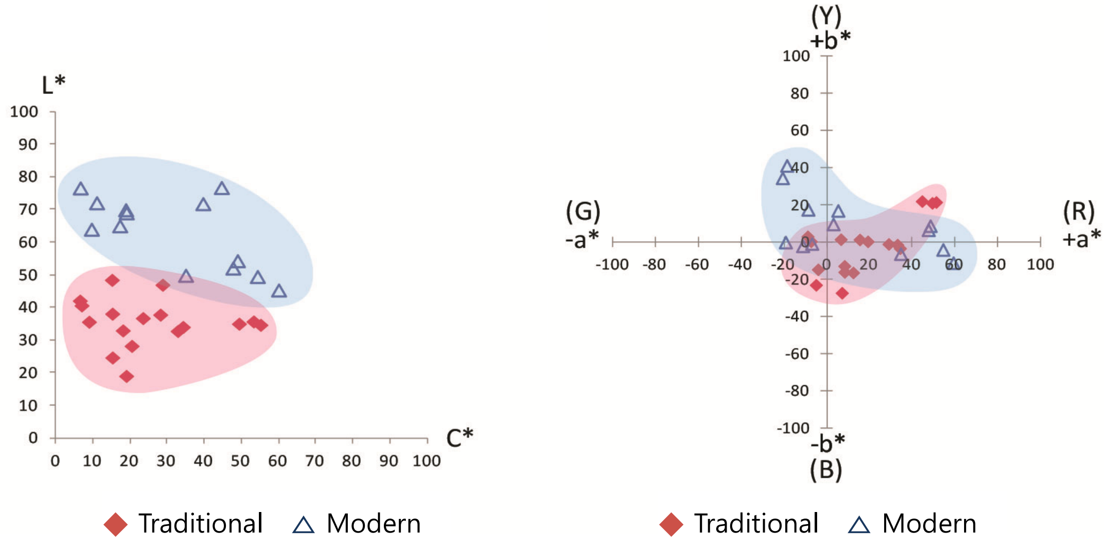

Figure 1. Color distribution with consistent images

3.2 Analysis by the fabric

Looking at fabric types selected by each image, all fabrics such as fabric for Hanbok, cotton, satin, chiffon and organdie were perceived as traditional, whereas only fabric for Hanbok except chiffon/organdie, cotton, satin were perceived as modern.

And looking at the rate selected as traditional or modern in proportion with the sample number of each fabric type as per <Table 2>, organdie, chiffon, fabric for Hanbok and cotton were more selected as traditional, while satin had the same perceived rate between being traditional and modern.

Based on these findings, the study was able to identify that fabrics with traditional image had no big difference, while thin and transparent fabrics such as organdie, chiffon were not perceived as modern.

Table 2. Selection rate of the image by the fabric

Fabric type	No. of samples	Traditional		Modern	
		n	%	n	%
Hanbok	24	8	33.3	5	20.8
Satin	24	8	33.3	8	33.3
Chiffon	16	3	18.8	0	00.0
Organdie	8	6	75.0	0	00.0
Cotton	28	6	21.4	4	14.3
Totall	100	31	31.0	17	17.0

n : No. of selected samples by the fabric

3. CONCLUSIONS

As a matter of fact, Hanbok does not get good response from contemporary young generation despite a diverse range of the industry's efforts to modernize and popularize it. And in an attempt to find ways to overcome this circumstance by modernizing materials and colors of Hanbok, this study used 100 color chips composed of fabric for Hanbok and modern fabric and conducted the survey on whether how people might perceive either traditional or modern depending on fabrics and colors.

Based on 31 and 17 samples perceived as traditional and modern respectively, the study conducted analysis of sets composed of identical or similar colors regardless of fabric types and as a result found that the scope of colors perceived as Hanbok were situated at high lightness and that of colors perceived as traditional were centered on low chroma and low lightness. On the other hand, the colors perceived as modern were evenly distributed among R group, Y group, G group except B group. Looking at the analysis by the fabric, fabrics with traditional image had no big difference, while thin and transparent fabrics such as organdie, chiffon were not perceived as modern.

Based on these findings, the study revealed that important factors influencing people to perceive either traditional or modern included R group colors with low lightness and low chroma - colors absolutely felt as traditional regardless of fabric types - and colors with high lightness -colors felt as modern - as well as thin and transparent fabrics such as organdie and chiffon.

If, building on these, the Hanbok industry were to produce Hanbok using colors with high lightness - perceived as modern - or using mainly fabrics other than organdie and chiffon, and ultimately combining colors perceived as modern with fabrics other than organdie and chiffon, it is expected to contribute to modernization and popularization of Hanbok.

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THE POSITIVE IMPACT OF IMAGE BY COLOUR FOR VULNERABLE PEOPLE

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ABSTRACT

The participants of "the Positive Impact of Image by Colour for Vulnerable People "project learned to re-discover their positive self-image, build their self-esteem and feel more confident to achieve their life goals all through simply enhancing their physical appearance and the colour of their clothing.

They have benefited from this advice by feeling more confident, finding work and having hope after major life changes.

The first part of the project was presented in the AIC 2014, in Oaxaca, Mexico, it was well received .
I would be honoured to present the results of this continuing project in Tokyo 2015.

1. INTRODUCTION

The proposal of this presentation at 2015 AIC Midterm Meeting in Tokyo is about how Image by Colour has helped vulnerable people.
I am currently volunteering my services in Australia to help people who are vulnerable, disdvantaged or feeling isolated from society. For example:
Victims of discrimination and racism , as victims of domestic violence ,victims of bulling , People with disabilities , women with emotional or physical hurts, whose self-worth was very low, refuges and migrants need to start a new life in Australia.

People with mental ill-health and mental disorders are particularly vulnerable to infringement of their civil and human rights and to discrimination [1].

Racism can isolate and exclude people preventing them from having equal opportunities to integrate to the society, The impact and negative effects increase distrust, fear and resentment , depression stress and anxiety. [2]

In Australian studies, self-reported racism has been associated with substance use, emotional and behavioural difficulties, and suicide risk for young Aboriginal people [3]

A 2009 joint report by the Women's Centre for Health Matters (WCHM), the Domestic Violence Crisis Service (DVCS) and Women with Disabilities ACT (WWDACT), *Women With Disabilities Accessing Crisis Services* found women with disabilities are more likely to experience abuse or violence than women without disabilities .[4]

The Image by Colour service supports respect of their diversity by creating a genuine, unique and harmonious image. This influences, from the first contact, the impression others have of them, trought to show the correct colour in their garments

2. METHOD

Coaching by customized instructional, training and guidance intervention designed to improve the performance and capacity of the participants, team. The Image by Colour, coaching is characterized by intense, sustained non-judgmental and assistance, support by giving feedback to set goals, identify obstacles, and develop plans trought their image and colours and strategies to achieve goals.

Image by colur coaching was integrated by one- to one colour analysys, support their individual needs in his vulnerable status and their guardrobe and also by "peer coaching" , that help to encourage with a very positive feedback of the participants to each other.

Imageby colour Coaching was provided to each particpant:

Hel ping Relationship and tools characterized by the provision of assistance, tesmtimonlila, personal colours and set of garments to start to use their right colours.

Particpipants receibed caring by created environments characterized by qualities such as helpfulness, concern, empathy, kindness, consideration, good will, responsiveness, and ways to love theirself.

2.1 Sample Preparation

The participants achieved to identify by couching one –to-one the difference between warm and cool colours . Identified their natural colours and subtones can use to achieve the feeling of the confidence to look younger , more vibrant and energetic. Their skin colour are smooth and their texture looks radiance, with healthy gleam in their eyes.

The participants identified wrong colours that affect their appearance: look older, exhausted, ill or dull.

The participants identified how enhance use their own friendly colours based on their skin, hair, eyes, persona and culture.

The participants identified their season and how combine their seasonal colours and enhance by their personality how combine, contrast and coordinate colours for their own benefit for different occasions through clothing, accessories and right hair colour.

The participants with severe level of disability received also one- to-one coaching, with less possibilities to identify why their range the colours was causing the positive impact of the colour , however the mood and attitude was recognized for them and cares. Trough their careers, who received all the information we continue the experimental procedure with this vulnerable sector.

2.2 Experimental Procedure

The participants in a team with peer gain a personal perception that why psychologists have determined that the colour is the first concept about a person's appearance. Its impact is immediate and long-lasting.

The participants recognize how the right and incorrect colours used in a period of 6 months was affecting their mood, apparent age, their attitude on life and the overall impression can make on others. They was using the "wrong colour" for some hours 2 days a week to measure trhe impact with others and in their own perception of them.

By groups the participants ask each other: What kind of first impression do you make?A first impression is the most important impression you'll ever make--and you get only one chance to make it .5

Left side wrong colours - Right side right colours

3. RESULTS AND DISCUSSION

Table 1. Positive Impact of Image by Colour		
	Increase selfesteem	Increase confidance in participants
• Economical disvantage	• 12	• 12
• Disability	• 6	• 6
• Feelings of Devaluation	• 25	• 25

Table 1. Positive Impact of Image by Colour

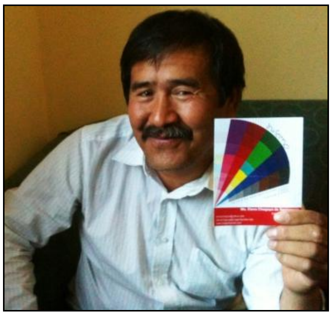
In the process ot the project the Positive Impact of Image by Colour for Vulnerable People the participants also experimented by wearing cloth new and brand name with status of expensive cloth but not in their range of positive colours, as consequence they have the opportunity to compare how they feel how the people treat them. The general impression is with that kind of cloth means wrong colours in expensive garners only cause the effect to focus the attention in the cloth, not in the person.

The discussion was centred about new cloth and good quality or famous brand names are better elements to create a positive image don't matter what is the colour.

Their validate that by wearing old, but in good condition garments in the right colours the participants by the coach of Image by Colour obtain the skill to coordinate an effective, smart and functional wardrobe that will help create a positive image of them with less effort and money.

The key of the reflection for the vulnerable sector is that a lot of them are accepting use garments are reusable, recycle or old by receiving as present, donation or by buying in : opportunity or second hand stores.

The result to wear in the last period of the project their correct sub tone and degradation of colours in the range of "best" colours enhance their harmony was a very satisfaction result for all of them and relatives to see then with a very happy and confident face.



4. CONCLUSIONS

All vulnerable sector, women and men, not just statues, famous or rich people can develop their self identify while gaining respect for their diversity through an enhanced genuine and harmonious self image.

To find, use and coordinate a range of positive and friendly colours is the key to portray you and create a positive image of yourself.

Be mindful that the holistic synergy in the vulnerable sectors need the support of the social workers, doctors or therapists and the valuable psychological support are parallel a this service. However dear lovers of the colour :

The benefit to support vulnerable people , who start to be selective , admire and value their image which already started to love in the mirror, the feeling of confidence to enhance to use their skills, talents . Enhance their proud of their unique diversity , background and personality is the best humble but impressive , important and impact job that the colour for Vulnerable people is causing..

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Faith in the power of color: Spiritual revival from the East Japan Earthquake disaster

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ABSTRACT

The Pacific Ocean coastal area of Tohoku, Japan suffered extensive damage due to a massive earthquake and tidal wave, which occurred on March 11, 2011. The entire infrastructure and memories of towns disappeared in a short moment. 15,891 people died, 2584 people were missing, and 6,152 people injured. Though the landscape changed beyond recognition, people seemed to experience a revival to the living world through the use of color. I discovered this when my eyes beheld the color in the landscape. This contrast between a relative figure and the background, can be considered as *hare* and *ke*, using Japanese concepts. Color is the accent spread on a level landscape as *hare*, meaning uncommoness. It works as a spice. For example, there was the cheerful color of *senbazuru* (one thousand paper cranes), *dashi* (a kind of float with a variety of decorations in festival parades), *tairyohbata* (good catch flag), and the flowers blooming on rubble of the collapsed schoolhouse painted by high school students and their teacher. These colors can be considered a sign of courage, or maybe as an anchor, or perhaps as many good wishes.

Color is a flower. Furthermore, while there is life, there is color. The faith of the entire culture and daily customs are formed as a result of personal modest daily beliefs. In this article, I wish to make certain that color accompanies the people of Tohoku to recover from this calamity. I will use these ideas as a clue to explore a relation between the Japanese spirit and treatment of color.

1. INTRODUCTION

Tohoku, Japan has a severe climate but has been blessed with the rich harvest from the sea, woods and fields. Many customs, traditions, and festivals bringing people into contact with nature have been handed down through the generations. The scenery of the coastal area was changed completely by the serious tsunami damage of the East Japan Earthquake on March 11, 2011. Several tidal waves caused by the intense earthquake destroyed almost everything, while reaching inland to the forest floor, carrying almost everything along in the undertow. The amount of wreckage was almost insurmountable. If I look at this from another perspective, the wreckage at least left some fragments of life before the tsunami. This situation caused most people inner conflict. It was a time of countless funerals. Sky, soil, and plants - this landscape without any artifact from the modern era closely resembled an ancient era (Figure 1,2). In those days, human beings constructed their life by using only basic tools and materials. People's minds as well as the material civilization were injured now.

When I visited there with a great deal of anxiety, I was convinced that color could bring out people's vitality to get them through their unprecedented loss. For example, I could see the cheerful color of *senbazuru* (one thousand paper cranes), *dashi* (a kind of float with a variety decorations in festival parades), *tairyobata* (good catch flag), and the flowers blooming on rubble of the collapsed schoolhouse, painted by high school students and their teacher. The brilliance of tint produced an attractive contrast in the landscape that had lost its focal point.

Figure 1:Migratory birds return as usual to the salt water paddy field in winter. (Rikuzentakata,December 23,2012)

Figure 2:"The miracle pine tree" also gave courage an anchor, and wishes to many survivors.(August 17,2012)

2. LANDSCAPE OF COLOR AS *HARE*

In this section, I will introduce the three phases after this calamity to consider the power of color as well as a healing: that of natural sight, traditional rite, and activity of people.

2.1 Flowers

Snow fell after the disaster in March; weeds covered up a scar in the ground in summer. Below, in figure 3 and 4 the scene looks like a calm grassland. But a vacant house in the midst of the grassland can be seen. A curtain fluttered from a broken window. The residential area from the past was quietly spread under the sky. Though the rubble was almost all disposed of, fragments of someone's life were still scattered throughout the bushes. Between the sky and the aimless ground, my eyes were attracted to yellow and red flowers. Then, I noticed that there were floral tributes placed here and there. I respectfully restrained from taking pictures since the flowers represented a private requiem. It was the season of *Obon* (a memorial service event for dead persons and ancestor spirits).

Figure 3,4; At Ishinomaki, Miyagi(August 8,2012)

2.2 *Senbazuru* (One thousand paper cranes)

There were dead cedar woods here and there at the foot of the mountains. Sea water reached the woods and left damage to the tree roots. After passing several such mountains, a colored banner on a protection wall suddenly appeared (Figure 5,6). The plates of *Tatsuganesan* were on a slope of lost woods. Other plates stating, "Thank you very much to everyone in the world" were on the protection wall, too. Banners of vivid colors were a length of *senbazuru,* one thousand folded paper cranes. *Senbazuru,* which is many folded paper cranes linked together, is the offering or charm which is an enduring symbol of wishes for a recovery from illness and also for longevity. These colored *senbazuru* banners, appealed with gratitude citing, "We make an effort to be fine."


Figure 5

Figure 6

Figure 5,6; on the way to Minami Sanriku cho from Kesen cho (August 8,2012)

The Japanese Kanji character for *Engi* (Luck) is found here. Sometimes, a small shrine is built at the entrance to a particular place, like a village, or the entrance to a mountain. Often, *Engi* marks the spot where a miracle took place. Every so often, it is used to repel vice or bad things. Engi can also be used as a memorial. This place became a new small shrine (Figure 7,8). One thousand folded paper cranes and floral tributes have been offered. The prayer says "Rest in Peace."


Figure 7


Figure 8

Figure 7,8; At the Disaster Prevention Office in Minami Sanriku cho (August 8,2012)

2.3 *Tairyohbata* (good catch flag)

A revival market *Isatomae Fukko* market was established at the foot of a mountain in Minami Sanriku cho(Figure 9). The Kanji of *Fukko* (revive) is the same sound as *Fuku*

Figure 9: Isatomae Fukko market in Minami Sanriku cho (August 8,2012)

(lucky) + *ko* (happy), so people like to use the latter kanji. Many cheerful good catch flags were waving with several other flags. The good catch flag is a lucky charm that wishes safety for a ship and offers a prayer for a big catch of fish. It is very familiar to the people of this region. The color red is believed to hold power like a talisman, and also represents rejoicing in Japan. There is also a practical use for red color in flags since it is easy to spot on a ship while sailors are at sea.

2.4 *Dashi* (a kind of float with a variety decorations in festival parades)


Figure10: Dashi, at Rikuzentakata (August 8,2012)

There is "Fighting Spirit Star Festival" which originated around 900 years ago in Kesencho, Rikuzentakata. At the neighboring town of *Takata*, "The Moving Star Festival" is also held every year nowadays. This festival takes place at the beginning of the *Obon*. Both festivals feature gorgeously decorated floats. People were able to hold the customary festival even though they were lacking many materials used prepare for the festival. Even though the festival decorations were only intended to be used once, they were assembled with the utmost care. This attention to detail might relate to*date*. *Date* is closely related to some important concepts in Japan, for example *kabuku, furiu* (or f*uryu*),and *basara*.. The spirit entailed in heavily decorating something is related to the *furiu* concept. Some of the dances and floats are named using *furiu*. Originally *furiu* was considered as something excessive. Recordings of this in the literature increased around the late Heian era to Kamakura era. The Kanji characters for *furiu* mean amorous in ancient Chinese language. Such meaning is included in the interpretation about *iro* in Japanese. *Iro* means mainly color, or amorous. Considering the common concept as explained earlier, it is possible to recognize excessive decorations and dramatic color as a natural progression. The remaining float became a spatial landmark in the grassland (Figure.10), although it is hard to remember its origins.

2.5 Persimmon

Persimmon is one of the predominant colors of autumn. The persimmon that has finished ripening on a branch is called *undakko* in the dialect of this district. The pronunciation of it is similar to the sound of the word meaning, "hold the luck" in Japanese, though the origin of this dialect has another meaning. Therefore, this brilliant color seems like an edible hope. People and birds share these gifts. Before it becomes *undakko*, people pick some of them to make dried persimmons. After peeling the skin, if they are kept hanging outside, sugar from the fruit seeps out. Fresh persimmons worn smooth through exposure to natural air glitter as they reflect the gentle sunshine in late autumn. (figure.11,12,13,14)..


Figure 11


Figure12


Figure 13


Figure 14

Figure 11,12: "Undakko" in nature,
Figure13,14: dried persimmon in field, at Rikuzentakata (December 23,2013)

2.6 Flowers blooming on the rubble

This disaster brought a many emotional difficulties for the people of the area. Everyone suffered extreme stress during the earthquake, and in the aftermath as they adjusted to a long period of being refugees. In such a situation, a teacher of fine arts from Hohara High School in Fukushima reached a sense of peace by drawing a picture. Then she started the project "Blooming flowers on the rubble" with her students. Though some of her students were not familiar with painting, everybody could make a flower bloom through their drawings (Figure15,16). The rubble used in this project is fragments of a collapsed schoolhouse. The teacher and her students gathered the pieces to be used for the paintings. Those "Flowers blooming on the rubble" will be placed beside the rebuilt schoolhouse in the near future. Sometimes they encouraged the refugees who lived in temporary housing by this project. Through this activity, they could exchange a smile with people here. The students of the project "Blooming flower on the rubble" graduated last March.

How much did the color comfort the silent rubble? Color becomes a flower here.

Figure 15,16; project "Blooming flower on the rubble" by students in Hobara High School and their teacher Atsumi Bansho, at the exhibition in Ginza, (February 23,2013)

3. FAITH IN THE POWER OF COLOR

On the way to Tokyo, I felt out of place, looking at the solid buildings and crowded houses since my eyes had experienced the ruin, the prefabricated temporary buildings or the containers in the disaster area. At this cityscape, the power of color seemed less important. What is existence of color? The evidence of contrast between an accent color and the natural color from the ancient era or the gray of an artifact can be related to vitality. There is a relationship between *hare* and *ke*. The landscape which pauses is daily life as *ke a*nd the tint of accent is *hare* as extraordinariness. When considering Japanese concepts, we can believe that color is related to the performing arts and entertainment. Try to take care with all things, realizing at the same time that there will always be change. It can be thought of as a kind of Japanese elegance. Variations in the festival is proof of *hare. Hare* appears with an upsurge, then disappears to become *ke*.

4. CONCLUSION

As stated above, the power of color is rooted in personal small daily beliefs. Faith in culture and customs is formed after understanding personal modest daily beliefs. Vitality is required to see color. Sensitivity to color is not only for discovery but is also a kind of proof of being alive.

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Types of Smart Cities | Cities Built from the scratch and Old Cities transformed into Smart Cities: What kind of colours can we use?

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ABSTRACT

Cities are the habitat of the knowledge based economy. Cities produce and attract human capital and are today giant interface of communication, Cities possess the critical mass for the production and diffusion of knowledge, innovation and integration of human networks, which enable sustainable growth. At the same time cities are the true heart of innovation. The aim of this paper is to create architectonic interventions on this new cities for the creation of spaces that all human beings felt comfortable as they are inside old cities and with modern and sustainable fields. This kind of new cities concept has to have more than only architecture Buildings and beautiful construction. They have to produce concepts of community for habitants and not only a networking but technologies. So this is the "bad" part inside this type of new U-biquous cities. All the Data from this cities has to be incorporate inside an Open Community Data, where the citizens participate actively on the decisions, and an empowering citizens in the construction of a participatory e-society. A city is not only a walkable place according to Jeff Speck: " …the author of "Walkable City: How Downtown Can Save America, One Step At A Time," a walk has to be useful, safe, comfortable, and interesting if you're going to get people out of their cars and into the sidewalks.". A city, and the Architecture that we have inside the city has to produce feelings and sensations to the population. A city is not an object as a simple "fridge". So, the focus is on the public spaces and on common areas inside the Buildings, how they connect with each other's is an objective and the Colors that we use, we see and we find are points that we can´t forget. The aim of this research is to determine some Architectural concepts that can help not only for cities, but especially for planners and architects, their role, their tools and theirs strategies. The paper argues that the strategic plan applied on this New Smart Cities it is helpful for the future sustainability of the maintenance of the space. Architecture systems could produce outcomes on the techno-economic scenario analysis and on the socio-economic impacts.

1. INTRODUCTION

"Smart Cities" are part of our modern society and are strong models on our generation, but as everything, we have the positive face and the negative face, it always depend of how spaces are used. These spaces are a reflection of the enormous technological advances provided by years and years of studies promoted by the human being, that in certain actions that go beyond the physical barrier allowing the people to live in a space at the beginning of virtually, without borders. Like many inventions changed the history, the Smart Cities are revealed as a tendency for new generations marking determining and creating a new type of culture. At the end, what are real Smart Cities? What are Smart Cities?[1]"…Across the world, the stride of migration from rural to urban areas is increasing. By 2050, about 70 per cent of the population will be living in cities, and India is no exception. It will need about 500 new cities to accommodate the influx…" according to this statement Human beings are trying to react to the law of supply and demand, and trying to find a way to be able to solve a future problem. Cities are modern creations[1]"…It is a city where information technology is the principal infrastructure and the basis for providing essential services to residents…" The origins can be at some especial lines[1]"…The concept of smart cities originated at the time when the entire world was facing one of the worst economic crises. In 2008, IBM began work on 'smarter cities' concept as part of its Smarter Planet initiative. By the beginning of 2009, the concept had captivated the imagination of various nations across the globe…" On article of 11 November 2014, on the SustainableCitiesCollective, Nina Bianchi e Kat Hartman, describe Smart Cities as[2] "…a skeptical image of a "remote-control city…". The definition says[3]"…A city can be defined as 'smart' when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement…". But Smart City means efficiency, but efficiency is where the human being is also involved in its development. Smart Cities are characterized as[3]"…Smart cities as «innovation ecosystems» could offer ample opportunities for sustainable, user-driven «intelligent services»…". If these spaces are well architectural designed, they can become multicultural areas and spaces of knowledge and development where the human being wants to live and feel with quality of life. However, the economic pressures have led some errors in planning and management. A city cannot provide this feeling[4]"…No other city in South Korea, has attracted more attention than Songdo, the skyscraper-intensive, apparently eco-friendly 'smart city' built along reclaimed waterfront land in Incheon, home of the country's largest international airport called Songdo International City, so called because of the 'ubiquitous' data-gathering technology. In recent centuries, and from 70's by Michael Graves and his concept of Re-design cities, or even the city model of Corbusier and several authors as Paolo Portoghesi were big influences on urban design. Colin Rowe also have been present as another influential but more focused on the American's city design. Léon Krier, Rodrigo Perez, Peter Eisenman, Daniel Libeskind and recently Norman Foster, are major influencers in these new concepts of Smart Cities. Maria Teresa Bilotta expose on her article on 22 December 2014 that Songdo is the first Smart City in the world [5]. It is a sustainable city, Green and full of technology and innovation. A city that contains a Central Park as referrer point, a semi imitation of Central Park in New York. A city that has 10 years of development. However, according Antony M Townsend, in his Smart Cities book [6] "…Songdo was originally conceived as «a weapon for fighting trade wars» the idea was «to entice multinationals to set up Asian operations at Songdo»… with lower taxes and less regulation…". Really Songdo since its inception that introduced the concept of a Free Economic Zone, an area with different regulation of the rest of the country, but it's not working like that and it has a lot of problems.

2. METHOD

This idea is based on logic with the concept and the implementation of Green Architecture and elements that create the Green Color on a city - the logic of Sustainable Urban and Energy. This initial question arises a sub - question to identify response that is characterized by knowing which color it has to be more present on the sustainable design method to be used. On 17 December 2014, The Guardian, by Steven Poole[7] said, "…The truth about smart cities: ‘In the end, they will destroy democracy…” and further underlines also “…The smart city is, to many urban thinkers, just a buzzphrase that has outlived its usefulness: ‘the wrong idea pitched in the wrong way to the wrong people’. So why did that happen – and what’s coming in its place?...” This research improve these cities to be projected and built today, improving its existence, its sustainability and improve the type of intervention in a new systems on the existing cities. There are situations that are not identifiable, as described Alain de Botton[8]”… Beautiful houses not only fail as guarantee of happiness, as can also be accused of failing to improve the character of those who live there …”, may not only be the image of buildings could describe the development of a city. Nerveless, Alain de Botton[8]identify a reality “…We have to ask what should be exactly the look of beautiful building …”. Zygmunt Bauman, on his book Trust and Fear at the Cities says[9]“…submit ourselves to the limits of our faculties: we know very well that we will never come to dominate completely the nature and our body also will never be immortal or also immune to the relentless course of time. Thus, we do not have, because another remedy that is not content with what exists. This is a finding that has no reason to discourage us or break the will to live, but rather should serve us encouragement and infuse us energy. While we can not completely extirpate the pain, we can, in some cases, eliminate it in part and in others relieve it. The question is to know about it persist, again and again, without faint…”.

2.1 Sample Preparation

A list of questions and analysis at experts ideas connected with the Smart Cities State of Art create this new type evaluation to apply in existing cities and in Future Cities.

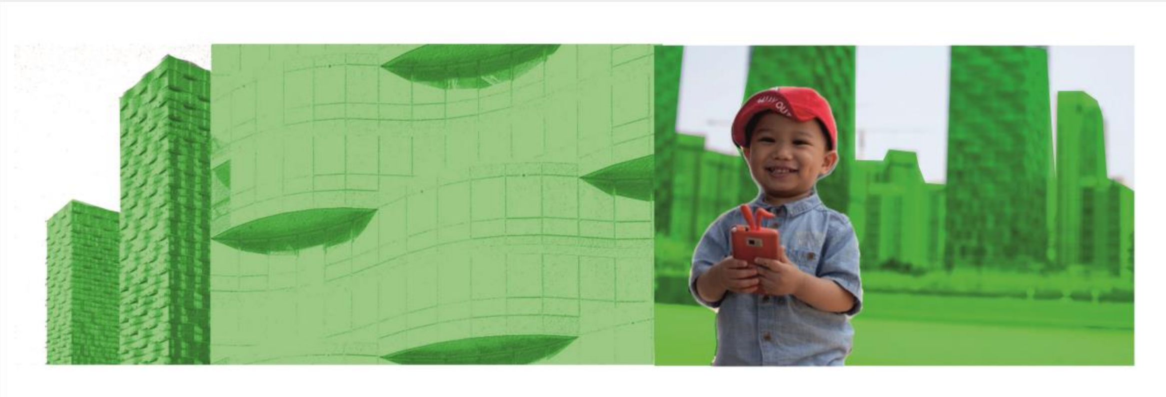

Figure 1: Songdo building Sharp I - by Ana Oliveira – transformed image

2.2 Experimental Procedure

This idea was based on interviews on experts, where were identified Colors on Smart Cities and the influences of colors on Smart Cities, searching for the best color to apply on the buildings and state of art of the predominant colors. Experts: CIKUTOVIC, Marco - AES Gener, Engineering Manager – Chile; DIAS, Solemain - Chadwick International School - Admitions Director, Brazil, DUMELIE, Geoff - Chadwick International School - Village School Counselor – Canada; HAN, Jisop - Opus Design and KPF - Director design – South Korea; JACKSON, Emma - Metroland Media Group - Canada-; KIM, May - Collins International - Real State advisor – Korea; MORE, David G. - Gale International - Project Manager – England; Polycarp, Clifford - Green Climate Found - Director Manager

– India, helped to create this analysis. Different colours were identified. And Green was the selected color. Green is a Sustainable color in all opinions.

Create an orientation basis on the demonstration of how architecture on city's can be changed according to the real importance and action in which the Green Architecture can produce big results in our days.

Figure 2: Flowchart illustrating the sample process.

With a Data Base and the Smart City concept, create a first a conclusion and a possible application on a Case Study.

3. RESULTS AND DISCUSSION

All Populations need to be informed and guided to preduce results from the initial planning of interventions inside Smart Cities. The solutions pass as well with improvement on the comunication with Universal Language because cities are not static are organic. People aspect cities with Quality and not ghost towns [10].

All this concepts with Green Architecture can be applied on Old Cities without the needing of a total demolishement. For choosing a color it's important knowing how people live and how people relate to city's too much important. Jan Gehl [10] explain [11] "... Cities are the places where people meet to exchange ideas, trade, or simply relax and enjoy Themselves ... The compact city - with development grouped around public transport, walking, and cycling - is the only environmentally sustainable form of city... the city must Increase the quantity and quality of well-planned beautiful spaces que are human in scale, sustainable, healthy, safe, and lively ... Cities ... They provide the structure que Enables cities to come to life, and to Encourage and accommodate diverse Activities, from the quiet and contemplative to the noisy and busy. The human city ... Creates pleasure for visitors and passers-by, as well as for those who live, work, and play there every day ... The Jan says: "We shape cities, And They shape us" ... "

The Green color is Balance and create positive feelings. Green color is Harmony and refreshment. Green color is Universal Love and equilibrium. It could have some negative feelings as stagnation and blandness as well. The Green color is on the center of the spectrum, a very important concept that people doesn't realize. A place with plenty of green transmit the water presence and a nature feeling. History and old elements are very important for the lives of human beings and Green produce that.

Symbols in a city are an automatic human reaction. Jan Gehl [10] also notes the following [11] "... walking, stopping, resting, staying and conversing. Unpredictability and unplanned, spontaneous actions are very much part of what makes moving and staying in city space such a special attraction."

Country	City	Color	RGB	
USA	San Francisco	Auburn	#841B2D	
Mozambique	Maputo	Camouflage Green	#78866B	

Thailand	Bangkok	Chamoisee	#A0785A	
Cuba	Havana	Cerulean Blue	#2A52BE	
Argentina	Buenos Aires	Columbia Blue	#C4D8E2	
Peru	Lima	Chocolate (Web)	#D2691E	
Germany	Berlin	Ash Grey	#B2BEB5	
Italy	Sicilia	Citrine	#E4D00A	
South Korea	Seoul	Dark Gray (X11)	#A9A9A9	
Austria	Vienna	Deep Violet	#330066	
China	Macau	Buff	#F0DC82	
United Kingdom	London	French Bistre	#856D4D	
Scotland	Edinburgh	Fern Green	#4F7942	
India	New Delhi	English Red	#AB4B52	
USA	New York City	Electric Yellow	#FFFF33	
Portugal	Lisbon	Cosmic Latte	#FFF8E7	
China	Beijing	Ebony	#555D50	
Italy	Rome	Camel	#C19A6B	
Japan	Tokyo	Amethyst	#9966CC	
France	Paris	Champagne	#F7E7CE	
Morocco	Marrakech	Café Au Lait	#A67B5B	
South Korea	Songdo	Cadet Grey	#91A3B0	

Table 1. Summary of the results from the experiment.

The Green color[14]represent fresh air. The color of the interior and exterior spaces are human influencers as is proved. Peter Zumthor [12] also transmits in his book Atmospheres [13] "... I enter the building see the room and - in the fraction of a second - have this feeling about it. We have perceive atmosphere through our emotional sensibility - a form of perception that works incredibly and Which We humans evidently need to help us survive ... I have no idea why that is so, but it's like that with architecture too ... ". Population, cities, governments, companies will benefit with this new concept. More oxygen, more quality with a Green color.

4. CONCLUSIONS

All of the Smart Cities are not follow the original concepts of Sustainable spaces, its important to change that. For trasforme and create a sustainable city, the amount the is needed is very big, so the direct focus on the population has to be very strong and productive. All Smart Cities have to improve to maintain the population, becouse only with this focus, the space is prepare to make and produce results to create mechanism to apply on new technologies or ether to transform the Spaces in Sustainable and autonoms areas. The Green color, in this case, can be applied in Songdo and in other Smart Cities in Asia because of the polution, but in the future, other colors can be supporting this idea. For now the Green is the solution.

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The Use of English Colour Terms in Big Data

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ABSTRACT

This study explores the use of English colour names in large datasets from informal Twitter messages and the well-structured corpus of Google Books. Because colour names in text have no directly associated chromatic stimuli, the corresponding colour categories of colour words was assessed from responses in an online colour naming experiment. A comparison of the frequency in the three datasets revealed that the mapping of colour names to perceptually uniform colour spaces does not reflect natural language colour distributions.

1. INTRODUCTION

Colour plays a central role in visual perception and can be a powerful tool to differentiate emotions, ideas and identities. We are able to see millions of different colours but we tend to organise them into a smaller set of colour categories and give them names such as yellow, peach or sky blue. There is a growing interest in the language of colour, and over recent years colour naming models have been used for gamut mapping (Motomura, 1997), image processing (Moroney *et al.,* 2008) and colour selection (Heer & Stone, 2012).

In this paper we explore natural language processing and data visualisation methods for understanding the use of colour names by analysing a large pool data from Twitter and Google Books. Because colours in language have no direct reference to chromatic stimuli, we accessed the associated colour categories of each colour name from the responses of hundreds of participants in an online colour naming experiment (Mylonas & MacDonald, 2010).

Twitter is an open micro-blogging platform that allows millions of users around the world to broadcast and receive in real time short messages, known as *tweets*, of up to 140 characters long. Twitter's conversations are public by default and organised by community-driven practices. This provides researchers with the opportunity to analyse multilingual everyday conversations outside of formal institutional environments.

In 2001, Google created a large corpus of n-grams based on ~4% of all books ever published. N-grams refer to the sequence of n words found in all digitized books. The first edition of the corpus consisted of over 500 billion words published between 1500 and 2000 in English, French, Spanish, German, Chinese, Russian and Hebrew (Michel *et al.* 2011). A new edition of the corpus provides syntactically annotated n-grams and their counts with part-of-speech (POS) tags from over 6% of all books ever published in 8 languages (Lin *et al.* 2012). POS taggers classify words as nouns, verbs and adjectives, etc. and provide an instructive form of word-category disambiguation in a given context.

An online colour naming experiment (Available at: http://colournaming.com) was designed to collect broad sets of multilingual colour names with their corresponding colour ranges in sRGB and Munsell specifications. Over the past seven years (2008-2015) the server has gathered responses from thousands of participants in fourteen languages: English, Greek, Spanish, German, Catalan, Italian, simplified and traditional Chinese, French, Korean, Danish, Lithuanian, Thai and Portuguese. The server also gathered the response time for each colour name and associated metadata regarding the cultural background, colour deficiency, hardware/software components and viewing conditions of the participants (Mylonas & MacDonald, 2010).

The Munsell system is the most widely used apparatus in colour naming research, despite its limitations, as it provides a pragmatic colour space to map colour names to perceptual colour coordinates. The system divides the colour space evenly into five primary hues (yellow, red, blue, purple and green) and five intermediate hues. Purple was included as a primary because there are about twice as many perceptible hue steps between blue and red as between red and yellow, or yellow and green, or green and blue (although in nature we might find relatively fewer purple colours). A renotation was carried out (Newhall *et al.,* 1943) with the objective to represent perceptually uniform hue, saturation and lightness spacing based on the principle of the Just Noticeable Difference (JND). The Munsell colours do not represent typical naturally occurring colours as their pigment spectra are smoothed in comparison to naturally occurring spectra and while it covers all the most important regions of colour space, some areas are not well represented (Buchsbaum & Bloch, 2002).

Considering that colour coding may reflect the colours available in our environment, previous studies have focused on uniform colour spaces and image statistics of natural scenes (McDermott & Webster, 2012). In the present study we asked instead whether colour language is efficiently represented in perceptual colour spaces and examined whether the statistics of colour in written language follow the distribution of colour names mapped to an approximately uniform colour space in an online colour naming experiment.

2. METHOD

We analysed 10,000 responses in the online colour naming experiment from 500 UK-resident English speakers, of which 90.3% reported normal colour vision. Colour name responses most often were of a single word (monolexemic) but could consist of an unlimited number of words. We identified the most frequent 50 monolexemic colour terms responded 20 times or more in responses from non-deficient observers over the age of 16. To access the associated colour categories of each colour name we retrieved all colour samples given the same name.

To explore the usage of colour names in informal, online conversations, we took the 50 most frequent monolexemic colour terms from experiment responses, and measured their probability in 1,036,103 random tweets from the Twitter API. We filtered Twitter's public stream with the geo-location coordinates of [-5.4,50.1,1.7,55.8] that correspond to a rectangle with edges approximately at the edges of Britain. We excluded tweets in other languages than English {'lang':'en'}. Each tweet was tokenised into unigrams using the Natural Language Toolkit (Bird *et al.*, 2009) and typographical conventions were removed resulting in 129,355,280 tokens.

Messages in Twitter are limited to max 140 characters and often consist of non-standard English that makes the task of word-category disambiguation challenging. For example, it is difficult to determine whether the word *orange* is being used metonymically as an adjective to describe the colour of an object, like an orange table, or is being used literally to describe a type of citrus fruit. To investigate the use of colour names in context and disambiguate their syntactic role, we also counted the probability of the 50 most frequent monolexemic colour terms from experiment responses in the syntactically annotated Google Books corpus of all digitised English books between 1500-2000. The frequency of occurrence of each unigram was counted by dividing the number of instances of each unigram in the given years by the total number of tokens (n=468,491,999,592) in the corpus for the same years (Lin *et al.,* 2012).

2.1 Sample Preparation

The 600 total test samples in the colour naming experiment were specified in the sRGB colour space and selected from the Munsell Renotation Data (Newhall *et al.,* 1943). The original dataset consisted of 2729 colour samples specified in CIE *xyY* colour space and viewed against a neutral grey background under illuminant C. Since achromatic colours were not included, nine neutral samples, one for each Munsell Value and a White and a Black sample at the extremes of the sRGB cube were added. Colour samples lying outside the sRGB gamut were discarded. Given the cylindrical coordinate system, the sub-sampling of the remaining in-gamut colour samples followed a similar approach to the advice of Billmeyer to Sturges & Whitfield (1995), namely to equalize the perceptual distances between samples (Mylonas & MacDonald, 2010).

2.2 Experimental Procedure

The procedure in the online colour naming experiment consists of six steps (Figure 1). First, we ask the observers to adjust his or her display to sRGB settings, and the brightness in order to make visible all twenty-one steps of a grey scale ramp. In the second step the participant answers questions relating to the lighting conditions, the environment and properties of the display. Then, in the third step, the participant is screened for possible colour deficiencies with a simple web-based Dynamic Colour Vision Test developed at the City University London (Barbur 2004). The fourth and main part is the *unconstrained colour-naming task*: any colour descriptor, either a single word, or a compound, or terms(s) with modifiers can be entered to describe each of twenty samples presented in sequence and randomly selected from the 600 in total samples. Along with the colour name typed on a keyboard, the response times (RTs) of onset of typing are recorded, defined as the interval between presentation of the colour stimulus and the first keystroke. In the fifth step we collect information about the participant's residency, nationality, language proficiency, educational level, age, gender and colour experience. In the last step we provide the participant with a summary of the responses.

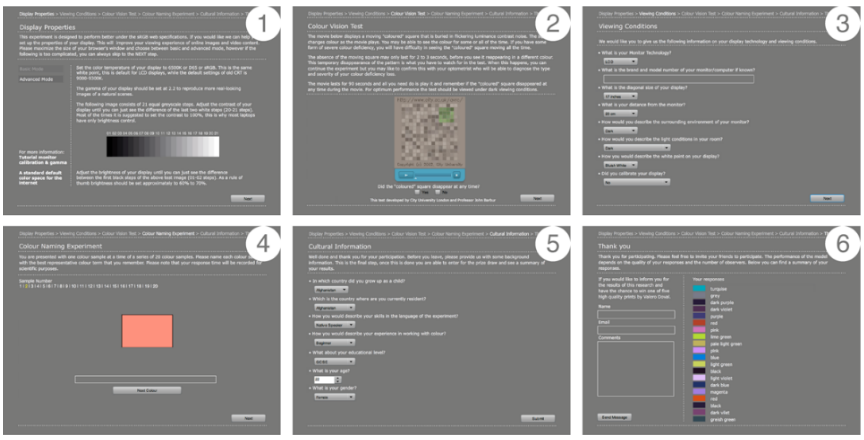

Figure 1: Flowchart of the experimental procedure (Available at: http://colornaming.com)

3. RESULTS AND DISCUSSION

The probability of the most frequent monolexemic colour terms from experiment responses in Twitter messages is shown in Figure 2. For clarity, we have chosen a cut-off of 30 most frequent terms in Twitter given that non-expert observers are able to identify 30 colour names in their native language without training (Derefeldt & Swartling, 1995). *Black* and *white* were the most frequent colour terms followed by *red*, *cream* and *blue*. *Yellow* was found in the 9th position while *indigo* and *teal* were ranked at the bottom of the list. The absence of context in this approach produced an issue of word-category disambiguation. For example, we were not able to disambiguate whether *cream*, *orange* and *salmon* were used as nouns or as adjectives. In Twitter messages this is a particularly challenging problem as the character limit and conventions of text communication forces users to compress more information into fewer characters without conventional use of grammar and syntax. For well-structured corpora such as books and articles, POS taggers achieve higher accuracy.

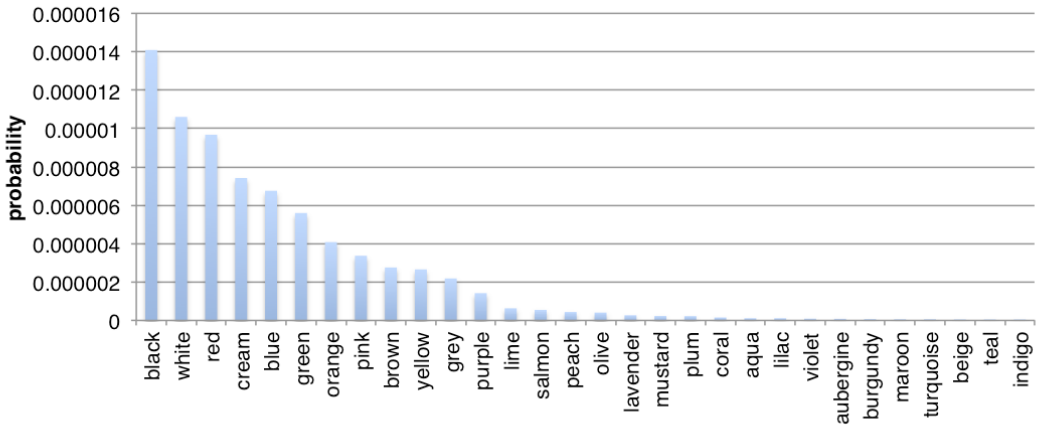

Figure 2. Top 30 most frequent colour terms in ~1 million Twitter conversations

Figure 3 shows the probability of the 30 most frequent English colour terms used as adjectives in the syntactically annotated Google Ngrams Corpus from the 50 most frequent monolexemic colour terms from experiment responses. *White, brown* and *red* were the most frequent colour terms followed by *blue*, *black, green* and *yellow*. The least frequent terms were *khaki*, *turquoise* and *maroon*.

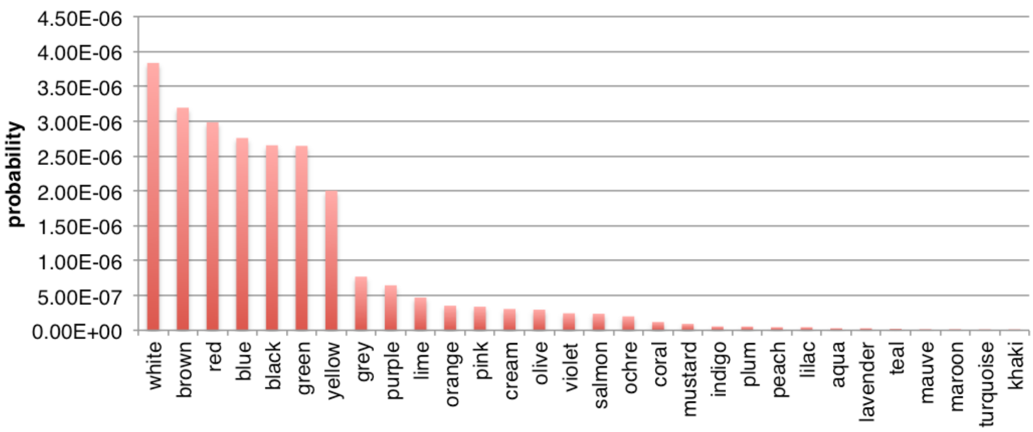

Figure 3. Top 30 most frequent English colour terms used as adjectives in Google books Ngrams between 1500-2000.

We retrieved the 30 most frequent colour terms with the highest average rank across Twitter and Google Books (*white, black, red, blue, brown, green, cream, yellow, orange, grey, pink, purple, lime, olive, salmon, mustard, peach, coral, violet, plum, lavender, lilac, aqua, indigo, maroon, teal, turquoise, burgundy, aubergine and beige*) and obtained all colour samples given the same name by hundreds of participants in the online colour naming experiment.

Figure 4 shows these colour categories by the size and their associated colour names. *Purple* was the largest colour category in the experiment followed by *blue* and *pink*. *Lilac* and *turquoise* were found in the 6th and 7th positions respectively. The colour categories with the smallest size were *coral, cream* and *lime*.

Comparing the distributions of colour names in the three datasets shows that while *white* was the most frequent colour term in Google Books and second in Twitter, in the online experiment it was found in the 26th position. *Purple* on the other hand was the largest category in the online experiment while in Twitter was the 12th and in Google Books the 9th most popular colour term. *Red* was found in the 3rd position in both Twitter and Google Books but in the experimental dataset was found in the 12th position.

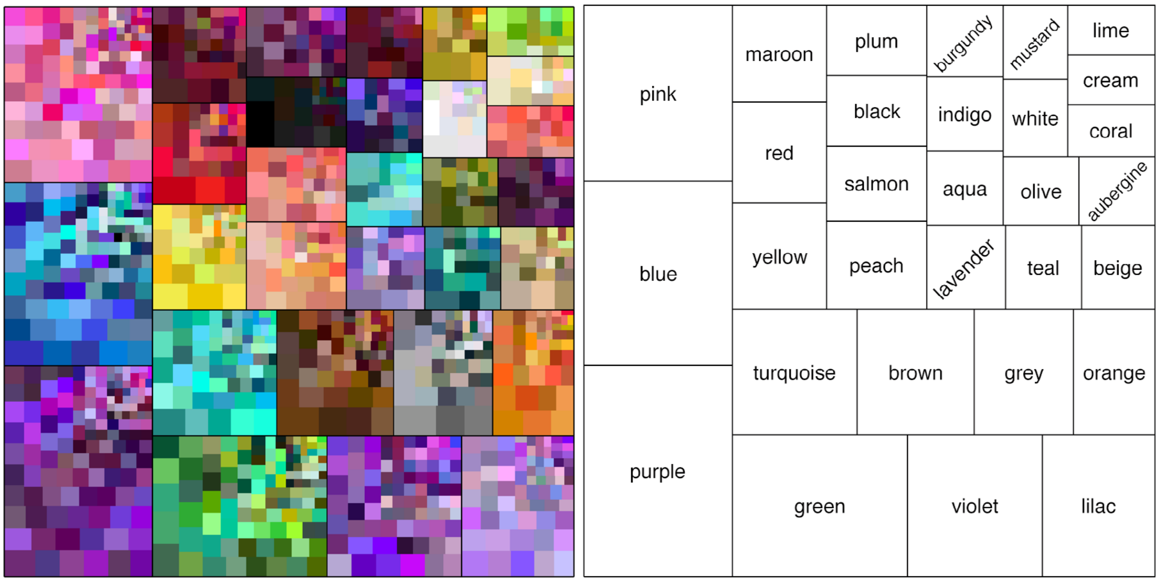

Figure 4. Treemap associated with the size of colour categories in the online colour naming experiment: (left) colour samples of each colour name; (right) colour name.

4. CONCLUSIONS

In this study we have presented the use of colour names in Twitter messages and Google Books and we visualised their associated colour categories using responses from an online colour naming experiment. The comparison of the colour distributions in the three datasets revealed that the mapping of colour names to perceptually uniform colour coordinates does not reflect natural language colour distributions. Future plans include the examination of the geometry of lexical colour spaces.

ACKNOWLEDGEMENTS

We thank all the volunteers who have contributed in this study as participants in the online experiment. This work was supported in part by the QMUL Media and Arts Technology programme, EPSRC Doctoral Training Centre and by the UCL Computer Science, EPSRC Doctoral Training Grant.

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A Proposal of a Colour Universal Design Game for Learning Dichromats' Confusion Colours

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ABSTRACT

The products based on the idea of colour universal design have spread by development of check tools for colour universal design in Japan. One of the next issues is how to educate colour universal design to a designer. We developed a game for learning the confusion-colour combinations of dichromats. In this paper, we introduce a development process of the game and some comments to the game from game players.

1. INTRODUCTION

It is well known that there is diversity in colour vision. Congenital colour-vision deficiency is one kind of colour vision types. Colour vision defectives cannot discriminate any colour combinations that are called confusion colours (Wyszecki and Stiles 1982). Therefore, colour vision defectives cannot receive information defined by the confusion colours in visual media or on visual displays. A colour universal design has been proposed against such a dichromats' disadvantage. A basic idea of colour universal design is to avoid using such dichromats' confusion-colour combinations. Some colour-universal-design aiding tools, for example Variantor (Miyazawa, Onouchi, Oda, Shinomori, and Nakauchi 2006) and Vischeck (Dougherty and Wade 2002), have been developed recently. However, the role of these tools is to check whether confusion colours are being used by simulating the dichromats' colour appearance, but is not to improve the designers' knowledge of dichromats' confusion colours. The knowledge of dichromats' confusion colours would allow designers to choose colours based on the colour universal design.

The purpose of this paper was to propose a colour-universal-design aiding tool to improve the designers' knowledge of dichromats' confusion colours. We developed a game which players can learn the confusion colours in order to improve the knowledge of dichromats' confusion colours.

2. DEVELOPMENT OF A GAME

2.1 The Conception of the Game

The conception of this game is that the player's knowledge of dichromats' confusion colours is empirically improved by playing the game. There are two approaches to accomplish the education of colour universal design for designers. One is the approach of making a designer learn the colour combinations that dichromats can discriminate. Using the colour combination learned, the colour design would be a universal design. For example, the colour pallet for universal design recommended by Japan Paint Manufactures Association (Ito 2011) is based on this idea. The other approach is for a designer to learn the typical confusion-colour combinations of dichromats. Namely, he/she learns colour combinations that should not be used for colour universal design. Currently, it is not clear which approach is better.

We adopted the latter approach, because we have thought that the latter approach would yield a designer the question whether the confusion-colour combinations are being used in visual displays whenever he/she looks at them.

2.2 The Features of the Game

It is the most important point of the game that a player plays the game frequently. Therefore, we gave the following features to the game.

1) The rule of the game is very simple.
2) One game finishes within 3 minutes at longest.
3) The game has contingency so that the player would not get bored it.
4) The game can run on a smartphone or a tablet terminal so that the player can play it anytime anywhere.

We chose an iOS programming with Xcode on MacOS X as a platform of the game development and developed the game guessing the confusion-colour combinations.

2.3 Calculation of Confusion-Colours Combinations

The confusion-colour combinations were calculated in the LMS colour space defined by the cone fundamentals proposed by Smith and Pokorny (1975). Eight colours were randomly chosen in the parallelepiped defined by the gamut of a colour display. The RGB primaries and the gamma characteristic of the sRGB standard were applied to those of the colour display, respectively. A confusion colour paired to each of the eight colours was randomly determined by shifting to the direction paralleled to the missing fundamental axis in the parallelepiped. An example in the case of the "Protan" is shown in Figure 1.

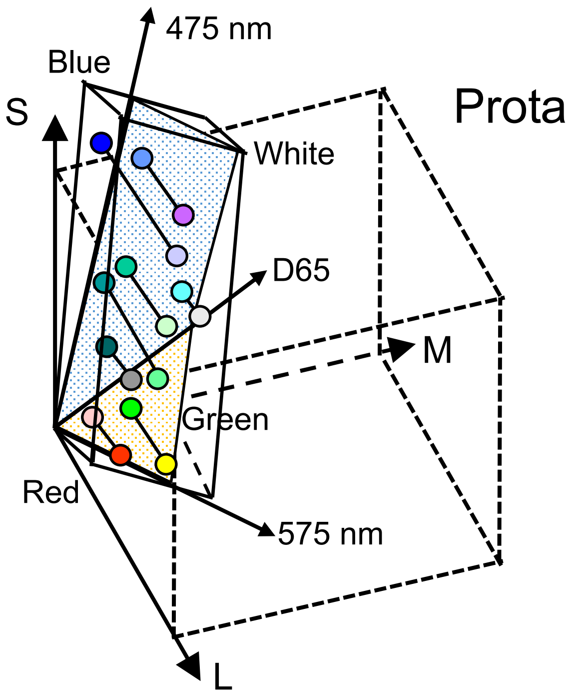

Figure 1: Method of determining the paired confusion colours.

3. HOW TO ENJOY THE GAME

The game screen is shown in Figure 2. The screen consisted of a Segmented Control and sixteen colour patches. Sixteen colour patches constitute eight pairs of the confusion colours as mentioned in Section 2.3. How to play the game and the rule of the game are as follows.

1) A player selects one type of dichromacy to learn from the Segmented Control: “Protan”, “Deutan”, and “Tritan”.
2) Eight confusion-colour pairs of the selected dichromacy are computed. Sixteen colour patches consisting of eight pairs are randomly assigned to a four-by-four arrangement and are displayed.
3) The player chooses two colour patches that are guessed to be a confusion-colour pair by tapping.
4) If the chosen two colour patches are a confusion-colour pair, the player will get 1 point and can move to a next choice. Otherwise, the game will be over.

We expect that the game player’s knowledge of dichromats' confusion colours would be empirically improved by repetition of the game play.

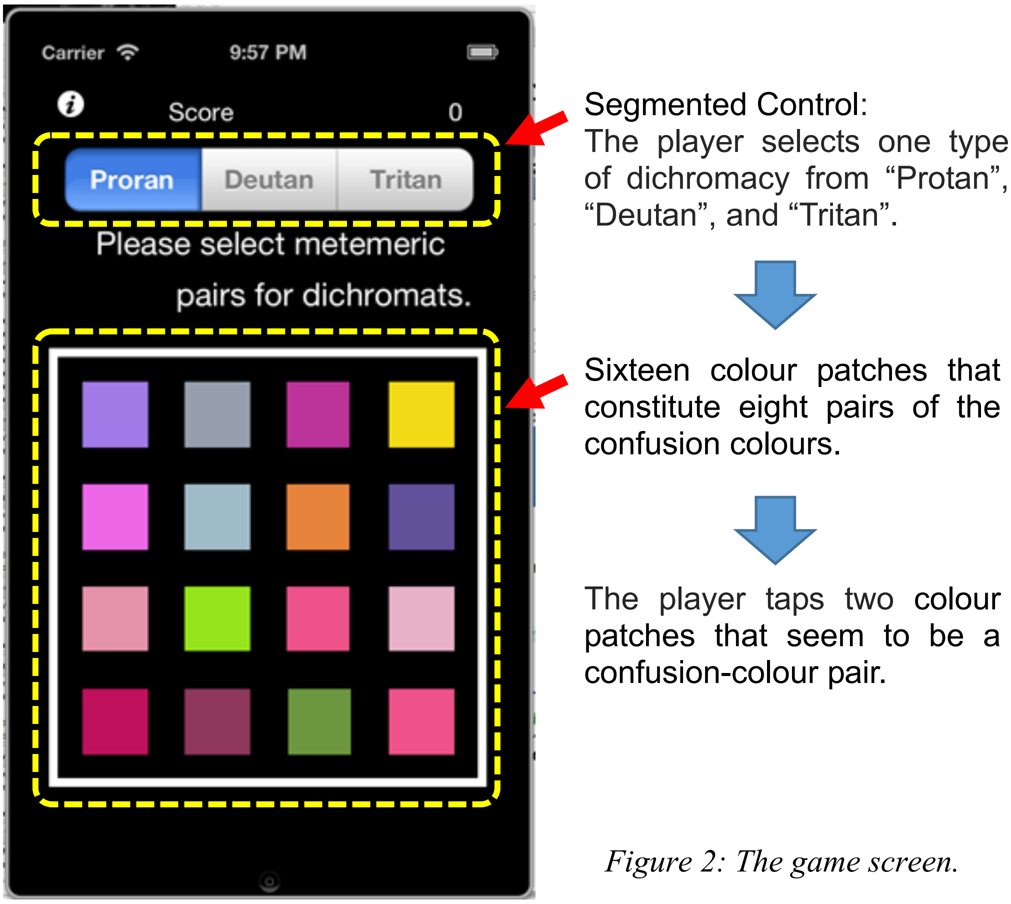

Figure 2: The game screen.

4. COMMENTS TO THE GAME

We got some comments from the game players who were students at school of design, Kyushu University. They were interested in the game guessing the confusion-colour pairs. Almost the comments were that it was difficult to choose the confusion-colour pairs without any knowledge of dichromats' confusion colours. Therefore, other supplementary materials may be required for the player in order to provide a basic knowledge of dichromats' confusion colours. Further, even if they have some knowledge of those, it was hard for them to complete the game when similar confusion-colours pairs were displayed. It may be necessary to add a constraint on the random colour-choice algorithm in order to avoid displaying similar confusion-colours pairs.

5. CONCLUSIONS

We developed a game for designers to improve the knowledge of dichromats' confusion colours. In this paper, we have described the development process of the game and players' comments to the game. However, we have not examined validity of the game in learning the confusion-colour combinations yet. We will examine whether the game player's knowledge of dichromats' confusion colours will be empirically improved by playing the game in the future study.

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Colour Management: Managing the Intuitive Issue, the Gamut Issue and the Engagement Issue.

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ABSTRACT

This research directly challenges the established and continued practice to implement colour-picker arrangements that are underpinned by colour science principles. Computer Aided Design software has evolved to empathetically resolve familiar real-world design challenges, whilst colour selection interfaces are predominantly governed by unfamiliar technical colour-spaces and additive colour behaviour (the intuitive issue). Importantly, the work confronts the current norm where colour-picker arrangements offer a user little insight into the potential colour difference between the various hardware components until hard copy proofs are produced (the *gamut* issue). Perhaps, more problematical still is the less obvious issue relating to an interface design strategy that allows users to *easily* select colour from the full monitor gamut (the *engagement* issue). The consequence of presenting exaggerated, yet easily accessed colour choice, in a technologically enhanced workflow can seemingly lead users to confidently select colours with little reflection on their tacit colour knowledge. This workflow can effectively negate inherent colour aptitudes which in the case of designers is likely based on paint and more naturally aligned to printer capabilities.

1. INTRODUCTION

The important concept that underpins this investigation is the hypothesis that creative digital colour users will benefit from a colour–picker interface that is designed to be consistent with their intuitive colour knowledge i.e. subtractive colour (Henry *et al.*, 2013; Henry, *2013*). This notion is seen to have particular significance for problematic digital colour tasks where the creative objective is to achieve an acceptable colour-match between the monitor display and colour printer. Such colour-sensitive objectives are often a creative requirement in the colour critical industries of fashion, textiles and graphic design. Hard copy proofs (colour-printouts) are regularly used as an integral part of the design development process, being central to effective in-house discussion, customer approval or in some cases as contractually binding manufacturing standards. Equally important is the understanding that this work doses not seek to invalidate technical colour management protocols but rather shares the views of other researchers in the observation that design communities working in colour critical environments often struggle to effectively apply ridged colour management workflows in a fluid and ever evolving design context (O'Neill *et al.*, 2008; Hirschler, 2010). A note worthy observation supported anecdotally in both industry and education contexts is the relationship between increased expectations in colour fidelity in direct relation to any increased investment in technical colour engagement. Subsequently, any disappointing results often lead to mistrust in the quality/capabilities of hardware, software or even user proficiency.

2. SUMMARY OF EXPERIMENTAL WORK

2.1 The Intuitive Issue

In the initial work the ability of users to predict colour mixtures in additive and subtractive systems was tested (the intuitive issue); it was shown that users can better predict the results from subtractive systems and it was assumed that experience with physical colorant system (e.g. paints) during childhood may be where the knowledge required is gained. This finding led to the hypothesis that a colour-picker tool based on subtractive colour mixing might be better, or more *intuitive,* than one based on RGB additive colour mixing. A series of experiments were conduced by which the accuracy of a colour match (where a participant tries to match or select a colour to match a given target) was assessed for a tool based on subtractive CMY primaries and compared with one based on additive RGB primaries. The subtractive CMY tool did, in fact, give better performance. However, most contemporary software presents a colour-selection environment rather than a colour-mixing environment; that is a colour map, for example, rather than RGB sliders. Therefore the new subtractive CMY tool was also tested against more contemporary solutions, (*Figure 1.*), and, in some circumstances, was shown to still give a better performance. The new subtractive tool works well when it has been explained to users (in terms of paint-mixing) whereas a similar explanation for the additive tool is unsuccessful.

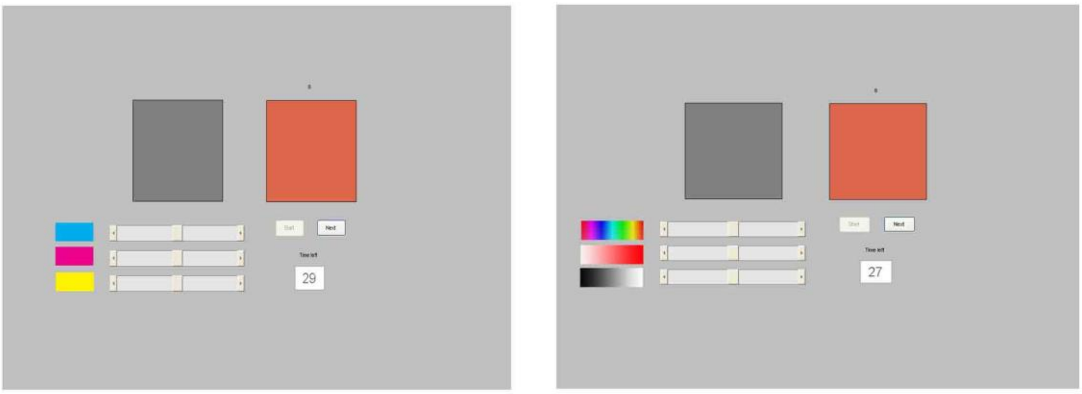

Figure 1: Examples of experimental colour-picker tools, a CMY slider bar (left) consistent with the experimental paradigm and an HCL arrangement (right) modelled on standard configurations.

2.2 The Gamut Issue

Further work explored more challenging cross-media colour matching scenarios questioning why users tend to select very bright and saturated colours on screen (i.e. *the gamut issue)*. Several conclusions were arrived at: (1) firstly, users are drawn to saturated colour and if presented with these will tend to select them (without even thinking about the consequences); (2) secondly, users tend to remember colours as being brighter and more saturated than they were (*Figure 2.*); (3) thirdly, the way in which the interface is designed encourages functional-fixedness (Dunker, 1945) and does nothing to challenge the user to think about the differences in gamuts, for example, between display and print.

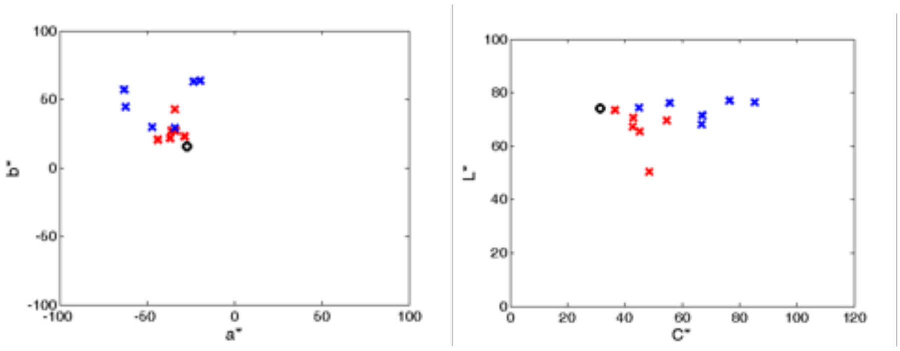

Figure 2: CIELAB coordinates (a and b*) (L* and C*) of one of the six targets (black circle) and the matches made by the observers on-screen (blue X) and in print (red X)*

2.3 The Engagement Issue

Previous studies of user colour-interface experience focuses their assessments on ease-of-use; how easily the participants could excel in basic colour-matching tasks when using different colour-picker arrangements. However, more current HCI (Human Computer Interaction) thinking has identified reservations with regards to interface strategies centred on ease-of-use preferring interfaces that exhibit aspects of possibilities-in-action. An underpinning and distinguishing quality of our colour-picker tool is the opportunity for a user to engage-in-use and connect with their existing colour knowledge, as well as gain an improved understanding regarding the nature of the digital colour challenges they are dealing with and use their skills and knowledge to make well-informed decisions. This new strategy is counter to existing colour selection strategies that seemingly encourage poor colour choice by presenting colour options that are not compatible with printing and only provide users with a relatively passive role in accepting colour outcomes governed by often concealed colour management infrastructures (i.e. the engagement issue).

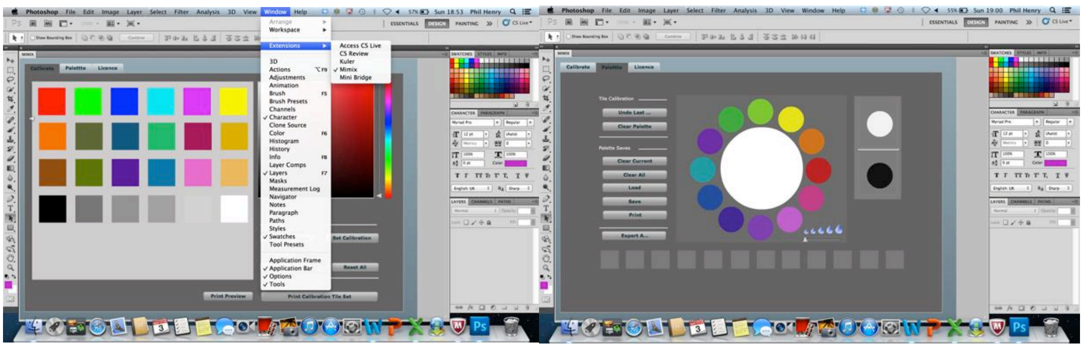

Figure 3: Illustrates views of the initial characterisation/colour matching exercise which introduces user to the gamut issue and the colour mixing interface which mimics subtractive/paint mixing

4. DISCUSSION

The results of this work challenge the established colour science convention suggesting that colour management methods are the most viable answer to tackling colour fidelity issues prevalent in many design industries, notably Textiles, Fashion and Graphics. Unquestionably, existing colour management does offer effective solutions providing the technical structures are correctly implemented and the practical constraints understood. However, a key criticism highlighted on all existing workflows is a procedure that allows users to make contextually poor colour decisions based on the colour information and options presented by the majority of colour-picker arrangements. Why, in the first instance, mislead the design expert with exaggerated colour options, then expect that any required compromises in creativity will be adequately resolved by colour science proficiency?

CONCLUSIONS

The final outcome of this research project is fully functional colour-creation software ColourMimix; it is developed as colouring tool for designers providing the means to create original palettes reproducible within the colour-space of a selected printer, ink set and substrate combination. This is achieved without the need for expensive and complicated colour management hardware or software; as an alternative the designer is in control from the outset using their colour judgment to set up the colour-picker tool to display only printable colour selections on the monitor screen. The software incorporates a unique intuitive interface and provides an alternative user-centred approach to managing digital colour. More detailed information regarding the software can be found at www.ColourMimix.co.uk and https://creative.adobe.com/addons.

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Suggestion for Teaching Natural Colors through Investigation and Analysis of Current Color Education for Children in Korea

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ABSTRACT

Modern people experience color in various ways and thus should have sufficient color education. Especially, color education is important for children, who are more affected by colors than adults. However, it is difficult to teach art since color education for children in Korea is taught by non-experts and consists of artificial colors, according to the results of a survey interviewing teachers of the Nuri Curriculum for children aged 3-5 years. Moreover, there is a lack of appropriate color education for children, and color is recognized as an important art activity. In this study, we suggest that Forest Experience Education as a method of color education for children based on the literature and interviews using qualitative analysis. Current color education for children in Korea utilizes parts of the Forest Experience Education curriculum but does not focus on natural colors or color use, even though there is a sense of seasons and many experiences of natural objects. Hence, we have developed guidelines on color activities for children involving color theory, sense, system, etc., implementation of basic color theory by early childhood teachers, and suggestions for natural color education based on standard colors (KS). Therefore, color education for children in Korea can upgrade the understanding of natural colors, and activities are expected to continue interest in color education.

1. INTRODUCTION

1.1 Background of Study and Purpose

Color education for modern people is being gradually recognized as useful. Professional color education is effective in utilizing colors and should be started during infancy. It is possible to know the mentioned contents which study the relationship between the child's intelligence and the ability of the color use, stated Lowen feld who is the art educationalist, the children have be highly intelligent and result various of color application as the tendency of the reference on the art is high, they live in the good educational environment for art, and the more children learn the art education. In other words, aesthetic sensibility of children is affected by their preceding education. Thus, art educators, historians, and psychologists should concentrate on art activities during childhood. For example, Paul Klee who is an artist in Germany had experience with the visual arts from childhood, and his artistic instincts consolidate music and the visual arts. There are positive effects of color education for children after becoming an adult. However, current color education for children (Nuri Curriculum) is not motivating and tends to concentrate on step-by-step skills.

1.2 Theoretical Study

The various activity progresses along the vitalization of the recent forest experience education, it tends to start in infancy. This is able to know directly or indirectly to search the advance of program on the various forest experience education, the foundation of Forest kindergarten, and the management.

Practically, early childhood education focuses on the seasons and experience of natural objects. First, for seasons as it is connected with the activity of the subject if we see the activity of the related nature included the instruction of Nuri Curriculum for teacher. The comment concentrated on the subject of "animals, plants, and natures" it tends to be concentrated on the contents around the subject, especially the contents of the season.

When using natural objects, it process variously as the very effective activity in the environment of city which is not enough to meet the nature, as the activity helping the weakness processing rapidly due to the future of the change of environment and the feature of location. Recent color education for children is based on Forest Experience Education, which is recognized as artistic education for children. In Forest Experience Education, all of nature becomes a playground, while using the forest for the education space regardless of the season and weather, the purpose is that learning the harmonious relationship between human and nature from childhood according to the reason of the well-rounded development and there is to develop the body and mental for children harmoniously. There are official organizations for Forest kindergartens in Germany and Denmark but in a state of developing the plan of the program and the invention of the forest kindergarten in Korea. For this reason, color education for children should be based on the seasons, the activity of subjects, and forest experience education, it is the lack of connection and not concentrates on the nature color and the color activity.

Humans attain the superiority over reaction of Type by a twenty two-month-old baby but do superiority over reaction of color from a four-year-old, transition period around a five-year-old is confused the reaction of type and color, and reaction of type attain supervisory over the reaction of type around a nine years old. Children respond more sensitively to color than shape. Thus, we studied children receiving Nuri curriculum (ages 3-5 years) who attended a daycare center and kindergarten from 2013 (Ministry of Education) to examine the current conditions of color education for children in Korea.

2. METHOD

2.1 Research Object

Humans attain the superiority over reaction of Type by a twenty two-month-old baby but do superiority over reaction of color from a four-year-old, transition period around a five-year-old is confused the reaction of type and color, and reaction of type attain supervisory over the reaction of type around a nine years old. Children respond more sensitively to color than shape. Thus, we studied children receiving Nuri curriculum (ages 3-5 years) who attended a daycare center and kindergarten from 2013 (Ministry of Education) to examine the current conditions of color education for children in Korea.

2.2 Research Method

2.2.1 Quantitative study

The method of study is as blow. To survey the present condition of color education for children related to Nuri curriculum, we studied and classified three articles on the present conditions of color education, present conditions of color activity, and satisfaction of color activities through a survey and interview of 50 professional early childhood teachers in Seoul and Gyoung-gi.

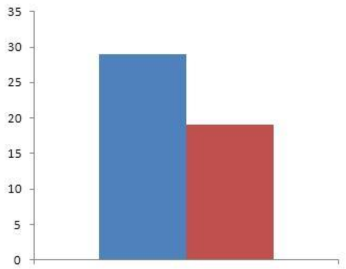
2.2.2 Qualitative study

Based on the results of the qualitative study, we interviewed early childhood teachers and investigated related books and theses.

3. RESULTS AND DISCUSSION

3.1 Results of quantitative Study

Figure 1 shows the answers to the survey question 'How important is it to use a teaching aid related to art activities for children?' Twenty-nine answered that it is important to apply art activities for children. Four people answered ‘yes’, 12 people said ‘somewhat’, and seven people answered ‘no’. Regarding the question ‘Have you ever experienced difficulties in making teaching aids or lack understanding of color?’, 40% answered that they lacked information as the majority and lack knowledge of existing color activities and teaching aids, and lack knowledge of the question ‘If you have difficulties in making teaching aids or lack understanding of color, what is the reason?’ Importance of color is recognized by professional early childhood teachers to teach the children, the suitable color education for children and the contents of activities among the art activities for the children are lack.



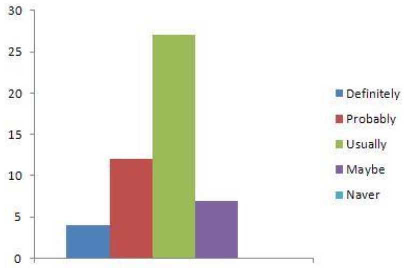


Figure 1:Art activities from children&Importance of color.

Figure 2. Difficult experience of the art activity/teaching aids according to the lack of understanding

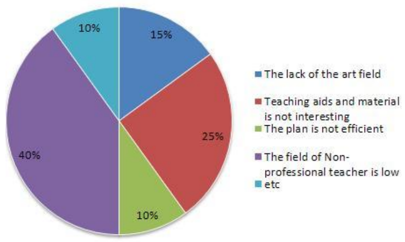
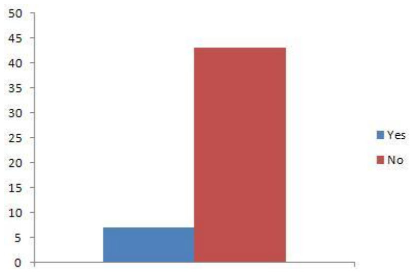


Figure 3:The cause of difficult experience of the art activity/teaching aids according to the lack of understanding

We investigated color education for professional early childhood teachers as well as books and teaching aids for art activities for children regarding the question question 'If you have difficulties in making teaching aids or lack understanding of color, what is the reason?' to search "the lack of information on the related field" and "the lack of the existing activities for color and the variety of teaching aid" to take first ranking and second, respectively. In the survey, an overwhelmingly majority of 43 people among 50 answered 'no'. Most color education is experienced at university, and total time to compete the course takes an average of 4 hours.

Finally, "non-artificial color" is 29% by the high rate and follows the aesthetic shape, inexpensive price, etc. regarding the art text book and teaching aid to improve. Art activities for children and education are important themselves based on an in-depth interview with early childhood teachers except the survey, there was the situation not to recommend high-quality color activity for children due to the understanding on the color field and the lack of information or the suitability of activity and teaching aid for many discretion and autonomy



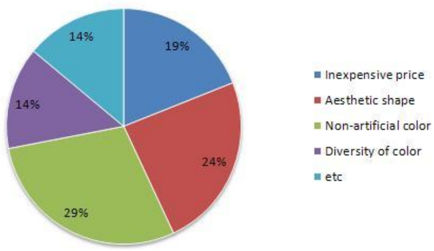


Figure 4:The experience related on the color education figure

Figure 5:The improvement of producing teaching aids of art activity from children

3.2 Qualitative and quantitative studies

First, it need to give the basic education for color theory the early childhood teacher who markedly lack of curriculum related on the color as the result of the Figure 2 of a quantitative study and as the Figure 4 having much difficult in doing art activity or the production of teaching aid according to the lack of color understanding. These lead to a sense of seasons, experience of natural objects, color, art activities in the Nuri curriculum, and education of natural colors in Figure 5.

According to contents of the Figure 1, we adjusted standard colors (Korean Industrial Standard, KS) in Korea to the color education and activities practically not to build the system and concept of color even though the importance for the color education is growing more, to mix the system and concept of color in the above Nuri curriculum in the activity of experience of around the fun and interests .

Next, this is present the various color activities and the teaching method. we try to suggest the activities aimed for natural color in the field of art experience of the observation, expression, feelings and the utilization of teaching aid, for example, in art activities for children to develop the activities for the color researching to be able to searching for in the natural objective using standard color(KS), to make the natural colored palette for children to be able to express and feel the natural color extracted natural objective to apply the concept of color management, through activity of the observation on the change of color of the natural object such as tree, flower, etc. to add the concept of the brightness and chroma to apply the color perception.

4. CONCLUSIONS

Color education for children in Korea lacks focus on natural colors and utilization but the various actives progresses recently according to the vitalization of for natural ecology. Thus, we suggest that color education for children should focus on natural colors based on qualitative and quantitative studies. First, basic education of color theory should be administered by early childhood teachers using Nuri curriculum. There are not many chances to learn about color even though early childhood teachers learn a wide range of art and music. Difficulties in early childhood education are lack of teaching-learning materials for adapting the Nuri curriculum *(2013: Park, Noh cited re-quotation)*. Color education in adapting to children is unfamiliar. Above all, art activities for children are influenced greatly by the ability of early childhood teachers.

Second, we developed color activities based on standard color (KS) excluding artificial colors the artificial color is from the understanding on need to give various chance to meet the natural color as the contents pointed out by the early childhood teacher to improve the color cognition and visuals

of children live the city life mostly.

Third, we provided guidelines for various color activities. Art activities should be performed twice per week in practice unlike the child participated in the activity to interestingly because the teacher have to depend on the certain guide line or plan when teaching. But the detailed suggestion does not present the various color activities to help this. This study is expected to lead to the color education from children in Korea to upgrade understanding on the natural color, the activities, and the consistent interest and study as presenting the direction of the color education from children and the natural color education.

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Thank you for the family to support at all times and Environmental Green Design Research Institute both in joy and in sorrow

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Color Mixture Learning using Personal Computer for Basic Design

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ABSTRACT

Media expressions by graphic designers have been digitalized from the 21st century. This paper is about a trial of basic education for designer in the digital environment.

There are two significances to introduce PC into basic education for designer. One is that physical color simulation can be done easily. The result of the Additive and the Subtractive color mixture can be expressed easily. We needed a lot of training to mix color well without PC. The second is that accurate drawing can be done easily and accurately to manage element of color and figure by the numerical value with graphics software. The basic operational directions of a graphic (translation, zooming, rotation and reflection) are also easy. More complex repeating work can also be performed quickly. These are very great advantages for design learner.

This design exercise is based on "color mixture". At first, each method of training is indicated. And after, student's impressions are also indicated. Significance of these trainings is shown from student's impressions.

1. INTRODUCTION

Basic design in the digital environment (the color and morphology manipulation) is a theme for this research. We focus on "the color mixture". Because of the color mixture by the three primary colors are used much for reproduction with the color for industrial design. We paid attention to symmetry of a graphic by morphology manipulation. Because of the most of graphics software are designed based on morphology.

The industrial color reproduction and understanding of graphics software are very important in present design. The significance in which combines these modern industrial technology with basic education for designer is important. The color design which made "color mixture" is a theme for the design exercises indicated as below. At first, the training of Additive, Subtractive and Juxtaposed color mixture were indicated. And next, student's impressions were also indicated.

2. METHOD

Attribute of the person for learning: Begineer of the graphic design. Student of the night graphic design department in Nippon Designers School. Number of students: 6 male and 17 female students, average age: 21 years old. Class name: Basic Design & Art 1（refer to 2-1 “Subtractive color mixture” and 2-2 “Additive color mixture”）, Visual design（refer to 2-3 “Juxtaposed color mixture”）

2.1 Subtractive color mixture

2-1-1 Training of CMY color mixture with a colored pencil and the painting on paper (for water-color painting use). Exercises for various CMY color mixture by painting applied "4-level gradation" in each CMY color.(Figure 1)

2-1-2 An exercise of the CMY color mixture with "the transparency film". Layers with the films can make CMY color mixture.(Figure 2, Figure 3, Figure 4)

Figure 1

Figure 2

Figure 3

Figure 4

2-1-3 Training of the CMY color mixture simulation of the exercise of 1-1 with the PC software. Each CMY color is divided in "4-level gradation" into "every layer" and simulate a subtraction color mixture.

In this study, we use Adobe Illustrator. Training method is as follows. (Figure 5)

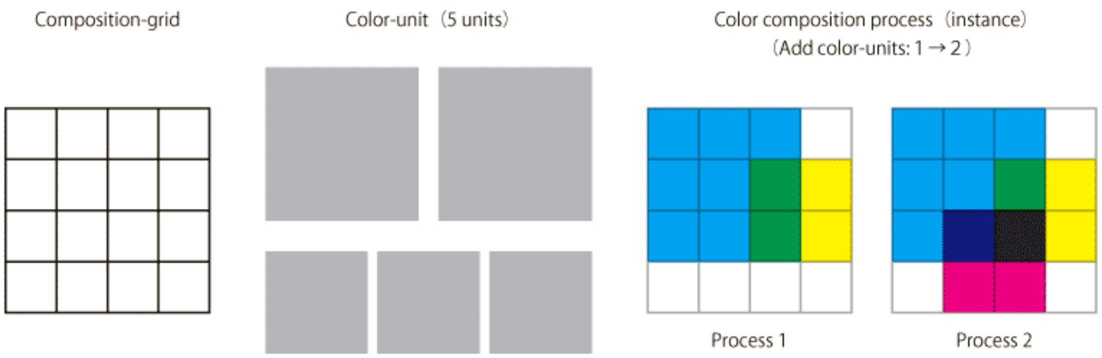


Figure 5: Practice process for CMY color mixture simulation.

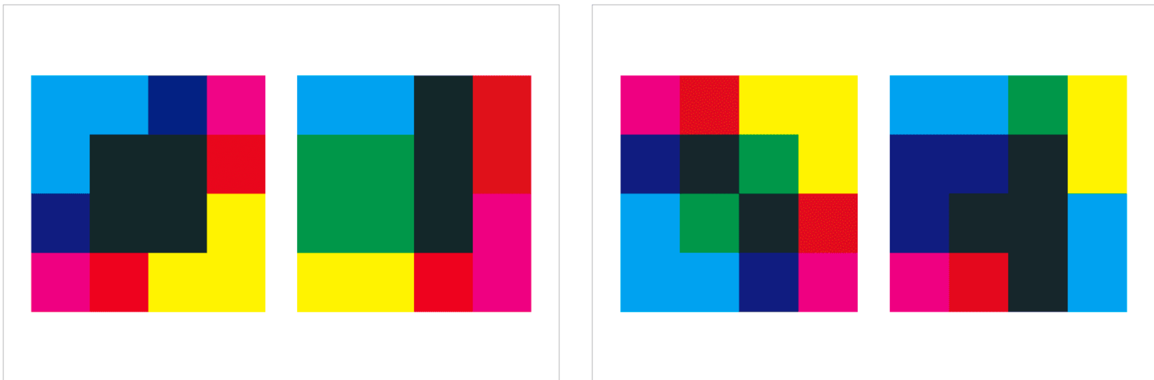


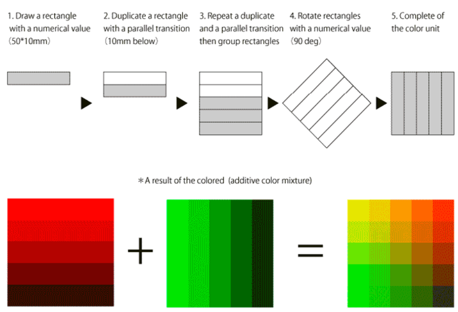
Figure 6: Student work examples.

2.2 Additive color mixture

2-2-1 Exercise for the Additive color mixture with the lights transmitted the each RGB color cellophane.（Figure 7）

Figure 7: Simulate the mixing result in the RGB color of flashlight.

2-2-2 Exercise for RGB color mixture simulation with PC software (“5-level gradation” and WEB safe colors in each RGB).



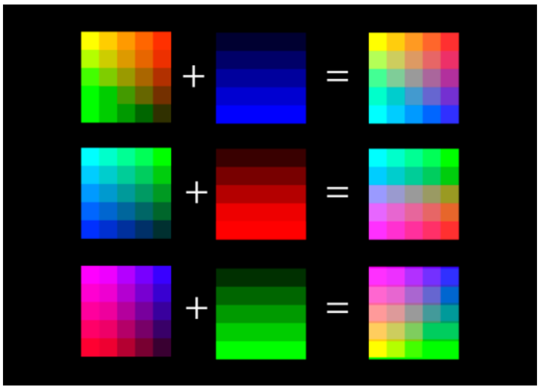
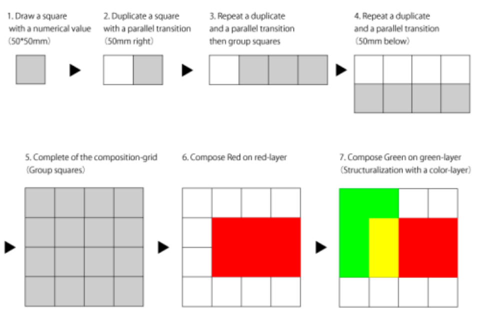


Figure 8: Working process for RGB color mixture. *Figure 9: RGB color mixing simulation.*



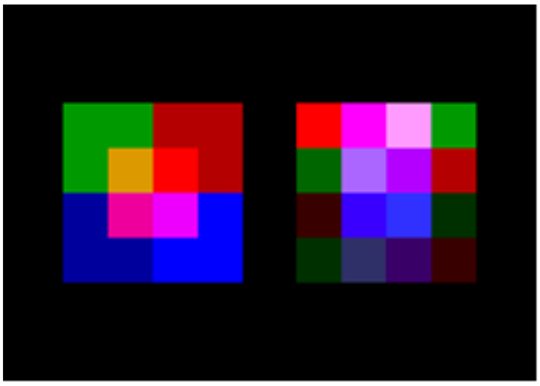


Figure 10: Practice process for RGB color mixture. *Figure 11: Student work examples*

2.3 Juxtaposed color mixture

As an example of the juxtaposed color mixture, to design the color pattern of the plain weave with the PC. Based on an example of the checked pattern using CMY, to create the pattern by student's color choice. Condition: To choose three colors of the option and design by Juxtaposed color mixture.

A work procedure: Each color plane assumes it a square of 3mm (step 1). To place the first color, the second color into checks form (step 2). To copy, rotate 90 degree and put on it (step 3). The third color locates it as a lower color of the ground. This is defined as “basic unit” of the Juxtaposed color mixture (step 4). To copy the basic unit, and a design of the checked pattern is completed in A4 size [length:298mm, height:210mm](step 5). To print the pattern to a piece of A4 size cloth. A book jacket is made to the size of the book by folding. A production process and the students’ work are as follows.

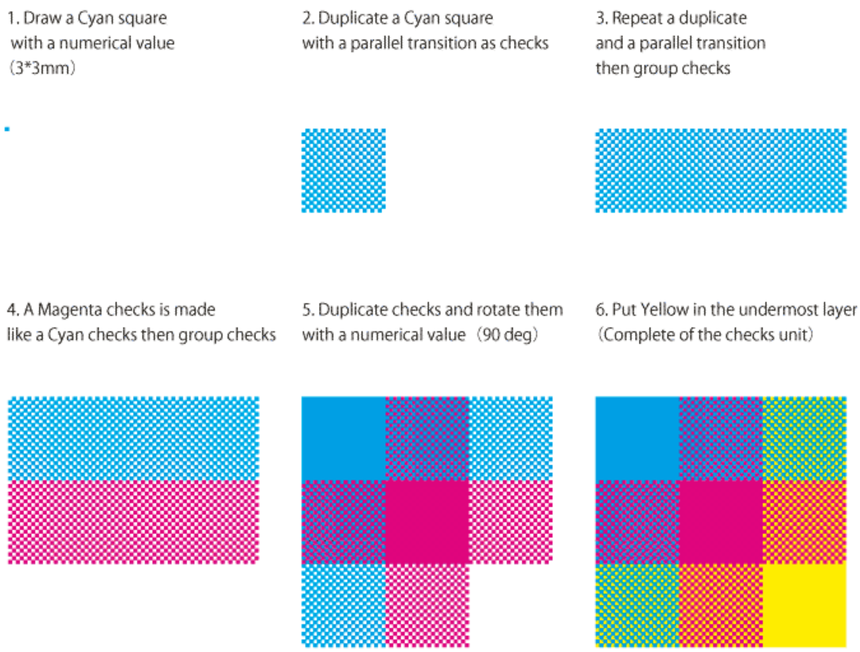


Figure 12: Working process for Juxtaposed color mixture

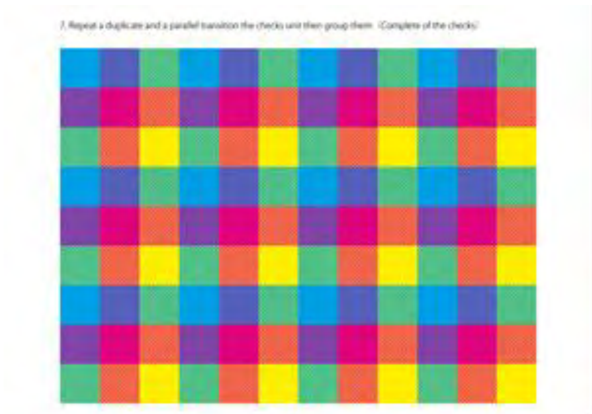


Figure 13: Replicate the basic unit of checked pattern to A4 size

Figure 14: Student work examples

3. RESULTS AND DISCUSSION

A production process and the work of the student are as follows.

"A function called color multiplication was convenient and understood well and it was interesting."

“I felt that it was easy to make a translucent design and the design with the united feeling.”

"I had color constitution like today’s class (in this training), and even other classes only changed a position to be piled up a little and an impression changed completely and was interesting".

"I was able to imagine only that I mixed paint when I heard the word color mixture, but I came to be able to imagine the color mixture to use “transparence origami” and the layer by this class"

"It was different from the image only to make colors juxtaposition when I only put one's color that I imaged when I mixed it. Therefore, it was necessary to simulate it many times and was serious. But I think it a very good study."

From these comment after the trainings, significance of the training is suggested.

The color is a very important topic in education for designer. When a learner handles the color, they face two problems. One is a color material and the color mixture. The color material with physical properties such as paint, it is difficult to predict the color mixing result, a number of empirical knowledge. In now, we also design using the color display and also need knowledge of RGB color. Another is the color scheme. Various color theories have been proposed, but in the actual design, it is difficult to well adapt their theory.

By introducing the PC for color education, these problems are easily solved. Additive and Subtractive color mixture are both physical phenomena. The PC software, a simulation of physical phenomena is easy. In particular color learning Additive color mixture was difficult with conventional color education. Also, in Juxtaposed color mixture, a huge number of fine color surface are needed. To create manually these color plane is difficult, but PC can create easily with graphics software.

Learning of color scheme is often used a color space that is abstracted such color wheel. This method is obtained by utilizing the geometric relationship of the color space. Color is treated as abstracted code (such as color number) in the space. This method is suitable to understand the color scheme theory, prior to the "toning" has been coloring material (such as colored paper) is required.

Learning the color, "toning" is also an important issue. For toning, it is necessary to understand the color caused by the three primary colors and color mixing principle, and also mixed toning to determine the interrelationship of color. Therefore, understanding of color mixing is the basis of the color scheme learning. This is an extremely benefit for beginners.

4. CONCLUSIONS

Among the practical challenges, "Juxtaposed color mixture" is very significant of practice (design of book jacket). In this exercise, relation between the principle of color mixing (juxtaposed color mixture) and the design work (checked pattern) including the design process is very easy to understand for the learner. Among the design education, education related to basic design & art such as colors is difficult to resolve with only abstracted theory. Also when theorizing, it is also important to consider whether to theorize at any stage. For example, in this study, we showed the theory (explicit knowledge) back to a more primitive stage called "color mixture" rather than " harmony theory" for the color scheme.

In the future, same as Additive and Subtractive color mixture, we would like to advance the research including its design process such as directly linked the modeling representation and formal knowledge and also help the first scholars for training challenges.

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The art of colour harmony: the enigmatic concept of complementary colours

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ABSTRACT

This paper explores the theory and practice of colour harmony based on the equilibrium of complementary colours. For centuries artists relied for their colour choices on studio experience and artistic knowledge handed down from master to apprentice while "scientific" colour theory remained mostly the preoccupation of scholars and philosophers. Many of the latter kind of theory were based on a comparison of visual harmony with theories of musical harmony, astronomy and mathematics (Kemp 1990; Gage 1993, 1999). This paper presents some reflections on those theories and argues that they have led the research of the aesthetics of colour astray for centuries.

1. INTRODUCTION

Complementary colour is a concept that is often referred to in textbooks on colour and in discussions on colour harmony. Complementariness in colours is sometimes described as oppositeness, although strictly speaking complementariness and oppositeness are two different concepts. Since ancient times artists and designers have either intuitively or consciously exploited the phenomenon of oppositeness in colours to achieve highly different visual effects. Some have aimed at maximum visual tension, others at harmony through equilibrium. Colour educators have tended to seek universal laws and principles or empirical evidence that would explain "scientifically" the phenomena and effects of colour experience. The principle of harmony through balance of opposites or of complementaries is an integral part of numerous colour harmony theories (Munsell 1905; Ostwald 1917; Itten 1961). What is meant by opposites or complementaries varies from one theory to the other and thus necessarily affects the interpretation of harmony in those theories.

The concept of harmony – and hence of colour harmony – is historically entwined in mathematics and theory of music and is not free of these associations even today (Arnkil 2013). The notion prevails that colours are separate entities belonging to an *a priori* system, and that they have fixed physical identities and locations in a system rather like the 12 tones of the diatonic scale in Western musical harmony. But what could harmony through equilibrium mean? Colour has no measurable weight, area or mass, which is perhaps why in art colour harmony has been understood as balance of metaphorical visual forces. (Kandinsky, Klee, Munsell). A scientific view of equilibrium presupposes a precise identification and quantification of energy, power, mass, etc. In the case of colour these forces have sometimes been identified as complementary wavelength distributions or opponent neurobiological processes. (Pridmore 2009). The latter type of investigation can contribute to the development of more sophisticated mathematical models of human colour vision, but is unlikely to deepen our understanding of the aesthetic function of colours in art and design. As artists through the centuries have shown, it is possible to identify balancing, opposite or antagonistic relationships in certain types of colour combination without attempting to pin down a precise calculable definition of those relationships. Such relationships need not lead to a "harmonious" visual outcome, but offer instead multiple expressive possibilities. The outcome depends always on several visual factors and variables of colour that cannot be left of the equation.

2. A SCIENTIFIC FOUNDATION FOR THE ART OF COLOUR?

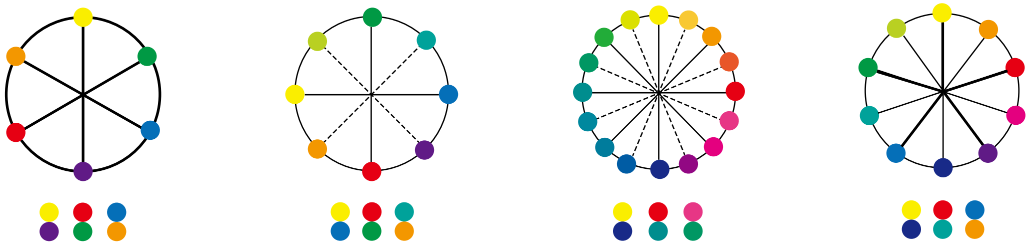

Figure 1. Schematic illustration of some colour wheels and their complementary hues. From left to right: Delacroix/Chevreul/Blanc; Hering; Ostwald; Munsell.

Almost every colour primer that says something about complementary colours makes reference to a colour wheel, stating that colours found diametrically opposite on the wheel are complementary to each other. (Itten 1973: 34, 78; Hope & Walch 1990: 89; Holtzschue 2002: 52–53; Hornung 2005: 15; Stone 2006: 236). Some textbooks insist that these relationships are extremely precise, because of their scientific foundation (Itten 1973: 34). Others, while forwarding a colour wheel -based harmony theory, admit that this principle is made rather uncertain by the fact that the colour relationship depends entirely on how the wheel is constructed. (Feisner 2006: 50). The origin of the various colour wheels, their differences, and their potential problems for predicting colour harmony are thoroughly discussed in Westland et al 2007. The wheel or circle as a symmetrical symbol of perfection suggests in itself completeness and harmony. This symbolism was idealized by the early Romantic painter Philipp Otto Runge in his spherical representation of the harmony of colours. 150 years later Johannes Itten modelled his own colour sphere and colour star on Runge's sphere and made them an iconic image of colour harmony in his book *Kunst der Farbe/The Art of Colour* (Itten 1973), The book was originally published in 1961, but is still immensely influential in colour pedagogy.

The two most famous colour systems that have made claims about both scientific colour ordering and colour harmony are the now forgotten Ostwald system and the still thriving Munsell system. Wilhelm Ostwald based his uniform hue difference scale on complementary wavelength pairs (Pridmore: 234), thus placing the concept of complementaries at the centre of his theory of colour harmony. Although Munsell also put great emphasis on "balance" in visual aesthetics, he abandoned in his hue circle his initial "compensatory" colour pairs in favour of perceptual uniformity. (Kuehni & Schwarz 2008: 115). The fitting together in one and the same colour space of perceptual uniformity of colour difference and symmetrically opposed complementary hues remains and unresolved challenge for colour science.

2.1. Opponent colours and opponent processes

In 1872 the German psychologist Ewald Hering (1834–1918) presented his theory of colour opponency which stated that a colour cannot appear both red and green at the same time and that there can be neither bluish yellows nor yellowish blues. It was first thought that Hering's opponent colour theory was irreconcilable with the Young–Helmholtz theory of trichromacy, but gradually it was realized (and proven also empirically) that they describe two different levels of the colour vision process. (Kuehni & Schwarz 2008: 100). Could Hering's opponent colours be called complementary and if so, does their complementariness have a neurological basis? Hering hypothesized that the neural opponency of red with green and yellow with blue was based on antagonistic physiological processes (Valberg 2005: 279). At first there seemed to be no evidence to support this hypothesis but the discovery of opponent-process colour-coded cells in the 1950s and 60s, first in the retinas of fish, then in primates and later in the human visual cortex seemed to finally prove the neurobiological basis of complementariness in these colours. It is worth remembering, though, that an important role of that process is not to only to provide us with good discrimination of reds from greens and blues from yellows, but to pack the signals from the three cone receptor channels into a more economical form through a process of signal subtraction. Hence we are much more attuned to colour *differences per se* than to *absolute* colours in any sense of the word.

Building on Helmhotz's and Hering's legacy, the CIE has produced ever more precise colour difference models. Do these improved scientific models contain the answer to complementary colours and colour harmony? Professor Anders Hård showed in 1985 in his article *Är komplementärfärger mer olika än andra färgpar?* (Are complementary colours more dissimilar than other colour pairs?) how ambiguous the concept of complementarity is even within a scientific frame of reference. He also concludes that artists "grasped the new scientific theories of subtractive complementaries, complementary stimuli and simultaneous and successive contrasts, as acceptable explanations, proof or definitions of phenomena *that they had since long ago known and worked with*." (Hård 1985, my italics). In a more recent article by Anders Hård and Lars Sivik the authors say:

> In color literature and encyclopedias, the concept "complementary colors" is defined in several different ways … As far as we understand, it is not possible to decide whether simultaneously perceived Color Elements are complementary according to any of these definitions unless one has acquired, through specific experimental learning, the knowledge of the particular definition in question. (Hård & Sivik 2001).

Hård and Sivik also point out that in their experiment carried out with 35 architecture students of architecture, showed no evidence that complementary colour combinations are experienced as more harmonious than other combinations: "The colors that were hue (Φ), chromaticness (c), and redness (r) identical, on the other hand, were judged as more harmonious than all the others, while the constellation where all the colors were completely different was judged as least harmonious." Neither were the complementary colour pairs perceived as more different than other combinations. The experience of difference depended rather on NCS lightness difference. (Hård & Sivik 2001: 26). The findings of Li-Chen Ou and Ronnier Luo corroborate these findings: in their 2003 study, equal hue and moderate lightness difference were among the most important contributing factors in harmony and there were no results for complementary colours. (Ou & Luo 2003).

2.2. Other dimensions of complementary colours

Complementariness is closely related to simultaneous contrast otherwise known as colour induction. (Pridmore 2009). Colour induction is in some degree present in nearly all colour juxtapositions, but it is most dramatic in colour combinations where a colour field of high chromaticness induces an opposite hue in an adjacent, more neutral colour field. This perceptually induced opposite hue is said to be the complementary of its adjacent hue stimulus. Another related phenomenon is that of *vibrating boundaries*, sometimes also called “simultaneous contrast” or “simultaneity” in art parlance. There are several explanations for this phenomenon (see e.g. Livingstone 2002), but it is most often attributed to complementary colours enhancing each other when juxtaposed in the form of hard-edged areas. So-called ‘simultaneity’ in the form of juxtaposed areas of saturated complementary-type colours in highly rhythmic designs were typical of the works the Robert and Sonia Delaunay. It is debatable whether they can be called ‘harmonious’ or that either artist even aimed at harmony. The effect is rather of vibrancy and a sense of rhythmic movement. Indeed, the proclaimed aim of Robert Delaunay was the creation of movement and a novel evocation of time and space through colour. (Gage 2006: 36–37) In the Pop- and Op-Art of the 1960s complementary-type contrasts in equiluminant combinations often created a restless, vibrating or kinetic effect whose very aim was the opposite of harmony. Such effects were widely used in advertising and especially in the graphic images of the 1960s pop culture and psychedelia.

Although complementary and antagonistic colours do not automatically create harmony in a colour composition, they may occupy an otherwise special place among colour combinations. Michel Eugène Chevreul (1786–1889) stated that colours appeared to their best advantage when juxtaposed as pairs of complementaries. In Chevreul’s colour circle, the three primary colours red, yellow and blue are placed at angles 60° in relation to each other, yielding the complementary pairs: red/green, yellow/violet, blue/orange, etc. Summarizing his findings on various types of colour juxtapositions, he concludes: “*This* [juxtaposition of complementaries] *is the only association where the colours mutually improve, strengthen and purify each other without going out of their respective scales.”*(Chevreul 1987: 134). But he goes on to say: “This case is so advantageous to the associated colours, that the association is also satisfactory when the colours are not absolutely complementary. So it is also when they are tarnished with grey.” (Ibid.).

3. DISCUSSION

Chromatic contrast not only provides us information about lighting, space and material qualities, but also affords us pure enjoyment and aesthetic pleasure, but sometimes also displeasure. Artists or designers can learn to control these factors only by experience, by tirelessly testing various options and by training their sensitivity to the multiple layers of visual experience at play in any art or design task. Josef Albers has demonstrated how creating with colours has very little to do with rigid rules and much with alertness, flexibility and tactical skill, with “thinking in situations”. (Albers 2013: 42, 68). He referred to theories of complementary colours, but never asserted that they were a guarantee of harmony. In fact, harmony was for Albers no more desirable than disharmony. Just as music consists of consonances and dissonances, so must visual art. (Albers 2013: 39–43). In contrast to his former teacher and colleague Johannes Itten, Albers had a deep distrust of formal rules of colour harmony – mainly because of they did not address the relational and situational nature of colour design. (See Albers 2013: 42). There have been attempts even in Albers's time to quantify variables such as surface area, complexity and colour intervals in mathematical representations of colour harmony (Moon & Spencer 1944). However, most of the models are able to include a very limited number of hues or other variables in the algorithm. Even the most sophisticated computational colour harmony models to date leave out crucial factors affecting the experience of harmony. These include the spatial array, cultural context, figuration, symbolism, texture, materiality and evocation of light and atmosphere. Computational rules of colour harmony so far appear to be self-predicting. There is no guarantee of their success outside their own form of presentation and mode of appearance, as even the creators of such models admit. (See: Ou & Luo 2003, Conclusions). A continuation of computational harmony studies with more naturalistic stimuli could be extremely challenging, but perhaps worth trying.

4. CONCLUSIONS

The concept of complementariness in colours has no single established definition. The "harmony" or "disharmony" of colours, whether based on complementariness or other relationships, is not scientifically quantifiable, but a qualitative aspect that requires artistic knowledge, sensibility and attention to several simultaneous layers of experience. The experience of visual balance is not dependent on any precise and quantifiable chromatic relation. The experience of visual harmony depends on multiple factors that can only be addressed through the sensibility, skill and experience of the designer or artist. Rules of harmony that are based on fixed, abstract formulae do not sufficiently take into account the multiple variables involved in real-life applications of colour and do not sufficiently address the needs of contemporary art and design. Complementary, opposite or antagonistic colours can, when used with skill, afford visual balance to the chromatic composition of images, objects or spaces, but they can also result in visual tension, restlessness, even discomfort. The latter effects can be and often are the very goal in today's designs or artworks. Present-day colour harmony research has received little or no attention from artists, designers and architects. The reason may be that "harmony" is too limited a concept for the needs of visual communication, expression and good design in contemporary life. Many of the confusions and misunderstandings concerning the role of colour in art, design and architecture arise from a lack of clearly articulated artistic knowledge about colour. It has sometimes resulted in artists taking recourse to science that they do not understand and scientists applying to art methods and rules which are blind to the multifaceted nature of art. The discussion between science and art in colour research can be useful only when the strengths and limitations of each approach are clearly identified.

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A Study on Influence of the Culture and Art Experience of Senior Citizens from Relationships between Culture and Art Education Space and Color Emotion Assessment

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ABSTRACT

Accordingly in this research, properties of evaluation vocabularies according to colors used in each Korean cultural art education indoor space is evaluated. Through analyzed resources, influence on senior citizen's color sensibility evaluation by the relationship between cultural art education space and color sensibility evaluation is analyzed. In order to achieve the goal of this research, SPSS statistic program 21 is used to conduct reliability analysis and T-test analysis. As a result of the research, among the three elements, ceiling, wall and floor in educational space, wall is the most influential when applied with color. Second, in oriental calligraphy room which has clear use and purpose, and used for visual art education space, color sensibility is clearly demonstrated per use of different colors. Third, there were difference in the sensibility each individual feels from the color of the wall between a group of individuals who has experienced cultural art and the group of individuals who has not experienced cultural art. There was significant difference in grey, pink, wine and yellow-green. The conclusion of this research is believed to be used as an important data to plan indoor education space color palette for senior cultural art education spaces.

1. INTRODUCTION

As the number of facilities allowing senior citizens to explore cultural art is increasing in Korea, geographical distance to/from cultural art center, transportation method is getting easier and the opportunities of experimenting various cultural art is growing. The difference in details and degree of emotional sensibility each individual feels from the colors in interior spaces are expected between individuals who have experienced cultural art and who have not. In the coming future and forward, Korean government is anticipated to generously support and invest in improving life quality by adopting cultural art experiences as universal opportunities. Consequently, as a first step in this research, emotional sensibility of senior citizens, the true users of cultural art education spaces are studied as a part of indoor color palette plan. As a second step, the purpose of this research in distinguishing the differences in emotional sensibilities between individuals who have experienced cultural art and who have not to identify the properties and use them resources for designing cultural art spaces since emotional sensibility of users who have experienced cultural art can be referenced in making color palette plans for indoor spaces distinctively designed for educational purposes.

2. METHOD

2.1 Experiment Outline

This research includes preliminary survey and main study. Physically and mentally healthy 57 senior citizens (31 females and 26 males) at ages between 55 and 63 without conditions of color blindness participated in this experiment. Preliminary survey was used to identify biological information along with physical and psychological conditions. The main study is conducted as color sensibility category in cultural art education space using general statistics and Likert's 9-point scale. Especially, the application of color in indoor space is limited to walls by referencing advanced researches. According to the preliminary survey conducted in this research, 94.09% of senior citizens responded that walls have the biggest affect to interior space images and sensibilities.

Figure 1: Basic 15 Colors for Color Sensibility Evaluation.

Accordingly, prior to conducting this survey, sufficient explanations on color stimulant in indoor spaces are provided. Survey participants were asked to evaluate emotional sensibilities they feel by looking at images of indoor spaces that best demonstrate the basic 15 colors (red, yellow-red, yellow, green-yellow, green, blue-green, blue, bluish violet, purple, reddish purple, pink, brown, white, grey and black) on 9-point scale.

2.2 Evaluation Subjects and Vocabulary Selection

Oriental calligraphy room that is designated as a social educational space located as a part of senior citizen welfare center which conduct cultural art educations such as photography, oriental calligraphy, oriental painting, art and architecture is selected as an evaluation subject. The basic colors are selected based on KS color system and the colors are applied to walls which has the most visual influence within indoor spaces. Vocabularies used in the evaluation are derived from the 2014 research of Lee, Jin-sook. As shown in (Table 1), total of sixteen pair of evaluation vocabularies are selected and SD (Semantic Differential Method) is used to conduct the sensibility evaluation.

Table 1. Color Sensibility Evaluation Vocabulary

No.	Vocabulary	No.	Vocabulary
1	Happy – Not Happy	**9**	Enjoyable – Irritating
2	Hopeful - Hopeless	**10**	Interesting - Boring
3	Stable - Stimulating	**11**	Calm – Excited
4	Comfortable - Tense	**12**	Active - Static
5	Pleasant - Unpleasant	**13**	Bright - Dark
6	Warm - Cold	**14**	Light - Heavy
7	Clear - Dozy	**15**	Confident - Fearful
8	Influential – Influenced	**16**	Strong - Weak

2.3 Evaluation Method

In this research, in order to evaluate the reliability of each evaluation vocabulary, reliability analysis (Cronhach-ɑ) is conducted using SPSS statistics program 21. Moreover, in order to evaluate fundamental properties of evaluation vocabularies based on colors, descriptive analysis is conducted. Lastly, T-test is conducted to analyze the effect of education space color on participant's sensibility between those who have experienced cultural art and those who have not.

3. RESEARCH RESULT

3.1 Reliability Analysis

Reliability analysis is a value that allows to verify how accurate and consistently the evaluation vocabularies are measured by survey participants. In other word, it is the probability of resulting in the same measurement regarding the same concept repeatedly.
Generally in the social science area, the standard that interprets Cronbach ɑ value sees that the value above 0.6 is credible. The total Cronbach a value is demonstrated as 0.940 therefore no specific vocabulary is removed. All 16-pairs of vocabularies are used as evaluation vocabularies.

3.2 Descriptive

In order to identify the property of evaluation vocabularies as results of cultural art education indoor space colors, the average value of evaluation vocabularies evaluated by the senior citizens is used to conduct descriptive statistics. Analysis result according to applied color is as shown in the following.
For color red, [stimulating], [Tense], [Exciting] and [Strong] were the most frequent sensibility vocabularies. [Bright] was the most frequent sensibility vocabulary for yellow-red. For yellow, [Happy], [Hopeful], [Pleasant], [Warm], [Clear], [Enjoyable], [Active] and [Confident] were the most frequent sensibility vocabularies. Especially in yellow, [Interesting], [Bright] and [Light] were the highest sensibility vocabularies. Yellow-green had [Pleasant], [Enjoyable] and [bright] as the most frequent sensibility vocabularies. Green had relatively frequent sensibility vocabularies in [Pleasant], [Clear] and [Strong]. Turquoise blue had relatively frequent sensibility vocabularies in [Stable], [Clear] and [Strong]. Blue had relatively frequent sensibility vocabularies in [Heavy] and [Calm]. [Cold] was the most frequent sensibility vocabulary for blue. [Cold], [Dark] and [Heavy] were the most frequent sensibility vocabularies for bluish violet. Purple had low distribution in overall, but among them, [Clear] and [Strong] were the most frequent sensibility vocabularies. Reddish purple had relatively high frequency in [Exciting], [Heavy] and [Strong] sensibility vocabularies. [Happy], [Active] and [Light] were the most frequent sensibility vocabularies for pink. [Heavy] was the most frequent sensibility vocabulary for brown. For white, [Pleasant] and [Calm] were the relatively frequent vocabularies and [Bright] and [Light] were the most frequent sensibility vocabularies for white. For grey, [Calm] and [Heavy] were relatively frequent. [Not Happy], [Hopeless], [Unpleasant], [Cold], [Irritating], [Boring], [Dark], [Heavy] and [Fearful] were the most frequent sensibility vocabularies for black.

3.3 Sensibility vocabulary evaluation analysis in cultural art education space

T-test analysis is conducted to evaluate the influence on education participants' sensibility by different colors applied to education spaces by conducting sensibility vocabulary evaluation analysis. T-test is an analysis method that compares the average between two groups. In this research, through an independent sample t-test analysis, the sensibility evaluation result gained from two groups, one who has experienced cultural art and another who has not experience cultural art is analyzed as t-value and significance probability value. Moreover, among total analysis result, only values that demonstrated significant differences are used. Oriental calligraphy room that has clear educational purpose within the space is used as an object space and the category of art education conducted in the objective space is applied as shown in (Table 2). Through questions that allow multiple confirmations, the participants are identified as individuals who have experienced cultural art and who have not.

Table 2: Cultural Art Category used in Calligraphy Room

Cultural Art Category	.Oriental calligraphy room
Applied Education Area	Photography, Architecture, Art
Number of Individuals who have experience cultural art	31

It is a result of comparison between two groups: one who has experience photography, architecture and art and another group who has not. In the calligraphy room, varying from whether individuals who have experienced the cultural art or not, yellow-green(6) had t-value of 2.769, pink(15) had t-value of -3.032, grey(3) had t-value of -3.030, grey(4) had t-value of -3.448, and grey(5) had t-value of -2.948. There was less than 0.01 of difference in significance level. Moreover, Reddish purple(5) had t-value of 2.546, pink(5) had t-value of -2.311, pink(14) had t-value of -2.361, grey(1) had t-value of -2.127, grey(8) had t-value of -2.330, grey(11) had t-value of -2.139, grey(12) had t-value of -2.198, grey(13) had t-value of -2.127, and grey(14) had t-value of -2.031. There was less than 0.05 of difference in significance level. In total of 14 categories of yellow-green, purple, pink and grey, statistically difference was demonstrated between the two groups.

4. RESULTS AND DISCUSSION

Based on the advanced technology statistical analysis result, color sensibility vocabulary properties are demonstrated in sensibility evaluation. Vocabularies show vocabularies that have the average value of 6-7 for each color and is in descending order. For colors that do not have numbers higher than 6 demonstrate vocabularies that fall in to the high values. Furthermore, they are vocabularies that are evaluated in educational spaces that have sensibility properties each color has.

Based on the result of independent sample T-test analysis conducted to analyze sensibility between the group who has cultural art experience and another group who does not have the experience, there were total of 14 differences in sensibility vocabulary in yellow-green, reddish purple, pink and grey. Especially, there was major difference in sensibility vocabulary for grey.

For the group who has no cultural art experience, yellow-green was described as [Cold] when the group who has cultural art experience described the color as [Warm]. More individuals in the group who has no cultural art experience felt [Pleasant] for color reddish purple. Moreover, for pink, the group who has no cultural art experience felt [Pleasant], [Light] and [Confident]. Lastly, for grey, the group who has no cultural art experience felt

[Happy], [Comfortable], [Pleasant] and [Influential] whereas the group who has the experience felt [Not Happy], [Tense], [Unpleasant] and [Influenced]. Many individuals in the group who has no experience felt [Stable] and [Calm]. Additionally, whereas the group who has no cultural experience showed medium value in sensibility evaluation of [Active-Static], [bright-Dark] and [Light-Heavy], the group who has the experience felt [Static], [Dark] and [Heavy]. Lastly, in yellow-red, green and purple, there was no difference in all evaluation vocabulary categories.

5. CONCLUSIONS

In this research, sensibility vocabulary evaluation is conducted among senior citizens based on different colors applied to cultural art education space. The evaluation is used to analyze the influence of cultural art education space on senior citizens' sensibility. Research result can be summarized as following:

First, according to the preliminary survey and main study result, in indoor spaces, wall color is the most influential part of the space that allows one to recognize the space and delivers sensibility.

Secondly, yellow and black are colors that deliver most sensibilities described in color sensibility vocabularies. Whereas individuals feel positive emotions towards the color yellow, individuals feel negative emotions towards black. Each color sensibility vocabulary is determined as indoor space color properties.

Third, according to the T-test analysis result, the sensibility derived from color is different in individuals who have experienced cultural art and individuals who have not. Hence, at this point, where the number of cultural art educational spaces for senior citizens and related programs are gradually increasing, sensibility of the users should be incorporated in designing cultural art education spaces.

The result of this research proposes conclusions that can improve the cultural art education quality and help design indoor spaces. This is expected to lead to bring positive influence to senior citizens who utilize cultural art education spaces and improve the leisure life satisfactory level. Additionally, government and municipal groups should establish various and appropriate spatial color plan, improve cultural art educational space facilities and allow planning color palette plans according to spatial properties.

Thus far, research results that demonstrates sensibilities that senior citizens feel according to different indoor spaces and educational space properties have been gathered. In the future, emotional sensibility will be evaluated through color experiences in various cultural art education spaces. Research result as such is expected to prove importance of color as environmental factor in senior citizens facility evaluation category. Furthermore, as a follow-up research, systematic color model development and utilization measure researches will be needed for senior citizen's cultural art educational space.

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Impressions of buildings derived from the combined effects of exterior colour, material, and window shape

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ABSTRACT

External appearance is determining factor in the overall impression of a building, and is greatly affected by the building's architectural surfaces. This study focuses on colour, material, and window shape as elements that affect the visual impression of a building's appearance to ultimately understand the extent to which they impact impressions of a building's appearance. A series of experiments was conducted to determine impressions derived from surface designs of an office building using the semantic differential method. The parameters were exterior colour, materials used, and window shape. In all, 29 colours were selected from the Munsell Coulor System, and three types of materials were selected from commonly used exterior materials in Japanese office buildings. Two types of window shapes were selected from commonly used exterior designs of office buildings. In order to display these elements to the study participants, 174 perspectives of buildings were created as stimuli, using a computer graphics program. Evaluations were sought from 38 observers using 30 semantic differential rating scales. Image profiles were then drawn using the average of each stimulus from the results of the experiments. Three factors—'evaluation', 'potency', and 'warmth'—were extracted and can be characterized by the above parameters. An impression evaluation was determined by the effect of the combination of these elements; however, according to the factor scores, the impact from impressions of colour, material, and window shape was not a constant trend. The results of this study show that colour is the most affective element with respect to impressions regarding architectural appearance; however, because material and window shape also have an impact, it is important to ensure that designs are created through a combination of these elements.

1. INTRODUCTION

The impression of an architectural object's appearance is affected by the components of the surface (i.e. colour, material, window shape). Several previous studies have been conducted on exterior colour and its effect on the overall impression of a building. The impression of exterior colour and impression of colour itself are evaluated by the same factors—the evaluation factor, activity factor, and warmth factor.

Regarding colour, the evaluation factor is related to chroma, activity factor is related to value, and warmth factor is related to hue. In recent years, there has been an increase in the type of exterior materials available for use, such as glossy materials or a different colour for the joints between tiles, which influence appearance. In addition, window shape also affects the impression. In this study, colour, material, and window shape were selected as elements that affect the visual impression of a building's appearance. The strength of impact that these elements have on impression, and the mutual relationships among them, has not been made clear in previous studies; thus, this study seeks to illustrate the extent to which these elements impact the impressions of a building's appearance.

2. EXPERIMENTAL METHOD

A series of experiments was conducted to determine impressions derived from surface designs of an office building using the semantic differential method. The parameters were exterior colour, materials used, and window shape. Twenty-nine colours were selected from the Munsell Color System (see Table 1), and three types of materials and two types of window shapes were selected from commonly used exterior materials used in newer Japanese office buildings.

Table 1. Assigned colours.

Hue	Value／Chroma				Hue	Value／Chroma			Hue	Value	
5R	8/4	6/10	5/6		5BG	8/3	7/8		N	9	7
5YR	8/6	7/12	6/4	3/2	5B	8/4	6/8	4/8			
5Y	9/3	8/14	7/4	6/10	5PB	8/3	6/8				
5GY	9/4	7/6	5/2		5P	8/4	6/8				
5G	8/4	5/10			5RP	7/2	7/8				

The three types of materials were mortar, porcelain tile, and metal panel. Window shape included a single window and a ream window. In order to display these elements to the study participants, 174 perspectives of buildings were created as stimuli, using a computer graphics program. The shape of the example building was a simple form, with window shapes set and exterior materials rendered in the surface colour white (N9.5). Figure 1 shows the images of the rendered building in two dimensions. Using these two-dimensional images, colour simulations were carried out to change only wall colour. The stimuli were presented to participants on a 21-inch CRT display at random. Evaluations were sought from 38 observers using 30 semantic differential seven-point rating scales.

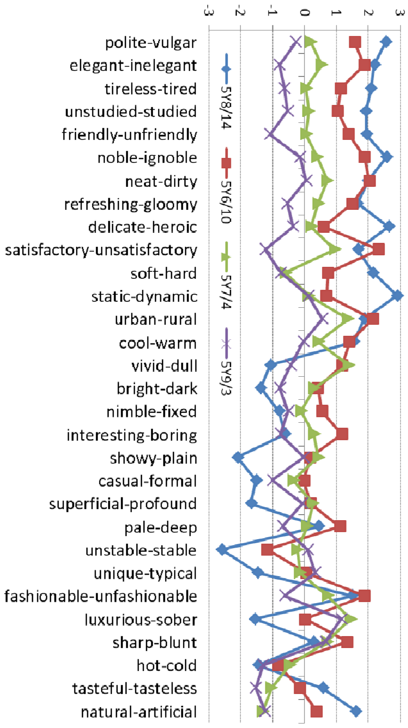
	Material -1	**Material- 2**	**Material- 3**
	Mortar	Porcelain tile	Metal panel
Window-1 Single window			
Window-2 Ream window			

Figure 1. CG images.

3. RESULTS AND DISCUSSION

3.1 Semantic Differential Rating

Image profiles were drawn using the average of each stimulus from the results of the experiments. Figure 2 shows the image profiles of the 5Y pattern (mortar and single window) which is used with a large number of colours in architectural walls. The impressions were different according to the degree of value or chroma under the same hue. For example, 5Y9/3 is a commonly used colour on building exteriors in Japan, and the impressions were ‘natural’ and ‘friendly’. In addition, the impressions of 5Y7/4 were ‘natural’ and ‘sober’, and the impressions of 5Y6/10 were ‘rural’ and ‘unfashionable’. 5Y8/14 is a vivid yellow, and its impressions were ‘tired’ and ‘ignoble’. In the case of the same hue, as value increased, the impressions were either ‘brighter’ or ‘paler’, and as chroma increased, the impressions changed to be more ‘dynamic’ and ‘heroic’. Figure 3 shows the effect of the window shape or materials used in the case of the image profile for 5Y9/3. In this figure, the case of mortar and single window indicates 0, and difference value of the other cases is shown. In Figure 2, the degree of change of the impressions is not large compared to Figure 3. In adjective pairs such as ‘elegant-inelegant’, depending on the window shape or the materials, evaluation toggled between positive and negative. On the other hand, adjective pairs such as ‘originative’, ‘satisfactory’ showed almost no change. That is, in regard to some adjective pairs, impressions were often affected by window shapes or the materials. Focusing on the materials, impressions of mortar were ‘bright’ and ‘casual’, impressions of metal panels were ‘refreshing’ and ‘urban’, and impressions of tile were ‘friendly’ and ‘tasteful’. When comparing the ream window and single window, impressions of ream window tended to be ‘cold’ and ‘casual’.



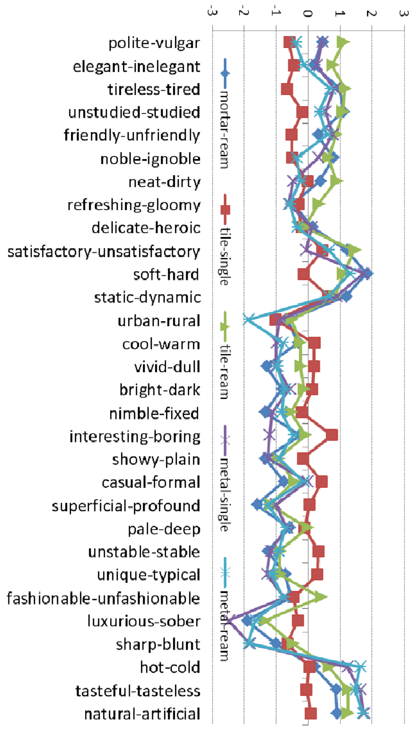


Figure 2. Image Profiles. (5Y, Mortar, Single) Figure 3. Image Profiles. (5Y9/3)

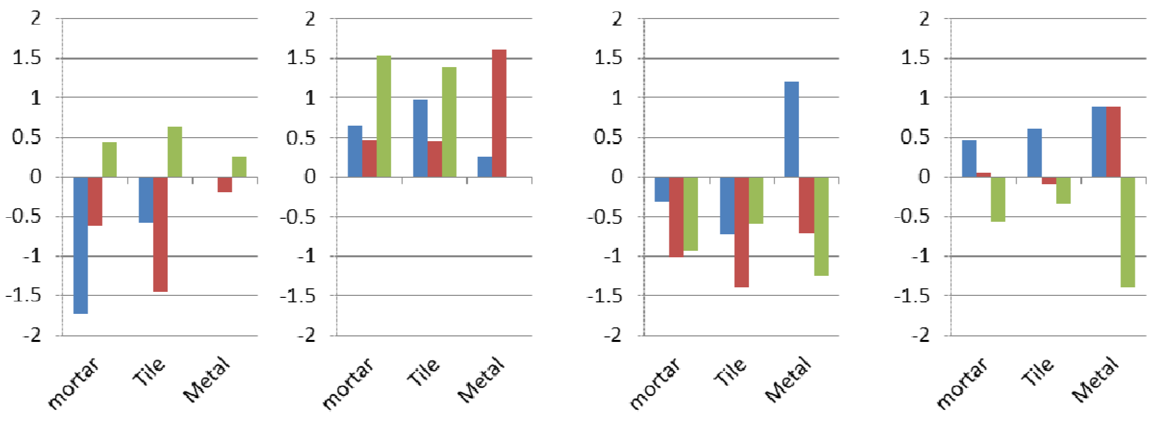
3.2 Evaluation of Tolerance

Using factor analysis, the semantic differential rating data were separately analysed, with the factor loading of each scale shown in Table 2. Three factors—‘evaluation’, ‘potency’, and ‘warmth’—were extracted from the results of this factor analysis. In the first factor (evaluation), the highest scores were obtained in the cases of achromatic and low chroma colours, while factor scores were low in the high chroma colours. Comparing among the different hues, the factor score was lowest in 5P. The materials and window shapes were not as clearly affected by the factor scores. The second factor (potency) was influenced by value, observed as high-value stimuli that were evaluated higher than others. Comparing hue factor scores reveals a higher tendency in 5P and 5GY. The score was highest in the cases of the metal panels. The third factor (warmth) illustrated whether the coolness or warmth of hue was reflected in the evaluation. In this third factor, the effects of the material and window shape were not clearly observed.

Table 2. The factor loading of each scale.

Adjectives	Factor 1	Factor 2	Factor 3	Adjectives	Factor 1	Factor 2	Factor 3	Adjectives	Factor 1	Factor 2	Factor 3
polite-vulgar	0.968	-0.146	-0.022	vivid-dull	0.026	0.946	-0.007	hot-cold	-0.121	0.085	0.940
elegant-inelegant	0.939	0.187	0.003	bright-dark	0.188	0.938	0.092	tasteful-tasteless	0.200	0.128	0.896
tireless-tired	0.922	-0.249	0.155	nimble-fixed	0.170	0.936	-0.064	natural-artificial	0.397	-0.341	0.787
unstudied-studied	0.911	-0.323	0.105	interesting-boring	0.128	0.932	0.027				
friendly-unfriendly	0.903	0.108	0.364	showy-plain	-0.359	0.902	-0.045				
noble-ignoble	0.891	-0.321	-0.066	casual-formal	-0.240	0.888	0.207				
neat-dirty	0.837	-0.134	-0.358	superficial-profound	-0.103	0.873	-0.297				
refreshing-gloomy	0.837	0.488	-0.083	pale-deep	0.524	0.781	-0.110				
delicate-heroic	0.832	0.301	-0.212	unstable-stable	-0.636	0.721	-0.109				
satisfactory-unsatisfactory	0.736	0.299	0.313	unique-typical	-0.555	0.710	-0.199				
soft-hard	0.669	-0.595	0.339	fashionable-unfashionable	0.668	0.704	-0.080				
static-dynamic	0.655	-0.552	-0.395	luxurious-sober	-0.530	0.645	-0.025				
urban-rural	0.627	0.355	-0.596	sharp-blunt	0.439	0.644	-0.561				
cool-warm	0.594	0.517	-0.531					Accumulated contribution(%)	39.196	75.229	89.208

Factor scores' mean score for each stimulus was calculated for confirmation. Figure 4 shows four examples of the factor scores in the case of the single window.

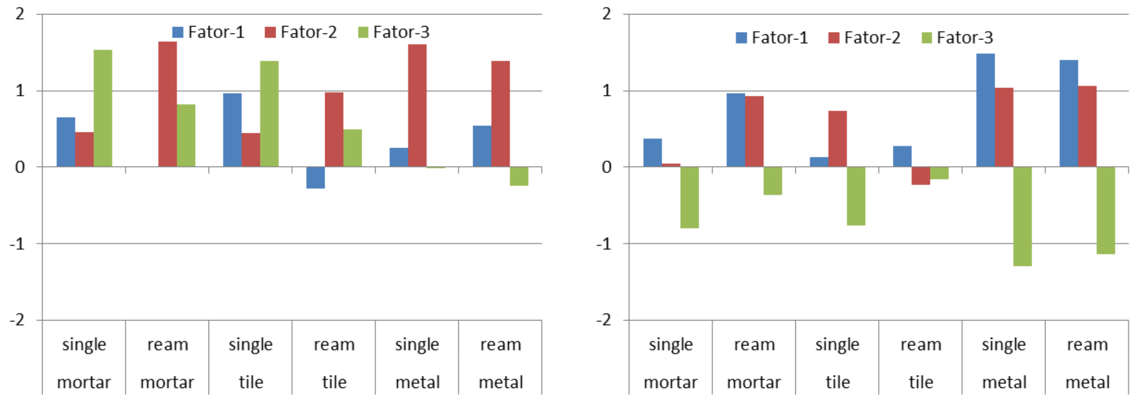


a) 5Y6/10 *b)5Y9/3* *c)5B4/8* *d)5PB8/3*

Figure 4. Factor Score. (single window)

Focusing on the first factor, factor scores of metal panels were higher by one point or more than the other walls in the case of cool colours. Focusing on the second factor, factor scores of metal panels were higher compared to other materials of the same colour. Focusing on the third factor, factor scores of metal panels were lower with almost colour. Features of the material due to their inherent differences are reflected in the trend of impressions between mortar and tile, but metal panel showed a different tendency.

Impressions of the first factor were affected by the window shape in 5Y9/3; however, the impact of the materials was observed more strongly than window shapes in 5B8/4 (see Figure 5).



a) 5Y9/3 *b) 5B8/4*

Figure 5. Factor score. (combination comparison between materials and window shape)

In the second factor, the factor scores of the ream window were equal or higher than the factor scores of the single window; however, factor scores of the ream window were low in the case of 5B8/4 (tile). In the third factor, the single window had higher factor scores than the ream window in any material in 5Y9/3; however, the scores were reversed in 5B8/4. Effects of the impression due to the difference of window shape were different based on the combination of materials and colours.

4. CONCLUSIONS

As a result of the factor analysis, three factors were extracted that describe the impressions and mutual relationships among colours, wall materials, and window shapes. Colour was shown to be the most affective element with respect to impressions regarding architectural appearance; however, material and window shape also have an impact. Effects of the impressions were different based on the combination of colours, window shapes, and materials; therefore, it is important to ensure that designs are created through a combination of these three elements.

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Analysis of Current Colors of Native Plants Growing Naturally in Korea

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ABSTRACT

Although there are numerous magazines and specialty publications covering a range of plants from foliage plants to wild flowers, plant colors are often misunderstood. Although color atlases for the design field have been developed, they are limited in their applicability to plants. The RHS color chart published by the Royal Horticulture Society is used as the standard for classifying flower colors by adjusting chroma and brightness based on principle hue. Although the RHS color chart is used in Korea for classification of plant colors, its specificity for British flowers limits its applicability to Korean wild plants. As it is not generalized in the ordinary domain other than by plant majors, it is hard to share information in other fields except for the relevant field. In addition, there are limits in terms of peripheral temperature, humidity, light conditions, and subjective perception of color. This research tried to develop an objective and rational standard color atlas for native plants growing naturally in Korea.

From February 2013 to January 2014, wild plants were photographed using Colorchecker Passport (Standard Colorchip), and colors were extracted using the Lightroom program. In analyzing native plants by season, a total of 187 color values were extracted, and Yellow Green showed the highest extraction yield with 37.9% of 116 colors extracted in the spring, followed by Yellow with 29.3% extracted in the spring. Of the 63 colors extracted in the summer, Yellow Green showed the highest extraction yield at 36.5%, whereas Yellow showed 31.7% and Orange and Reddish Purple both showed 9.5%. Of the eight colors extracted in the fall, Yellow Green and Yellow showed extration yields of 37.5%, whereas Purple and Reddish Purple both showed 12.5%. In the winter, native plants hibernated and were not extracted. Based on this research, the availability of natural colors will increase. Studies on color atlases on plants in Korea should be conducted.

1. INTRODUCTION

1.1 Purpose and Implication of the Research

Native Korean plants are all plants that exist and grow naturally in mountains and fields of Korea. A large variety of plants are categorized as native Korean plants, including endemic plant species that only exist in Korea (An 2008). In 1952, Nakai reported that there are 2,898 species of native Korean plants and over 4,000 more species of native Korean plants have been discovered since then, including 407 Korean special species (Lee 2001, Yoon 2002). Korea is a peninsula in the northern hemisphere temperature region (adjusted to the south of China and surrounded by the ocean on the east, west, and south), which means there is a comparatively wider variety of native plants compared to other countries (Koo 1999). In this era of globalization, development of native plants, which have climate and cultural specificity, is essential (Oh 2002). Consequently, there are many recent studies on native plants. As well as their physiology and growth/development, including thier habitat environments (Lee 1990), category and ecology (Jeong 1991), cultivation (Ha 1998), and breeding(Yoo 1984). Yet, there is still a lack of research on the color of native plants, such as stainability of natural plant extracts (Park 2004) and applicability of fruit colors from native plants (Kim 2011). There are also many different variables affecting colors, including surrounding temperature, humidity, lighting, and subjective factors in perceiving colors (Han 2006). Especially, plant colors are of a much wider variety than fragmentary manmade colors, which means they can be more emotionally expressive. However, due to limitations in collecting objective data and application methods thereof, the full range of plant colors is not being fully used (Kim 2012). Color atlases, which are objective analysis tools, are being continuously developed, For example, there are also numerous accurate published color atlases such as Seoul Color and Guides to Public Design Color Standards. However, such color atlases are insufficient when applied to colors of plants. The RHS (Royal Horticulture Society) color chart, which is a color standard in the field of horticulture, is currently used for categorizing colors of plants in Korea. Yet, there is a limitation in matching colors of native Korean plants with the color chart defined in England with their own flower colors (Kim 2014). Furthermore, such color charts are not widely used in various fields other by plant majors, which means there is a difficulty in sharing information amog fields other than plant-relatedones. Thus, this study was designed to prepare fundamental data for designing an objective and reasonable standard color chart for Korean native plants.

2. METHODS

2.1 Research Target and Range

To analyze colors of native Korean plants, a total number of 140 plants were selected through relevant research references (Yoon 2002), advice from three professional florists, and local investigations as follows: 86 species that bloom in spring, 48 that bloom in summer, and six that bloom in autumn.

2.2 Experimental Procedure

2.2.1 Investigation Method for Colors of Native Plants

From February of 2014 to January of 2014, pictures of target native plants were taken using a DMC-LX5 Panasonic camera. The pictures were taken under the same lighting conditions (clear daytime at same time range) using a Colorchecker Passport (Standard Colorship)(Figure 1) of X-Rite, which provides standards for processing using color modification programs (Figure 2). In order to accurately modify the white balance, the pictures were saved as RAW files (Baek 2012).

Figure 1: The Colorchecker Passport(Standard Colorchip) used in the study

Figure 2: Taking pictures of the targets(native plants) using Colorchecker Passport

2.2.2 Native Plants Color Analysis

Prior to the color analysis, a monitor-modification process was performed using the Eye-One Xtreme iO bundle of X-rite in order to increase accuracy of the color reproduction process. Adobe Photoshop Lightroom 5.6 program was used to reproduce the original colors of the targets, with sRGB designated as the standard RGB color range (Baek 2012) and the image files saved by exporting the pictures. Using the Adobe Photoshop CS5 program, color coefficients of each image were investigated (Figure 3), and the color chips were produced to reproduce the colors as images (Figure 4). Since plants have various patterns and colors, different colors could be extracted from a single species (Kim 2014). Both background and pattern colors were extracted from patterned plants, and only the background color was extracted from solid-colored plants. For a collection of objective data, the above process was repeated three times.

Figure 3: Investigation of color coefficients(RGB) using Adobe Photoshop CS5 Program

Scientific name	R	G	B	Color image
Paeonia lactiflora Pall.	208	2	133	

Figure 4:Creation of color image using the color coeffiecients(RGB)

2.2.3 Color system of Korea Industrial Standard (KS)

The KS is managed by the Korea Technology Standards Association, and the color standards are matched with the KS according to the Industrial Standardization Act (Moon 2011). The KS color system consists of 10 basic colors: red (R), yellow red (YR), yellow (Y), green yellow (GY), green (G), blue green (BG), blue (B), purple blue (PB), purple (P), and red purple(RP) (Park 2007)(Figure 5).

Figure 5: Basic colors of KS color system

3. RESULTS AND DISCUSSION

3.1.1 Analysis of Native Plant Colors (Spring)

Of the 85 spring native plants, a total of 116 color coefficients, including pattern colors, were extracted. Specifically, GY group colors showed the highest extraction yield of 37.9%, followed by Y group colors (29.3%), P group colors (13.8%), and RP group colors (10.3%). The R (5.2%) and YR (3.4%) group colors were extracted in small proportions (Table 1).

Table 1. Analysis of Native Plant Colors (Spring)

No	L*	a*	b*	R	G	B	H	V	C	C	M	Y	K	Color
1	16.05	25.19	11.14	89	35	42	8.83R	1.55	5.44	19	41	38	45	
2	19.22	32.83	18.04	106	31	39	9.12R	1.87	7.57	19	49	46	38	
3	25.50	20.93	8.76	107	60	65	5.98R	2.49	4.42	19	38	36	38	
4	42.35	22.36	11.41	152	96	99	5.27R	4.11	5.02	20	41	40	20	
5	55.16	53.58	5.56	221	191	201	1.87R	7.68	2.66	13	25	21	0	

3.1.2 Analysis of Native Plant Colors (Summer)

Of the 45 summer native plants, a total of 63 color coefficients, including pattern colors, were extracted. Specifically, GY group colors showed the highest extraction yield of 36.5%, followed by Y group colors (31.7%), RP group colors (9.5%), and O group colors (9.5%) (Table 2).

Table 2. Analysis of Native Plant Colors (Summer)

No	L*	a*	b*	R	G	B	H	V	C	C	M	Y	K	Color
1	27.16	22.36	12.60	114	62	63	7.60R	2.65	4.90	19	40	39	35	
2	48.72	13.60	6.22	154	117	122	4.52R	4.72	3.16	20	34	32	19	
3	72.32	20.70	14.47	230	168	167	6.94R	7.07	5.51	9	34	34	0	
4	36.63	41.54	19.74	162	63	74	4.93YR	3.56	9.42	20	58	54	146	
5	50.18	51.52	62.68	218	82	2	0.19YR	4.86	14.88	14	67	99	0	

3.1.3 Analysis of Native Plant Colosr (Autumn)

Of the seven autumn native plants, a total of eight color coefficients were extracted. Specifically, Y and GY group colors showed the highest extraction yield of 37.5%, followed by RP group colors (12.5%) and P group colors (12.5%) (Table 3).

Table 3. Analysis of Native Plant Colors (Autumn)

No	L*	a*	b*	R	G	B	H	V	C	C	M	Y	K	Color
1	55.73	-0.79	50.87	154	145	57	9.73Y	5.41	6.95	20	23	58	19	
2	81.41	-6.47	84.08	223	210	1	9.82Y	8.01	11.52	12	17	99	0	
3	92.05	-6.47	73.37	255	237	0	9.14Y	9.10	12.65	0	7	100	0	
4	74.96	-0.04	33.45	199	192	139	0.55GY	7.34	0.55	20	22	43	1	
5	96.74	-6.36	7.71	246	247	242	7.5GY	9.57	7.50	3	3	5	0	

3.1.4 Analysis of Native Plant Colors (Winter)

In winter, all native plants hibernate, so no colors were extracted.

3.1.5 Integrated Native Plant Color Analysis

As a result of the analysis of colors of Korean native plants, GY and Y group colors showed the highest extraction yields from plants in all three seasons. Although in small proportions, RP group colors were also found from plants in all three seasons (Table 4).

Table 4. Intergrated Native Plant color analysis

Color name		R	YR	Y	GY	G	BG	B	PB	P	RP	Total(%)
Season	Spring	5.2	3.4	29.3	37.9	0.0	0.0	0.0	0.0	13.8	10.3	100.0
	Summer	4.8	9.5	31.7	36.5	0.0	0.0	0.0	0.0	7.9	9.5	100.0
	Autumn	0.0	0.0	37.5	37.5	0.0	0.0	0.0	0.0	0.0	12.5	100.0

4. CONCLUSIONS

Colors of Korean native plants were analysed, and no colors were extracted from plants in winter, when all native plants hibernate. In the three other seasons, GY and Y group colors were found in large proportions from native plants. Although in small proportions, RP group colors were found as well.

Currently there is no color chart for colors of Korean native plants, so this study is expected to increase the applicability of plant colors and can be used as fundamental data for investigating Korean native plants in the future. Moreover, there is a necessity for continuous production of relevant research from various approaches.

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Effects of Accent Colour on the Apparent Distance to a Wall and the Apparent Volume of an Interior Space: The Validation Experiment in an Actual 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 in an actual experimental space. 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 accent colour area, as well as its hue. If the wall contains a greater amount of the accent colour, the wall will seem to advance and the interior space will appear cramped. Conversely, if the wall contains a lesser amount of the accent colour, the degree of the effect will be smaller.

1. INTRODUCTION

Colours produce many psychological effects, such as contrast, assimilation, advancing, receding, and area effects, among others. The authors studied the advancing and receding effects of the colours on the apparent distance to a front wall located in an interior space painted in a single colour. Notably, houses contain many accessories, such as curtains, blinds, paintings, etc. These components are perceived as accent colours in an interior space. Thus, the study also sought to evaluate the effects of the accent colours on a wall, considering the apparent distance to the wall and the apparent volume of the interior space by using scale models. However, as these effects need to be confirmed in an actual space, this study evaluated the effects of an accent colour on a wall in an actual experimental space. Consideration was given to the apparent distance to the wall and the apparent volume of the interior space. It was found that accent colours on a wall have effects on the apparent distance to a wall and the apparent volume of an actual interior space.

2. EXPERIMENTAL METHOD

Psychological experiments were conducted in an actual experimental space (see Figure 1). Two distinct spaces of the same size (i.e., the standard space and the comparison space) were set side by side. They were separated by an N8 curtain. The walls of the spaces were painted with N8. Fluorescent lamps of high colour-rendering type were installed. The average interior illuminance level was approximately 500 lx. An extremely thin square panel painted in a single colour was hung in the center of the wall of the comparison space. There were three experimental conditions based on the panel size: (1) a large panel (hereafter referred to as EC50) occupying 50% of the wall; (2) a mid-sized panel (hereafter referred to as EC10) occupying 10% of the wall; (3) a small panel (hereafter referred to as EC2) occupying 2% of the wall (see Figure 2). A total of seven panel colours were selected. Table 1 shows the assigned panel colours. A total of 22 experimental patterns were created. They included combinations of seven colours, and were constructed with panels of three different sizes as well as without a panel. The subjects consisted of twelve females and two males with age ranging between 20 and 24. The subjects had no colour-vision deficiencies. The experimental panels were randomly presented to each subject. The fourteen subjects were asked to evaluate the apparent distance of the front wall of the comparison space based on their comparisons of both spaces. The comparisons were rated by using a seven-point rating scale. The magnitude estimation method was adopted to evaluate the apparent volume of the comparison space. The subjects were also asked to compare the ratio of the apparent volume of the comparison space with that of the standard space, whose value was set to 100.

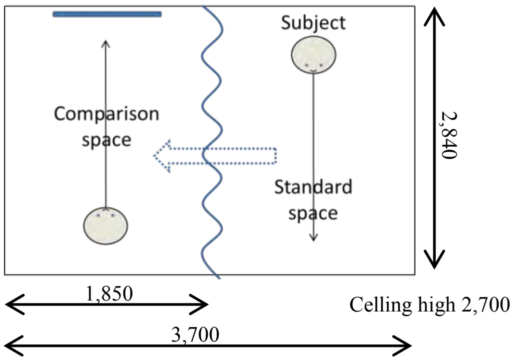

Figure 1: The plan of the experimental spaces.

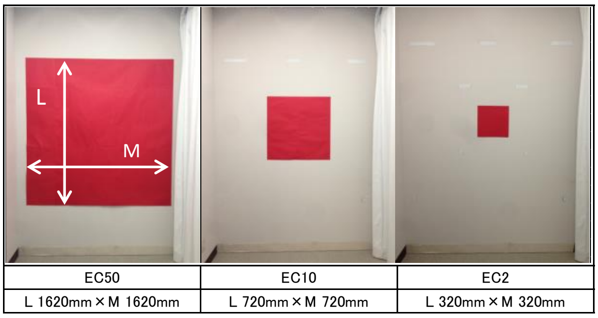

Figure 2: The panel sizes.

Table 1. The assigned panel colour.

NO.	Colour term (Designation of the study)	Hue	Value	Chroma
1	RED (R)	5R	4	12
2	YELLOW (Y)	5Y	8	10
3	GREEN (G)	7.5G	5	8
4	BLUE (B)	10B	5	8
5	PURPLE (P)	5P	4	6
6	BLACK (Bk)	N	2	−
7	WHITE (W)	N	9.5	−

3. RESULTS AND DISCUSSION

3.1 Apparent distance to the frontal wall

Figure 3 shows the apparent distance to the wall for each colour in each panel size. For EC50, the wall seemed to advance for all the colours except W. The degree of advancement was greater for the warm colours, as well as for Bk and P. For EC10, the wall seemed to advance for all the colours. The degree of advancement was greater for the warm colours. For EC2, the wall seemed to advance for all the colours except B and G. As in the previous cases, the degree of advancement was greater for the warm colours. The values increased proportionally to the area of the panel.

To clarify the relationship between the apparent wall distance and the experimental factors, an analysis of variance was conducted using the General Linear Model procedure. The experimental factors chosen were the hue and area of the panel. The effects of all the factors were statistically significant (Level of significance: 0.05). Figure 4 shows the profile plots of each significant experimental factor. With respects to the hue of the panel, the front wall appeared to advance significantly for all the colours except B. The degree of advancement was greater for the warm colours. With respects to the area of the panel, the front wall appeared to advance for all the sizes, with a decreasing degree of advancement following the order EC50, EC10, EC2.

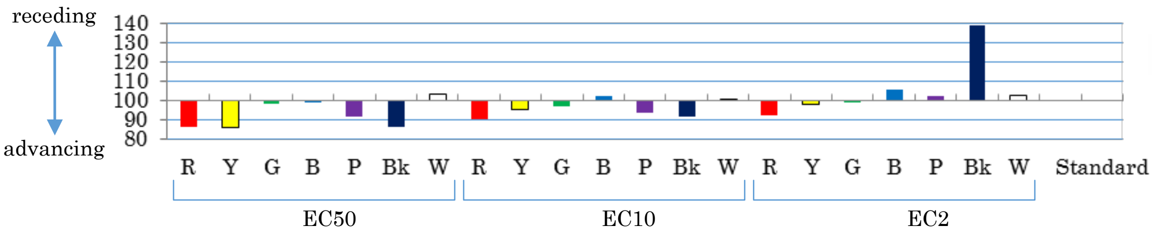

Figure 3: Apparent distance to the wall for each colour in each size.

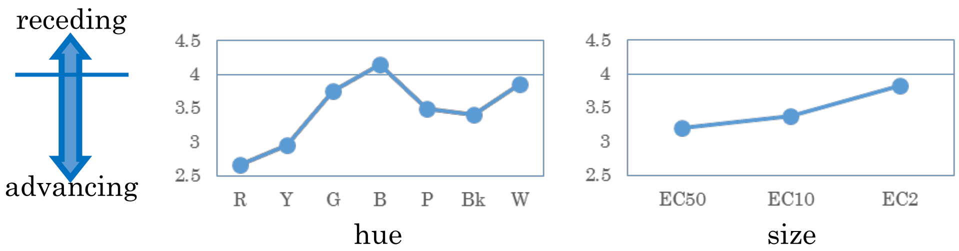

Figure 4: The profile plots of each significant experimental factor.

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 smaller for all the colours except W. The degree of shrinkage was greater for the warm colours, as well as for Bk and P. The values of EC10 showed a similar tendency to those of EC50. However, the degree of shrinkage for EC10 was smaller than that observed for EC50. For EC2, the interior space appeared smaller for the warm colours, while it appeared larger when blue and black were used.

In addition, an analysis of variance was conducted. The effects of all the factors were statistically significant (Level of significance: 0.05). Figure 6 shows the profile plots of each significant experimental factor. With respects to the hue of the panel, the value of the interior space appeared significantly cramped for all the colours except B and W. The degree of restriction was greater for the warm colours. With respects to the area of the panel, the value of the interior space appeared cramped in EC50 and EC10. For EC2, the volume appeared equivalent to the standard space.

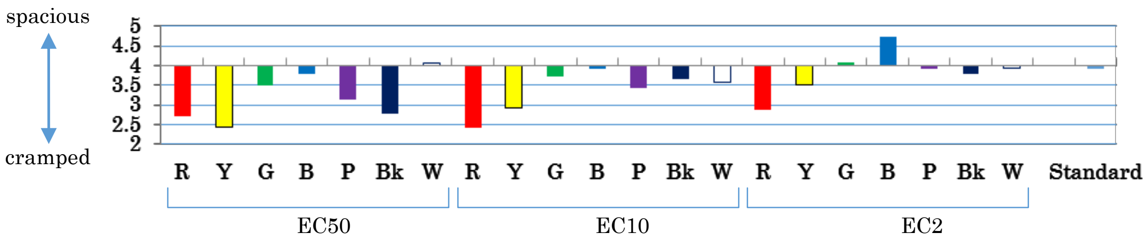

Figure 5: Apparent distance to the wall for each colour in each size.

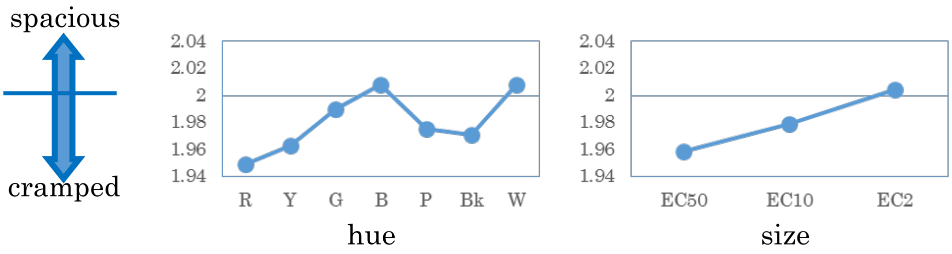

Figure 6: The profile plots of each significant experimental factor.

3.3 Relationship between the apparent distance and the apparent volume

The correlation coefficient between the apparent distance and apparent volume was quite high: 0.837.

4. CONCLUSIONS

The following conclusions were obtained by conducting experiments in the actual space. In relation to the presence of an accent colour on the wall, the apparent distance to the wall and the apparent volume of the space can vary. The apparent distance to the wall and the apparent volume of the space depend on the area of the accent colour, as well as its hue. If the wall contains a greater amount of an accent colour, the wall seems to advance and the interior space appears cramped. However, if a cold colour is contained, the wall seems to recede and the interior space appears more spacious. The degree of the advancement was greater for warm colours, in line with the perceptual effect reported in previous research. It was found that the presence of an accent colour on a wall influences the apparent distance to a wall and the apparent volume of an actual interior space.

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Metamer Mismatching as a Measure of the Color Rendering of Lights

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ABSTRACT

We propose a new method for evaluating the colour rendering properties of lights. The new method uses the degree of metamer mismatching for the CIE XYZ corresponding to flat grey (constant reflectance of 0.5) quantified in terms of the metamer mismatch volume index proposed by Logvinenko et al. (Logvinenko 2014). A major advantage of this method is that unlike many previous color rendering indices it does not depend on the properties of a chosen set of representative test objects.

1. INTRODUCTION

Evaluating the colour rendering properties of lights is an important issue in the lighting industry. It is well known that the colours of objects viewed under lights of identical correlated colour temperature may look very different under the different lights. Several color rendering indices have been used in the past. Perhaps the most widely used is the CIE colour rendering index CIE Ra (CIE 1995), which is based on computing the average color difference induced by the illuminant for a fixed set of reflectances. The CIE Ra is a color fidelity measure. There have also been preference-based measures such as Judd's flattery index (Judd 1967) and Thornton's colour preference index (Thornton, 1972), in which the focus is more on the subjective preferability of lights. More recently Smet et al. (Smet 2010, Smet 2015) have suggested a memory-color-similarity measures, Sa and Rm (a non-linear scaling of Sa), based on how a light affects the colors of a sample set of familiar objects (green apple, banana, orange, lavender, Smurf, strawberry yoghurt, sliced cucumber, cauliflower, Caucasian skin, sphere painted Munsell N4 grey) in comparison to the average subject's memory of the colors of those objects as determined by psychophysical experiments.

The CIE Ra is defined in terms of a reference illuminant and the test light being evaluated. For test lights of CCT less than 5000K the reference illuminant is chosen to be the ideal blackbody radiator of the same CCT. For test lights with CCT of 5000K or greater, the reference light is chosen to be the standard CIE daylight D-series illuminant of the same CCT. There are 8 test color samples (Munsell papers) whose color differences, after an adjustment for chromatic adaptation, under the test and reference lights are evaluated.

The CIE Ra has been widely criticized, especially for the evaluation of LED lights. One of the key problems with it is that it is based on measuring the colour differences that arise across a small sample of 8 (sometimes generalized to 14) coloured papers. Not only may such a sample not represent what the colour differences for all other possible surface reflectances may be, it also gives manufacturers the opportunity to tune the spectra of their lights to perform well on the standard sample.

Variants of metamer mismatching have been previously used as a measure of the color rendering of daylight simulators. In particular, the CIE Metamerism index is a measure based on calculating the average color difference between each of a set of reflectance pairs that are initially metameric matches under the reference light but not necessarily metameric matches under the target light. However, this method is limited to the specific reflectances used. Whitehead et al. (Whitehead 2012) extend this general idea by using a large number of randomly generated metameric spectra and then assessing the fraction of them that noticeably change colour when the illuminant changes. In contrast, the method proposed here is based on measuring the size of the metamer mismatch volume, which is the volume of colour signals (i.e., XYZs) induced under the second light by the set of all theoretically possible reflectances that make a metameric match under the first light.

1. METAMER MISMATCH INDEX

The background for the proposed measure of colour rendering is the concept of metamer mismatching. Consider a colour signal XYZ (in CIE standard coordinates) observed under a first light. Metamer mismatching refers to the fact that the possible XYZ that might be observed under a second light is only constrained to lie within a convex volume of possible XYZ values. The size of the volume depends on the XYZ and the lights involved; however, the volume for the XYZ of flat grey is the largest. The metamer mismatch volume represents the range of possible XYZ that can arise under the second light and so provides a measure of how varied the XYZ under the second light can be—the less the variation, the better the color rendering.

The boundary of the metamer mismatch volume can be calculated using the code of Logvinenko et al. (Logvinenko 2014), which finds the maximum amount of metamer mismatching that can occur for any given XYZ and pair of lights. Figure 1 shows an example of the metamer mismatch volume for the XYZ of flat grey for a change in illuminant from an ideal 2900K blackbody radiator to a 2900K LED. Even though the two illuminants are of the same CCT the metamer mismatch volume is quite large: it fills a sizable fraction of the entire object-color solid. The object-colour solid is the set of all possible XYZ that can arise for all possible reflectance functions $\rho(\lambda)$ (i.e., $0 \leq \rho(\lambda) \leq 1, 380 \leq \lambda \leq 780$nm). The metamer mismatch volume depicted is the set of all possible XYZ that could arise under the second illuminant for any reflectance that is metameric to flat grey under the first illuminant.

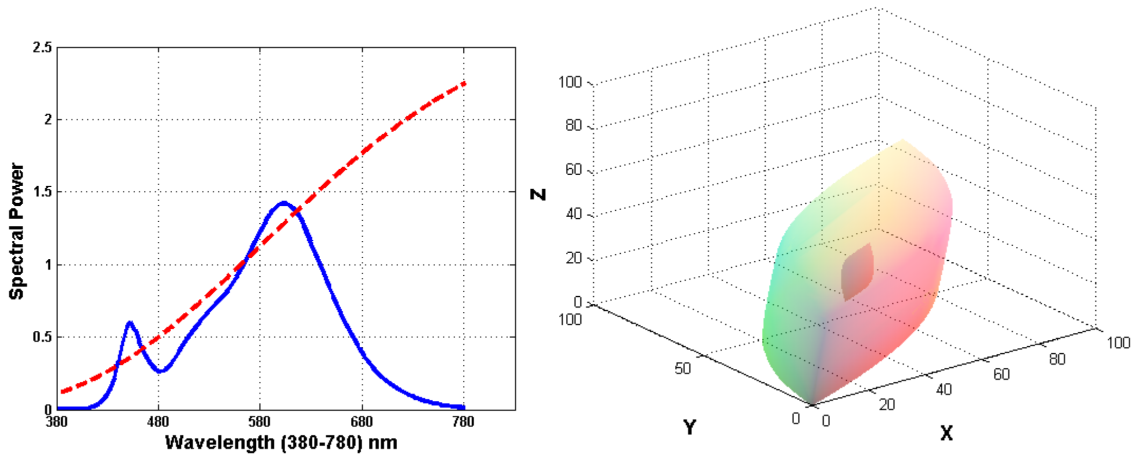


Figure 1: Left: Spectra of a 2900K LED (blue) and that of an ideal 2900K blackbody radiator (dashed red). Right: Metamer mismatch volume (for the XYZ of flat grey lit by a 2900K blackbody) shown inside the object-colour solid of the 2900K LED for the case when the illuminant is changed from the blackbody to the LED. Coordinates are the CIE 1931 XYZ space.

Since both the object color solid and the metamer mismatch volume change with the second illuminant, we consider size of the metamer mismatch volume relative to the size of the object color solid it generates. In particular, both scale with the intensity of the second illuminant. Hence, the metamer mismatch volume index (MMVI) (see Logvinenko et al., 2014 Eq. 15 for a formal definition) for a given XYZ and a pair of illuminants is defined as the ratio:

$$MMVI = \frac{\text{volume of the metamer mismatch volume for the given illuminant pair}}{\text{volume of the object color solid under the second illuminant}} \qquad (1)$$

Note that this ratio is also independent of any linear transformation of the color coordinate space and so will be the same for any LMS space obtained as a linear transform of CIE XYZ as for CIE XYZ itself.

In terms of colour rendering, the larger the MMVI, the poorer the colour rendering of the second light relative to the first light is likely to be. Since the MMVI is volume based, we find it more intuitive to consider MMVI^(1/3). The Metamer Mismatching Colour Rendering Index (MMCRI) is then defined as:

$$MMCRI = (1 - \sqrt[3]{MMVI})\times 100 \qquad (2)$$

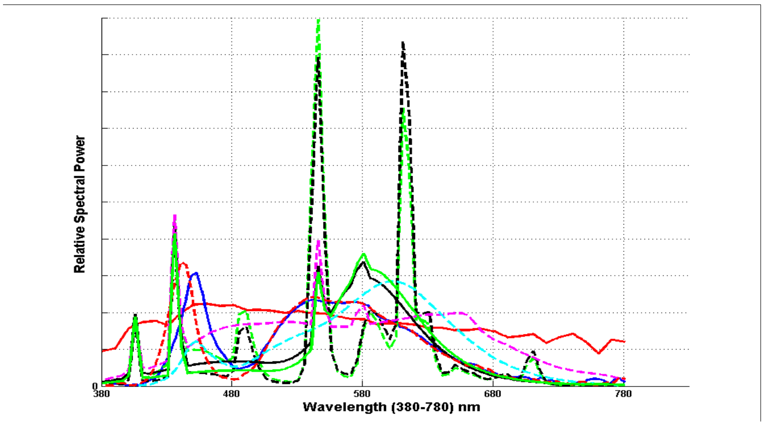
where the MMVI is for that of the XYZ of flat grey under the first illuminant. The scaling by 100 is simply to make its range match that of the CIE CRI Ra.

4. COMPARISON TO OTHER COLOR RENDERING INDICES

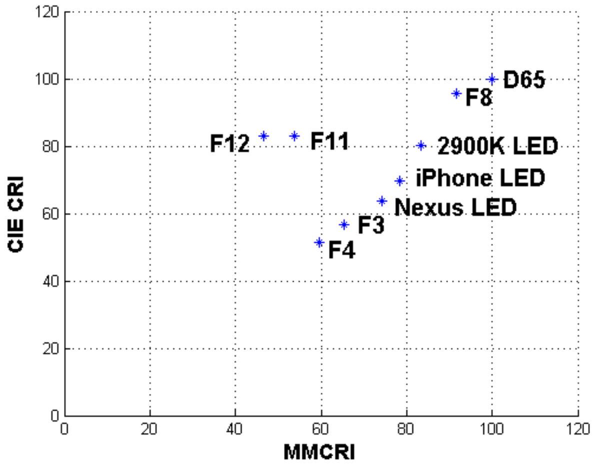
The MMCRI can be computed for any pair of illuminants as a measure of the color rendering properties of the second light relative to the first. However, the CIE CRI Ra for a light L is defined relative to an 'ideal' illuminant (blackbody or D-series) of the same CCT as L. For comparison with Ra we use the same choice of 'ideal' illuminant as the first illuminant when computing the MMCRI of L.

We have computed the MMCRI and CIE Ra for several light spectra across a range of CCTs and technologies and compared them. In particular, we measured the spectra of several commercially available LED lights and also used the spectra of the CIE standard illuminants. When plotted as in Figure 2 we see a good correlation between the two indices—an indication that the MMCRI behaves reasonably—but with notable differences for some illuminants. It is exactly such differences that the proposed new method is intended to reveal. In particular, we note that F11 and F12 have a high CIE Ra but a low MMCRI. Since F11 and F12 are both dominated by three narrowband peaks, it seems unlikely that their color rendering properties are very good, and this is confirmed by the MMCRI.

As second test, we make use of the set of lights Smet et al. included in their paired comparison experiment (Smet 2010). Smet's set contains: a halogen lamp (H), a fluorescent lamp approximating CIE F4 (F4), a Neodymium incandescent lamp (Nd), a Philips Fortimo LED module with a green filter (FG), an RGB LED lamp (RGB) and a LED cluster (LC) optimized to obtain a high Sa, all of which are plotted in Figure 3. The various color rendering measures are compared in Table 1.



(2a)



(2b)

Figure 2: (2a) The illuminant spectra used for testing: D65 (red), F3 (black), F4 (dashed green), F8 (dashed magenta), F11 (dashed green), F12 (dashed black), 2900K LED (dashed cyan), Nexus LED (dashed red) and iPhone LED (blue). (2b) CIE CRI versus MMCRI.

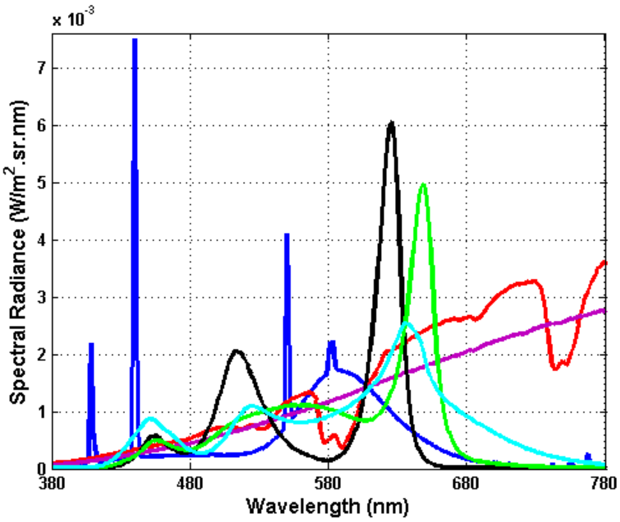


Figure 3: The spectral power distributions of the six light sources (provided by Smet) and used for the comparison of the color rendering measures listed in Table 1. The lights (see text) are F4 (blue curve), FG (green), Nd (red), LC (cyan), H (purple) and RGB (black).

Table 1. Comparison of Color Rendering Measures. Measures include: Sa, memory color similarity (Smet 2010), Ra (CIE CRI), NIST CQSa Color Quality Scale (Davis 2010), and MMCRI (proposed metamer mismatch index). The data reported in the table for Sa, CIE CRI Ra and NIST CQSa are quoted from Table 2 of Smet et al. (Smet 2010, page 26235). The MMCRI results were computed based on the MMVs for a change from the blackbody radiator having the CCT of the given illuminant to the given illuminant. The lights were approximately equal illuminance ranging from 239 to 251 lux, and CCT ranging from 2640 to 2878. The spectra of the lights are plotted in Figure 3.

Light source	Sa		CIE Ra		NIST CQSa		MMCRI	
	Sa	Rank	Ra	Rank	CQSa	Rank	MMCRI (Grey)	Rank
F4	0.6672	5	52.8	5	53.9	5	55.53	5
FG	0.7787	3	80.6	3	87.2	3	83.99	3
Nd	0.7841	2	73.7	4	87.0	4	89.46	2
LC	0.7899	1	81.0	2	89.0	2	74.95	4
H	0.7662	4	99.6	1	97.2	1	99.64	1
RGB	0.6548	6	31.9	6	50.5	6	49.30	6

The results in Table 1 show a general agreement in ranking across all the methods in that the same lights are given ranks 3 (FG), 5 (F4), and 6 (RGB). Ra and CQSa rankings for all six lights are identical. MMCRI agrees with Ra and CQSa on 4 of the rankings, but swaps the rankings of Nd and LC, ranking Nd 2nd, in agreement with Sa and the reported popularity of Neodymium lights in terms of their sales. Since LC is an LED cluster designed to optimize Sa, it is not surprising that it is ranked first by Sa. Similarly, since H is a halogen light closely approximating a blackbody radiator, it is also not surprising that MMCRI, Ra and CQSa all rank it first since they assume that a blackbody is the ideal light source in terms of color rendering. This is an assumption that Smet et al. (Smet 2012) challenge, but as yet no general alternative has been proposed.

It should be noted that the Sa rankings in Table 1 do agree with the 'preference' and 'fidelity' rankings reported in Table 3 of Smet et al. (Smet 2010, p. 26237). However, one problem Table 1 reveals about the Sa measure is that it ranks many of the lights almost identically. In particular, FG, Nd, LC and H all have Sa values of 0.778 ±0.012. Effectively, Sa divides the lights into just two groups: (FG, Nd, LC, H) and (F4, RGB). In comparison, with MMCRI there are clear differences in the scores such that there are four distinct groups: (F4, RGB), (LC), (FG, Nd) and (H).

4. CONCLUSION

A new measure of the color rendering properties of lights is proposed based on the general concept of metamer mismatching. The amount of metamer mismatching—effectively the range of theoretically possible color signals arising under a second light—is taken as an indicator of the difference in the color rendering properties of the second light relative to the first. The greater the degree of metamer mismatching, the poorer the color rendering is considered to be. Previous color rendering indices have been based on a fixed selection of object reflectances. Although there have been attempts to optimize the set of test reflectances (Smet 2013) a finite set will always remain the source of some bias. In comparison, the proposed method, through the calculation of the metamer mismatch volume, takes into account all theoretically possible reflectances

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Visual Impression of a Real Room Affected by Lighting Conditions and by Colour and Texture of the Walls

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ABSTRACT

Colour scheme plays an important role in the process of interior design. Different combinations of wall colours, textures and lighting conditions can bring out differences in terms of semantic feelings and aesthetic judgements. That makes an important issue to find out appropriate combinations of colours and light sources for an interior environment. To address the issues, interior colour design was taken as an example in our psychophysical study of wall colour and lighting conditions.

The aim of this study is to investigate visual impression of a real-room space, a "shooting studio" with a size of 3m (width) x 3m (depth) x 2.5m (height). The backgrounds for the three "walls" were made of coloured cloth sets that can be changed easily by a rail system. The lighting conditions were varied by adopting different light sources. Six wall colours were used in the study: grey, white, black, light brown, light blue and light green. Six lighting conditions were adopted, generated by two correlated colour temperatures (CCT), 6500K and 2700K, and three lighting directions, including (a) light travelling up and sideway, (b) a non-directional floor lamp and (c) light travelling down). This resulted in 6 (background colours) x 6 (lighting conditions) = 36 experimental conditions. In addition to these 36 experimental conditions based on cloth background, 12 extra experimental conditions based on paper background were also used to investigate whether the results were influenced by the background texture (i.e. cloth vs. paper). The 12 paper-background experimental conditions were selected randomly from the 36 cloth-background experimental conditions in terms of wall colours and light sources.

Ten semantic scales, including like/dislike, comfortable/uncomfortable, warm/cool, spacious/small, bright/dark, clean/dirty, relaxing/tense, elegant/inelegant, classical/modern and harmonious/disharmonious, were used to measure the emotional effects of combinations of the wall colours and the lighting conditions. Twenty-two observers with normal colour vision, including 11 males and 11 females, participated in the study. During the experiment, each observer was asked to sit in the room and to rate for each experimental condition using the 10 semantic scales.

As a result, the 10 scales were classified using principal component analysis into two underlying factors, "brightness" and "warmth". The "brightness" factor was found to correlate closely with bright/dark, clean/dirty and spacious/small. The "warmth" factor was highly correlated with the remaining scales. Note that "like/dislike" was correlated more closely with the "warmth" factor (R=0.75) than with the "brightness" factor (R=0.45), implying that warmth was more important than brightness to increase the preference. High

correlation was found between the cloth-background and the paper-background experimental conditions in terms of all semantic scales, with the highest correlation coefficient 0.92 for classical/modern, followed by 0.90 for spacious/small, and the lowest correlation being 0.66 for both like/dislike and comfortable/uncomfortable. This suggests that the texture of walls had a stronger impact on preference and comfort than on the other scales.

1. INTRODUCTION

Other than colour harmonization, conditions such as adjacent colouring area proportions, and lighting are issues of consideration in the process of allocating colours in the real time environment. Therefore, this research is using real-room environment as the condition, for considering colour harmony appearance and reality application adding different lighting condition. Expecting this research could get the colour harmony theory closer to the practical application. Academia and industries has always been interested in the topic: Impression of the interior environment. Instead of setting a real-room as the experiment condition, There are lots of existing research using computer-simulated interior graphics as the stimulus. Now a days, colour harmony research apply modern colour science technology, some of the colour harmony quantitative model were using in the interior graphics and put forward a satisfied predictive. However, could the model apply to a real interior environment is still unclear.

2. METHOD

Different lighting condition and wall colour were used to find out the colour harmony model[1] in the real-room. For the goal to investigate whether the results were influenced by the background texture (i.e. cloth vs. paper), 12 extra experimental conditions based on paper background randomly picked from the 36 conditions using cloth background. Analysing the data that collected from both experiment using cloth and paper background to find out whether they show the similar correlation with colour harmony model.

2.1 Sample Preparation

Observers: a total of twenty-two observers with normal colour vision, including 11 males and 11 females, participated in the study.

Stimuli: a "shooting studio" with a size of 3m (width) x 3m (depth) x 2.5m (height). The backgrounds for the three "walls" were made of coloured cloth sets that can be changed easily by a rail system. The lighting conditions were varied by adopting different light sources. Six wall colours were used in the study: grey, white, black, light brown, light blue and light green. Six lighting conditions were adopted, generated by two correlated colour temperatures (CCT), 6500K and 2700K, and three lighting directions, including (a) light travelling up and sideway, (b) a non-directional floor lamp and (c) light travelling down). This resulted in 6 (background colours) x 6 (lighting conditions) = 36 experimental conditions. 12 of the 36 conditions were randomly picked to replace the cloth-background to the similar colour paper-background, as illustrated in *Figure 1*. This experiment was using Super Seamless paper-background to find an similar colour that matched the cloth-background as the wall colour condition. The same six wall colours were used in paper background: grey, white, black, light brown, light blue and light green. CIELAB values of cloth-background are shown in *Table 1* and paper-background are shown in *Table 2*.

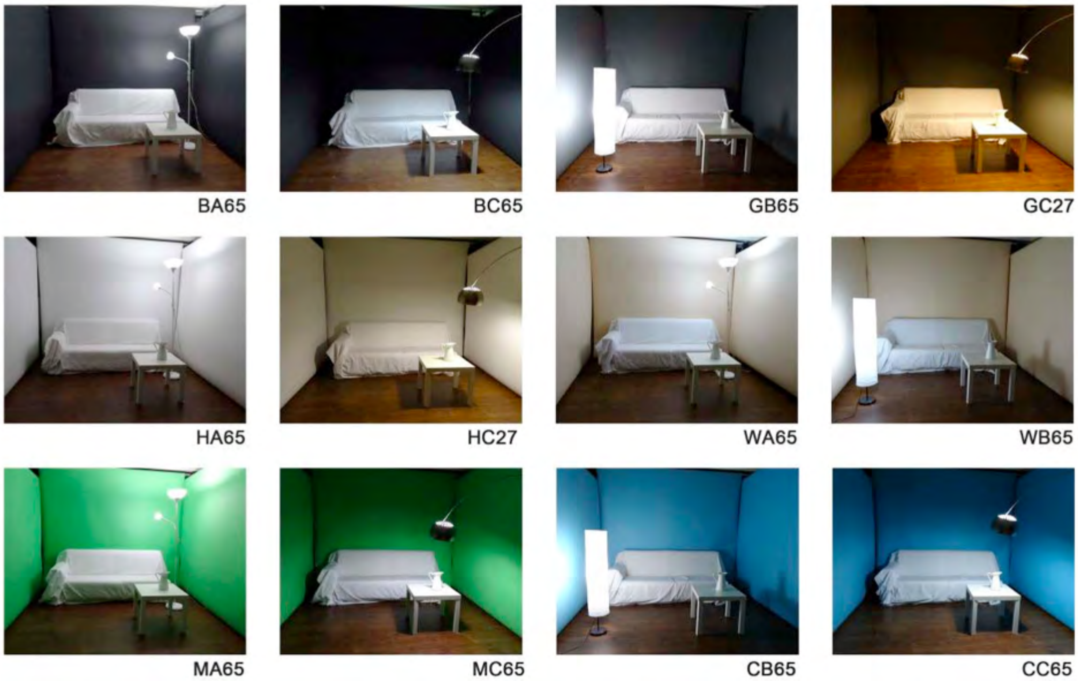

Figure 1: The 12 paper-background experimental condition

Table 1: CIELAB reference value of Cloth-background.(X-rite 962)

	L*	a*	b*	C^*_{ab}	h_{ab}
Black	16.8	0.1	-1.5	1.5	273.9
Grey	40.5	1.8	-11.2	11.4	279.2
White	93.8	2.0	-8.2	8.5	283.9
Light Yellow	88.4	2.1	14.4	14.5	81.6
Light Blue	54.7	-7.5	-2.8	8.0	200.5
Light Green	65.7	-14.7	43.0	45.5	108.9

Table 2: CIELAB reference value of Paper-background(X-rite 962)

	L*	a*	b*	C^*_{ab}	h_{ab}
Black	25.05	-0.26	-0.69	0.73	249.58
Grey	42.99	-1.54	-0.06	1.54	182.35
White	95.18	1.35	-3.5	3.75	291.05
Light Yellow	85.89	5.25	14.34	15.27	69.89
Light Blue	69.61	-18.18	-16.6	24.62	222.39
Light Green	71.95	-27.5	31.54	41.85	131.08

Scales: A survey were emitted, asked 19 observers (8 males and 11 females) to list 15 adjective in the impression of a "living room" before the experiment. Pick out the 8 most repeated adjective and add "like/dislike" "harmonious/disharmonious" to find out the colour preference and colour harmony in the real-room environment. Result as Figure 1. Ten semantic scales, including like/dislike, comfortable/uncomfortable, warm/cool, spacious/small, bright/dark, clean/dirty, relaxing/tense, elegant/inelegant, classical/modern and harmonious/disharmonious, were used to measure the emotional effects of combinations of the wall colours and the lighting conditions.

2.2 Experimental Procedure

Every observer will sit in the room and adapted for 30 seconds. Then start to value the real-room experimental condition in 10 semantic scales. Each of the semantic scales were forced choice in 6 categories. As a case of "spacious/small", the categories were"very spacious", "spacious", "slightly spacious", "slightly small", "small" and "very small". Every observer has to do the complete experiment twice to make sure the repetitive of experiment. The 12 stimuli were randomly picked in the experiment.

3. RESULTS

The aim of the study was to investigate visual impression of a real-room induced by lighting conditions and the wall colour. To see there was any difference between cloth and paper background in the observer responses, the experimental data were divided in to two groups of back ground texture. The correlation coefficients of the 10 scales between 12 cloth and paper background experimental conditions are shown in *Table 3*.

Table 3. Correlation coefficients of the 10 scales between 12 cloth and paper background

like/dislike	bright/dark	warm/cool	spacious/small	comfortable/ uncomfortable
0.656	0.807	0.773	0.904	0.664
clean/dirty	relaxing/tense	elegant/ inelegant	classical/ modern	harmonious/ disharmonious
0.855	0.718	0.721	0.922	0.722

As the result in *Table 3*, most of the observer's data were highly correlated. "Classical/modern" is the highest; "spacious/small" "clean/dirty" and "bright/dark" comes second; "like/dislike" is the last. As we could know, the difference between background texture didn't had significant influence in the scale of "classical/modern" "spacious/small" "clean/dirty" and "bright/dark". Therefore, difference between background texture did influence the result of "like/dislike". For reference in *Table 4*, most of the adjectives were scored slightly higher in paper background than cloth background. Texture of the background could possibly in a similar change tendency of observer's data, a degree of score difference may be observed.

Table 4. The average score of the raw data (paper and cloth background in 10 scales)

	Cloth background	Paper background
Like	3.40	3.94
Comfortable	3.40	4.02
Warm	2.84	3.45
Spacious	3.47	3.70
Bright	3.80	3.68
Clean	4.04	4.17
Relaxing	3.28	3.89
Elegant	3.50	3.90
Classical	2.65	3.37
Harmonious	3.58	4.04
average	3.40	3.82

4. CONCLUSION

This study aimed to investigate the influences of background texture on the visual impression of a real-room environment. The results show that (1) observers had higher preference in paper background which seems to be like the real wall texture. (2) Although general scores of paper background were higher than cloth in 10 scales, the experimental data show high correlation coefficients for the 10 scales between cloth and paper background. This could explain that observers will have a similar scoring trend in the same lighting condition and different background texture.

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Suggesting appropriate color range for indoor space based on EEG measurement

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ABSTRACT

In Color influences the human body in physiological and psychological manner, and interest in research on revealing such influence through brain wave measurement is increasing. The current study observed human physiological reaction in different indoors color environment, through an analysis of brain wave in the range of 8 to 13Hz, commonly known as the alpha wave. The frequency of RSA (8-11Hz/4-50Hz), or “slow” alpha wave, and RFA (11-13Hz/4-50Hz), or “fast” alpha wave, were studied. Centering on the changes to the brain wave after the color stimulus, the current study analyzed what influence 9 different colors had on the human body. Four groups came out in the result: 1) Red, Green-Yellow, Blue-Green, Yellow-Red incurred decreased RSA and increased RFA; 2) Yellow increased RSA and decreased RFA; 3) Blue and Purple increased both RSA and RFA. 4) Green and White decreased both RSA and RFA. The results of the current study is useful in that they can be used as a practical data for classifying colors appropriate for various purposes in residential spaces.In residential spaces, these colors are more appropriate for living rooms, in which rest combined with basic activities takes place, rather than bedrooms, in which rest leading to sleep takes place.

1. Introduction

1.1 Background

Colors have their unique wavelengths and are physical elements that greatly influence the physiological and psychological health of humans. The techniques related to color therapy and color correction that use color characteristics are applied in various industries, but there exists no quantified data or systematically conducted research. Therapy that treats diseases using the full color spectrum is referred to as chromotherapy. It has seen increased use in the field of medicine, with several studies touting the effectiveness of this method. [1] Moreover, while there are a number of fragmentary hypotheses on the influence that indoor colors have on the human body, it is time to have research that objectifies conclusions with systematic experimental evaluation.

Therefore, the study created a mockup environment designed to quantify the human body response to the unique wavelengths of colors and performed experimental evaluation of human body response through measurement of brain waves.

1.2 Previous Research

The leading method that has been used in the earlier studies to investigate the physiological responses in the human body consists in analyzing the changes in brain wave caused by color stimulation. Studies examining brain wave responses to colors suggest that colors can actually exercise influence on brain activity. Several clinical studies have been conducted to examine whether color therapy might help relieve symptoms related to diseases such as epilepsy and Parkinson's. [2][3] Earlier studies on colors and brain wave responses have shown that certain neural patterns can deliver physiological and psychological relaxation and excitement. While there exist differences in methods used in several previous studies, the physiological and psychological responses are summarized as follows. Pressey examined the physiological and psychological changes generated by the colors red, blue, and white. The color red was shown to stimulate sensory nerves. In other words, red activates blood circulation by stimulating all five senses: olfaction, vision, audition, gustatory, and tactile. Pressey found that the presence of red increased blood pressure, heart rate, and breathing caused increased perspiration in the skin, muscle contraction, and frequent eye blinking. Blue works to decrease blood pressure, heart rate, skin responses, and eye blinking. Finally, he found that white was related to psychological tension and stress. While white facilitated increases in blood pressure and heart rate, it did not cause the same magnitude of changes as did the color red. Studying children's responses to color design, Hong (1994) found that children who spent six months in a room painted blue showed much less nervousness or hostile speech compared to those who did not do so. Park and others (1999) conducted an experiment where a colored structure was composed of red, blue, and white walls, and participants had their blood pressure and heartbeat checked during a 20-minute interval. The authors found significantly higher heart rate from red to white, white to no color, and no color to blue. In addition, higher blood pressure was observed from red to white, white to blue, and blue to no color. Lower blood pressure was observed from no color to red, red to blue, and blue to white. These results suggest that blood pressure and heart rate decrease in line with "colder" colors and increase along with "warmer" colors.

1.2 Study Aims

As confirmed in previous literatures, alpha wave occurs in a state of comfort, such as when the body is relaxed; the more relaxed the body is, the greater the amplitude. A characteristic of this wave is that it appears continuously and regularly, with the most presence in parietal and occipital regions of the brain, and seen the least in the frontal region. Especially stable alpha wave is observed when the body is in a relaxed state with eyes closed, while the wave is deterred when the body is emotionally excited or when it is staring into an object with eyes open. What changes may occur to the alpha brain wave, then, when subjects are exposed to various indoors color environments? The goal of this study is to classify frequencies comprising alpha wave, 8 to 13 Hz, into segments, to analyze physiological reaction of the human body to various indoors color environments. The results will serve to provide a practical data on what effects indoors color environment has on the human body.

2. Methodology

The experimental set up included a windowless room that was 1,500 mm × 1,500 mm × 2,400 mm for the ceiling, wall, and floor lengths, respectively. Light was installed at 600 mm × 600 mm on the center of the ceiling while a dimming system was installed to ensure a light intensity of 100 lx for the different colors using the standard D65 illuminant. Stimulation was applied with three basic colors for respective wavelengths, a high-level chroma was selected, and paint was applied using nine colors. To prevent noise while measuring brain waves, acoustic noise and outside light were removed, and the room was kept at a temperature of 20 to 21 degrees Celsius with 50 to 55% humidity.

Color	Munsell	NCS	Experimental environment
	5R 4/14	S 2070-R	
	2.5YR 6/14	S 0580-Y50R	
	5Y 8.5/12	S 0570-Y10R	
	2.5GY 8.5/10	S 0570-G70Y	
	7.5G 5/8	S 2565-G	
	7.5BG 5/8	S 2555-B30G	
	10B 5/10	S 2060-B	
	7.5P 3/10	S 4050-R50B	
	N9.5	S 0500-N	

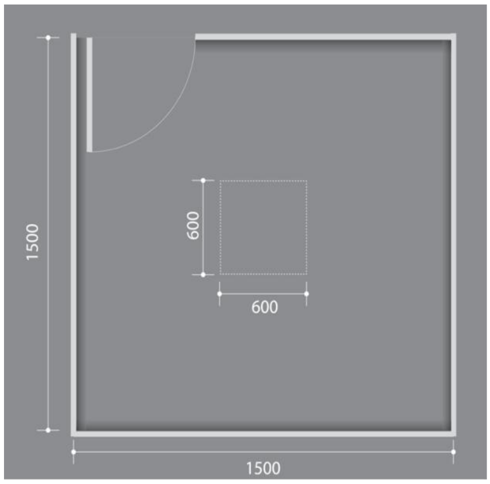

Fig.1. Experimental Environment

2.1 EEG Measurement and Analysis

To assess brain wave patterns, the current study used PC-connected equipment, QEEG-8 (LXE3208, Laxtha Inc., South Korea), to measure physiological signals. The measurement of brain waves was done through monopolar derivation across eight sites on the surface of the subject's head. In accordance with the International 10/20 system, electrodes were placed on left and right sides of the prefrontal (Fp1, Fp2), frontal (Fp3, Fp4), parietal (P3, P4), and occipital lobes (O1, O2). The reference electrode was placed behind the right earlobe, and the ground electrode was placed behind the left earlobe. Gold-coated tray-shaped disk electrodes were used. To minimize friction with the skin, extraneous substances were wiped off the surface of the subject's head. Electrodes were smeared with adhesive electrode gel (Elefix z-401ce, Nihon Kohden) to provide a better signal.

The measurement method used was as follows. The subject was seated comfortably in a chair within the white room. After attaching the electrodes, the subject was allowed to relax and adjust to the space for five minutes. Next, EEG measurements were taken for 60 seconds in the green, blue, and red rooms (room order was counterbalanced across subjects). In order to account for any potential afterimage from experiencing one color to the next, the subject took a one-minute break in the white room before moving to another room. Since protracted brain wave measurements tend to be distracting, the 60-second time limit was used to ensure quality data collection. In addition, subjects were instructed do mental counting in order to stay alert and avoid any other cognitive distraction. Following EEG measurement in each room, to prevent any additional afterimage effects from colors, a white stimulus was presented in between the evaluation objects and to provide subjects with a one-minute break. Measurements were repeated three times to ensure stable data collection.

Raw data were collected with Telescan (CD-TS-2.2, Laxtha Inc., South Korea), a real-time data and time series analysis program. Data for the 4–50-Hz band were obtained through frequency filtering, which was subjected to another conversion in order to perform an analysis as to the relative and absolute power for different channels. In addition, to ensure stable data collection during this analysis, the first second at the beginning and end of each recording session was removed, leaving 58 seconds available for further analysis. For all data analysis, the raw data CDF file was converted to a .txt file, and then to a Microsoft Excel file, to quantify and average EEG data signals for all 30 subjects. SPSS 20.0 statistical software was used for the converted data while differences in the three Power Spectrum values within the β-wave area was accomplished using the Friedman Test.

2.2 Subject Composition

A total of 57 subjects, including 16 teenagers, 26 individuals in their 20s or 30s, and 15 individuals in their 60s, were recruited for the current study. Since EEG signals vary largely across individuals, subjects with high or low EEG signals (i.e., outliers) were removed from the analyses. Therefore, a total of 21 subjects remained in the final sample: 7 teenagers, 7 individuals in their 20s or 30s, and 7 in their 50s or 60s.

3. Result

RSA (8-11Hz/4-50Hz), also known as “slow” alpha wave, occurs when the body feels comfort while it is slightly sleepy. RFA (11-14Hz/4-50Hz), “fast” alpha wave, occurs when the body feels comfort while it is concentrating. The current study aspires to measure what effects 9 different colors have on the human body, based on the characteristics of such ranges of the alpha brain wave. The result of brain wave measurement in 9 different color stimulus environments can be classified into the three following groups. In the first group, 8-11Hz range decreases after color stimulus as shown in fig. 3, but the 11-13Hz range increases. Red, Green-Yellow, Blue-Green, and Yellow-Red are the colors that cause such physiological change. In residential spaces, These colors are more appropriate for living rooms, in which rest combined with basic activities takes place, rather than bedrooms, in which rest leading to sleep takes place.

Contrary to the results in the first group, in the second group 8-11Hz range occurs more frequently after color stimulus, as shown in fig. 4, while 11-13Hz is displayed less frequently after the stimulus. Yellow is the color that causes such physiological change. The color is deemed more appropriate for bedrooms in which rest leading to sleep takes place, rather than for living room where basic activity takes place alongside relaxation.

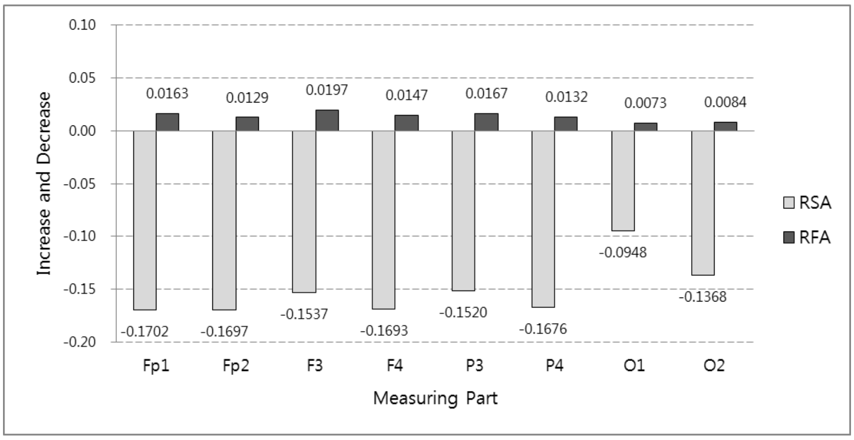

Fig. 3. Increase and decrease each ranges of the alpha brain wave in Red space

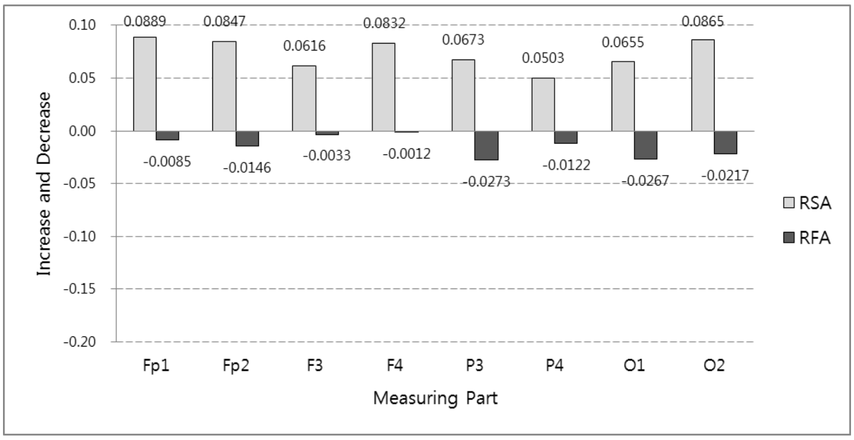

Fig. 4. Increase and decrease each ranges of the alpha brain wave in Yellow space

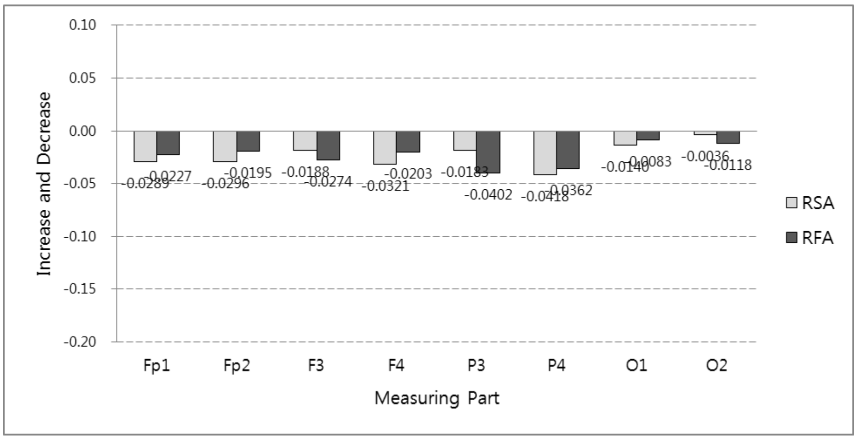

Fig. 5. Increase and decrease each ranges of the alpha brain wave in Green space

The third group displayed increased 8-11Hz wave and 11-13Hz wave after color stimulus except prefrontal lobe. Blue and Purple cause such physiological change. The fourth group displayed decreased 8-11Hz wave and 11-13Hz wave after color stimulus, as shown in fig. 5. Green and White cause such physiological change. These colors are less appropriate for living rooms and bedrooms where relaxation takes place; study rooms or workrooms, in which residents focus on certain activities, would benefit more from using these colors.

4. Conclusion

The purpose of the current study was to analyze human physiological reaction in various indoors color environments, by segmentalizing the range of alpha brain wave (8-13Hz), that increase when the body feels comfort. Based on the result, the study classified colors that are appropriate for different spaces in a residential space, which makes the results of this study a practical data on the effects of indoors color environment on the human body.

The 9 colors used in the current study, however, are colors with high levels of chroma to give a clear stimulus for the purpose of analyzing the effects of color. This makes it difficult to implement the results of this study on an actual residential space. As such, future research will have to delve into the issue raised by brightness and chroma, with a basis on the findings of this study on color.

Acknowledgements

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Development of the Interior Color Coordination Recommendation System of Living Space for University Student Living Alone Using Genetic Algorithm

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ABSTRACT

In this research, we constructed by genetic algorithm an interior color design system for college students who are living alone. As the first step, we investigated what color configurations college students living alone usually used for interior furnishings, as well as the affective impressions elicited by those color configurations. Next, we studied the colors associated with the adjectives which express spatial conceptions. On the basis of the results, five candidate fitness functions were determined. Then we ran the systems each adopting one of the candidate fitness functions, and evaluated their performance against actual human preference. It turned out that the system with the the fitness function wherein the three evaluation functions shared the same weight approximated the psychological data most precisely, which inferred that the ability to pinpoint the colors associated with the adjectives expressing spatial conceptions might play a vital role in generating the color configurations required by users.

1. BACKGROUND

Nowadays a lot of college students are interested in the interior furnishings of their rooms, but, especially to those living alone, practical difficulties such as economic pressure and the need of a good feeling usually add up to a significant barrier. Considering that in the recent years the shops selling cheap colored furniture are increasing in number, we get an idea that it is possible to improve interior furnishings by just changing their color configuration. Hence, in this research, we construct a system which can propose appropriate color schemes for interior furnishings through genetic algorithm (GA).

2. STUDY OF ROOMS OF COLLEGE STUDENTS LIVING ALONE

2.1 Objective

In order to select the sorts of furniture employed in the interior color design system, in this study we screened the interior furnishings in the rooms of college students living alone.

2.2 Subjects.

20 college students (10 males & 10 females, ages: 20.70 ± 1.34) who are living alone in the Kanto region participated in this study.

2.3 Method

From the photos of the subjects' rooms, we recorded the colors, the number of items, and the positions of each sort of furniture. Then, via subjective color measurement, we divided the sorts of furniture into two categories: The sorts of furniture belonging to the first category possessed great color variation while those belonging to the second group had small color variation.

2.4 Results

The category characterized with great color variation included shelf, bedstead, coverlet, bedsheet, curtain, table, rag, chair, desk, television table and pillow. The category characterized with small color variation included television, bed, wall and ceiling. The colors of the furniture in the latter category were fixed in the interior color design system constructed in this research.

3. STUDY OF RELATIONSHPS BETWEEN INTERIOR COLOR CONFIGUATION AND AFFECTIVE IMPRESSION

3.1 Objective

This study is intended to clarify the factorial structure of the affective impression elicited by color configuration of interior furnishings in the rooms of college students living alone through a psychological experiment using Semantic Differential method. The interpretation of the factors extracted in this experiment is carried out in the form of propositions.

3.2 Pilot Study

Objective: This pilot study aims to determine the range of color selection for each sort of furniture depicted in the experimental stimuli. Each experimental stimulus is a picture representing a certain color configuration of interior furnishings.

Method: We measured the colors of the sorts of furniture engaged in this research using the color system NOCS developed by Nakagawa Color Lab.

Results: With regard to the sorts of furniture with a high degree of color variation, the shelves had four colors, bedsteads four colors, coverlets 14 colors, bedsheet 13 colors, curtains 22 colors, tables three colors, rags 12 colors, chairs eight colors, desks three colors, television tables two colors and pillows 13 colors. The fixed colors of television, bed, wall and ceiling were also specified. The details of the color variation are shown in Table 1.

Table 1: Colors used in Experimental Stimuli (Munsell values)

interior	H	V	C
coverlets	10R	8	2
	5B	8	1.5
	5B	6.5	6
	5GY	7	10
	5P	3	7
	5PB	1.5	4
	5R	4	14.5
	5RP	6.5	7.5
	5Y	9	9.5
	5Y	6.5	3
	5YR	6	11
	5YR	4	2.5
	N	1	
	N	9	
pillows	10Y	7.5	11
	10YR	7.5	2.5
	10YR	5.5	1
	10YR	4.5	2.5
	5GY	7	10
	5PB	1.5	4
	5R	4	14.5
	5RP	6.5	7.5
	5Y	9	9.5
	5YR	7.5	10
	5YR	4	7.5
	N	1	
	N	9	
tables	N	1	
	N	9	
	10YR	8	3
desks	N	1	
	N	9	
	10YR	8	3

interior	H	V	C
bedsheet	10R	7.5	6.5
	10Y	7.5	11
	10YR	5.5	1
	10YR	4.5	2.5
	5B	9	1.5
	5GY	8	6.5
	5GY	8	8
	5PB	1.5	4
	5R	8.5	1.5
	5R	4	14.5
	5Y	9	9.5
	N	1	
	N	9	
bedsteads	10YR	8	3
	N	1	
	N	6	
	N	9	
rags	10GY	2	4.5
	10R	7	9.5
	5GY	8.5	1.5
	5GY	5	5.5
	5PB	1.5	4
	5R	4	14.5
	5RP	8.5	2.5
	5RP	3.5	6
	5Y	9	9.5
	5YR	2.5	2.5
	N	1	
	N	9	
shelves	10YR	2.5	2.5
	10YR	8	3
	5YR	6.5	5
	N	1	

interior	H	V	C
curtains	5R	4	13
	10R	7.5	6.5
	10R	7	9.5
	10YR	4.5	2.5
	5B	8	1.5
	5G	2.5	3
	5G	8	1
	5GY	8	6.5
	5P	1.5	4.5
	5P	5.5	2.5
	5R	7	7.5
	5R	4.5	1.5
	5RP	6.5	7.5
	5RP	3.5	15
	5RP	2.5	8
	5Y	8.5	7
	5YR	2.5	2.5
	5YR	2.5	4.5
	5YR	7.5	2
	5YR	6	11
	N	1	
	N	9	
chairs	10YR	7	6.5
	5PB	3	14.5
	5PB	5.5	9.5
	5R	4	14.5
	5RP	6	9.5
	N	1	
	N	3	
	N	9	
television tables	10YR	8	3
	N	9	

Totally 102 college students (54 males & 48 females, ages: 21.45 ± 1.25) took part in this experiment. The subjects were divided into three groups:

Group A: 19 males & 15 females (ages: 21.03 ± 1.23); Group B: 18 males & 16 females (ages: 21.03 ± 1.23); Group C: 17 males & 17 females (ages: 21.03 ± 1.24).

3.4 Evaluating Method

60 adjectives gathered from previous researches, e.g. "light", "clean" and "calm", all of which express spatial conceptions, were used in this experiment. Every adjective is a two-point ("match" or "does not match") rating scale.

3.5 Experimental Procedure

30 pictures (shown in Figure 1), used as the experimental stimuli, were generated by Interior Designer Pro 2 on the basis of the results of the aforementioned pilot study. The color configuration in every stimulus picture was randomly determined. The stimuli were displayed to the subjects by iPad (Retina Display MD370J/A). Every subject group was assigned a different set of ten stimuli. The order of stimulus displaying was counter-balanced.

Figure 1: Experimental Stimuli

3.6 Results and Discussion

In the process of factor analysis, maximum likelihood estimation was used to extract the factors, and the Promax method was employed to rotate the factors. The rotated factor loadings matrix is calclated which shows that 13 factors, i.e. "Pop", "Cool", "Elegant", "Natural", "Formal", "Eccentric", "Light", "Classical", "Tropical", "Dandy", "Profound", "Quiet" and "European", have been extracted in this experiment. When interpreting a factor, we distinguished the stimuli whose factor scores are greater than zero on the factor from the stimuli whose factor scores are less than zero on the factor, and then examined the two groups respectively. Take the factor "Pop" as an example. The stimuli in the high-factor-score group used more colors with high or intermediate saturation than those in the low-factor-score group. In the high-factor-score group, coverlets in highly saturated red and those in highly saturated yellow were used more frequently than in the low-factor-score group. On the other hand, in the low-factor-score group, blue coverlets and achromatic coverlets were employed more frequently than in the high-factor-score group. In the light of it, the characteristics of the high-factor-score group on this factor could be expressed in the following four propositions: 1) The group uses many highly saturated colors; 2) The group uses many intermediately saturated colors; 3) Many of the coverlets in this group are highly saturated red; and 4) Many of the coverlets in this group are highly saturated yellow. As to the low-factor-score group on this factor, its characteristics could be expressed in the following three propositions: 1) Many of the coverlets in this group are blue; 2) Many of the coverlets in this group are achromatic; and 3) The group uses very few highly saturated colors. In the same manner, we made clear, in the form of proposition, the characteristics of the other factors by scrutinizing their associated high-factor-score group and low-factor-score group. As a result, totally 46 propositions were formulated.

4. STUDY OF COLOR SELECTION RANGE OF INTERIOR FURNISHINGS

4.1 Objective

This study is targeted to preclude the interior color design system from outputting color configurations of interior furnishings which seldom appear in the real life.

4.2 Method

Based on the results of the pilot study described in Subsection 3.2, focusing on the colors employed in the experimental stimuli, we specified subjectively the range of color selection for each sort of furniture.

4.3 Results

We assigned a wide color selection range to every sort of furniture with a high degree of color variation shown in the results of the pilot study. On the other hand, we assigned a narrow color selection range to every sort of furniture with a low degree of color variation shown in the results of the pilot study.

5. SETTING AND RUNNING OF GENETIC ALGORITHM PROGRAM

5.1 Outline

The users were required to select five or more adjectives which appropriately described the ideal interior design for their rooms from the adjective list introduced in Subsection 3.4. The users were also asked to report their genders and whether they had any experience of living alone. This personal information served as one part of the input information to the GA system. The outputs of the GA system were the $L^*a^*b^*$ values of the color configurations of interior furnishings which were expected to match the adjectives selected by the users.

5.2 Parameter Setting

Encoding: The chromosome structure encoded 33 variables, that is, the $L^*a^*b^*$ values of the colors of the 11 sorts of furniture employed in the system.

Crossover & Mutation: The crossover operator and the mutation operator were applied respectively to the two furniture categories introduced in Section 2, namely the category characterized with great color variation and the one characterized with small color variation. And, the $L^*a^*b^*$ values of each sort of furniture were treated as one set.

5.3 Fitness Function

Based on the results of the study introduced in Section 3 and the study on color-adjective association, we determined the fitness function $F(x)$ as a liner sum of 3 sub functions (details shown on the poster).

6. EXPERIMENT FOR TESTING SYSTEM PERFORMANCE

6.1 Objective

This experiment aims to clarify the effectiveness, the users's satisfaction and the deficiencies of this interior color design system via real-world testing.

6.2 Subjects

8 college students (2 males with experience of living alone, 2 males without experience of living alone, 2 females with experience of living alone and 2 females without experience of living alone; ages: 22 ± 0.58) living in the Kanto region participated in this experiment.

6.3 Experimental Procedure

The achromatic version of the stimulus picture No.8 used in the study introduced in Section 3 (shown as Figure 2) was displayed to the subjects for the reason that this picture contained the most achromatic colors among the stimuli used in that study.

The subjects were required to imagine themselves as college students living alone and select from the adjective list described in Subsection 3.4 five or more adejctives which best depicted their ideal images of the color configuration of the interior furnishings in the room.

The personal information of the subjects and the adjectives selected by them were input into five variants of the system each defined by a set of α, β and γ values, i.e. the weights of the three evaluation functions in the fitness function. The $L^*a^*b^*$ values encoded by the first chromosome in the last generation of the evolution process of each system variant were employed to colorize the stimulus picture used in this experiment, producing a chromatic picture as the output of the system variant. Prior to the colorization, the $L^*a^*b^*$ values of the resulted five pictures were transformed into *RGB* values.

The α, β and γ values characteristic of each system variant are shown as follows:

(1) α=5, β=3, γ=2. (This set of values was set as default in that it best fitted the empirical rules.)
(2) α=1, β=0, γ=0. (This set of values allowed only the first evaluation function to take effect.)
(3) α=0, β=1, γ=0. (This set of values allowed only the second evaluation function to take effect.)
(4) α=0, β=0, γ=1. (This set of values allowed only the third evaluation function to take effect.)
(5) α=1, β=1, γ=1. (This set of values allocated equal influence to the three evaluation functions.)

Then, the five pictures were displayed to the subjects one after another, and the subjects were asked to evaluate on a 5-point rating scale to what extent the pictures matched their ideal images. The subjects were also required to write down the reasons for their ratings in the form of free answer. During the data analysis, the ratings of every stimulus were averaged across the subjects, and the average ratings of the stimuli were compared with one another. Prior to the averaging, the five degrees on the rating scale were transformed to the quantitative values “100”, “50”, “0”, “-50”, “-100” from the end “match well” to the other end “match badly”.

6.4 Results

Output Example: Take as an example the outputs of the five system variants to the input information of Subject A. As the adjectives best depicting his ideal image, this subject selected “calm”, “good-looking” , “stylish”, “heart-warming”, “gentle”, “kind”, “natural”, “simple”, “monotone”, “unified”, “light”, “clean”, “warm”, “trig”, “refined”, “modern”, “chic” and “formal”. The pictures generated based on the output information of the five system variants corresponding to these adjectives are shown as Figure 2.

Overall Tendency: With regard to the first evaluation function, the fitness of a large number of stimuli remained almost the same over time, converging eventually to a relatively low value. A possible explanation for this phenomenon is that this evaluation function best fitted the empirical rules, thus being heavily constrained.

Next, we compared the average ratings of the five pictures. The picture with the highest average rating was the one output by the fifth system variant. In the fitness function of the system variant, the three evaluation functions shared the same weight.

In addition, many subjects wrote in their free-answer questionares that “although the picture matches my ideal image, I don’t like the colors of the interior furnishings in the picture” or “the colors of the interior furnishings in the picture aren’t my favorate ones, so I don’t think the picture matches my ideal image”. In view of it, it is resonable to believe that the color preference of an individual can influence his/her evaluation of the color configuration of interior furnishings. Especially, when the subjects disliked the colors of the sorts of furniture of a large size, such as coverlet, they tended to give negative responses. Besides, a proportion of the subjects had color-adjective association different from the general condition. As a result, to these subjects, using colors as the general condition suggested often brought about negative responses.

No.1, Syatem 1 No.2, System 2 No.3, System 3 No.4, System 4 No.5, System 5

Figure 2: Output Picture No.1 - No.5 for Subject A

7. CONCLUSIONS

In this research, we contructed an interior color design system that could visualize users' ideal images of color configuration of indoor furnishings. The only information users are required to input into the system is a set of adjectives depicting their ideal images of indoor color configuration. The results of the real-world system test demonstrated that the fitness function in which the three evaluation functions shared the same weight best matched users' ideal images. It infers that the more precisely the system simulates users's general impression to the adjectives expressing spatial conceptions, the better the outputs of the system approxiamte users' ideal images. In addition, based on the results of the study on the relationships between interior color configuration and the elicited affective impressions as well as the results of the real-world system test, we can say that color preference has a great impact on the evaluation of color configuration of interior furnishings. It suggests the possibility of improving the simulating accurary of the system by integrating the information about users' color preference into the input information to the system..

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Chromatic integration of the architectural surfaces with environment: analysis and classification of case studies

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ABSTRACT

The introduction and application of new products in the building market, joined to the continuous elaboration and re-interpretation of already known materials, in particular of those dedicated to the facades, produces new effects on the perception of the chromatic truth of the places where these are employed. Among these products and materials there are someone, employed in multiple shapes, finishes and textures, those use has been consolidated in the realization of facade claddings (concrete, metals, glass, plastics, composites, smart etc.). Their use in the context in which these facades are located produces particular chromatic effects, different from those of the tradition, or similar to it: chromatic agreements, contrasts (see Itten), dematerialization of the building envelope etc. Is it possible to lead a chromatic analysis of meaningful cases having the target to supply useful instruments to the design phase?

This study has the proposal to complete a chromatic surveying of famous buildings by the means of common graphical instruments such as the pixel filter: a tool useful to identify the dominant tones that can be obtained from a photographic relief. Captured colors can be inserted in a diagram to classify their combinations: one dominant, two colors, three colors, four colors, contrast of light and dark, contrast of warm and cool colors, etc..These kind of studies would have to lead us to the definition of a table of chromatic harmonies and contrasts. The study means to consider all the elements of the context: sky, green, water, buildings etc, so as to be able to contemplate also the chromatic variants due to the change of the luminous or atmospheric conditions. Knowing that "varying the field of vision whichever chromatic manifestation can be obtained, just because seeing it is not never an objective fact, but it is participation, subjective interpretation" (Tornquist 1999).

1. INTRODUCTION[1]

This research, which began in 2003/2004 with a dissertation on the color of metal claddings, followed several developments in the following years, first within the research unit Colour and Light in Architecture at Iuav University of Venice and currently under the research center Eterotopie - Color, Light and Communication in Architecture. The research aims to identify and classify the color design strategies adopted by many designers to achieve specific color effects: integration with the landscape, contrast, highlight of certain parts of the building and so on. Relapse is the last possible embodiment of a system of guidelines for the design already integrated, as regards the sun screens, in the book "Superfici Dinamiche" (Franco Angeli, 2012), as regards the metals in "Facciate metalliche" (Utet , 2012) and for media buildings in “Schermi Urbani” (2012).

2. METHOD[1]

The research analyzed architectural envelopes made with different materials and technologies, from traditional up to innovative materials: plaster, wood, ceramics, concrete, GRC, metal, glass, plastics, textiles, composites, smart. For each category of façade material we analyzed a representative sample of case study, than we used multiple images, then transformed with a computer tool to get the main colors of the composition: the pixel filter. The pixel filter allows, blurring the original image, to detect the dominant colors of the analyzed photo (we always tried to use images of the building with a good portion of the context). The result can be approximated to one, two, three or four main colors that could constitute chromatic agreements or contrasts obtainable from color theory and its recent developments.

> The chromatic fact is the pigment, i.e. the coloring material that can be determined and analyzed from a physico-chemical point of view, which assumes its content and meaning through human perception through the retina and the brain. The eye and the mind can achieve an exact perception only for comparison or contrast. [...] The color evaluation, in contrast to the physico-chemical facty of color, constitutes the psycho-physical fact of color that I define the chromatic effect. Physical reality and color effects are identified only in harmonic chords. In all other cases, the reality of the color is changed simultaneously, producing a new, different effect (Itten 1961: 17).

In addition to issues related to the change in the size of the visual field, we took note of the limits imposed by the studies that have made an important contribution on the three-dimensional use of the color material.

> Even photography is the two-dimensional representation - that we read as truth - a three-dimensional reality. A higher order can not be explained by a lower one, therefore it is not possible to realistically represent a work created in three dimensions through the use of two dimensions (Tornquist 1999: 108).

The goal of the research was to understand how most important contemporary designers use color to achieve desired color effects of integration or contrast with the surrounding environment.

> If in the field of materials we assumes, for example, a base material subjected to a process of transformation, we get something that is different from the material we used and which is the product. Similarly, when you design, you introduce into the design process (similar to a machine) the basic materials, consisting of all the information needed to design [...] and you transform them into the particular product represented by all the documents of the design (Ciribini 1984: 12).

The process we performe in the color composition seems to look very similar.

2.1 Case studies[1]

Among the case studies, for the plaster surfaces, there is the Housing and Office Complex Zeleni Gaj, šiška, in Ljubljana, 1999-2001, by Bevk Perovic 'Architects. The surfaces of the facades are colored in gray, while the top floor set back from the facade is white. The neutral color of the facades highlights the lodges and the wooden frames. The pixel filter highlights the gray tones that tend to mix the building with the environment of other residential projects.

Among the buildings with wooden envelope we analyzed the Damiani Holz & Ko Building in Bressanone, 2012, by Modus Architects. The envelope made entirely of laminated spruce wood contrasts with the blue sky and the green mountains (contrast of complementary colors), while the base in grey concrete blends with the color of the horizontal surfaces.

Among the buildings with ceramic cladding there is the Central St. Giles in London, 2010, by Renzo Piano. The large facades of ceramic material are characterized by the colors orange, green, yellow and red. The pixel filter reduces the composition in two main colors: red and green, two complementary colors. The context instead merges into a uniform gray given by the buildings of the surrounding city.

Another case study for ceramic materials is the Music Hall and House in Alguena, Spain, 2011, by COR Asociados. The cladding of the music hall is completely covered with pearlescent ceramic with a mirror finish. This finish reflects the colors that surround the building blending with the environment. In fact, with the pixel filter the building seems to disappear, leaving only the colors of the blue sky and of the earth.

Among concrete envelopes we analyzed the Asylum Les Cabanyes in Barcelona, 2008-2010, by Arqtel architecture. The building is entirely made in grey concrete, while the parts set back from the front edge are brightly colored. Window holes and lodges have surfaces colored in red, orange, yellow and green. With the pixel filter gray surfaces seem to disappear highlighting the blue sky and the colors red and green in the portico. The contrast of complementary colors is just in front of the building.

Among GRC claddings there is Soccer City Stadium in Soweto in South Africa, by Boogertman + Partners and Populous. The large envelope is clad in panels of GRC colored by earthy colors. The shape looks like a traditional African pot: the Calabash. The pixel filter shows that the building merges with the color of the earth in contrast with the blue sky in a game of primary colors contrast (red and blue).

Among the metal claddings we analyzed the Parking Structure Art Façade in Indianapolis (USA), 2014, by Urbana. The large flat facade of the parking is characterized by metal strips colored in blue and yellow. The strips, similar to many post-it, are bent and positioned so that the building, from one side, appears completely blue and from the other side completely yellow. The building was designed to be seen in motion so that the façade, while being static, seems dynamic, due to a change in color between yellow and blue. The pixel filter highlights how this contrast of primary colors is only in front of the building.

A similar game was played by Architecture Studio in the glass envelope of Advancia School of Business, in Paris, 2010. The facades are characterized by blades of frosted glass in red and yellow color. In some places the alternation of the two colors produces an effect of interpenetration. The color contrast is only in the façades of the building.

Among the buildings with plastic claddings we analyzed the Civic Center Roberto Gritti in Ranica (BG) Italy, 2009, by DAP Studio. The polycarbonate shell is colored only on the inner face so as to present a lighter color in the outside. The colors are cold: purple, blue and green and are immersed in the surrounding natural background. With the pixel filter the building seems to dematerialize.

Among the buildings with textile surfaces there is the Basketball Arena in London, 2012, by Wilkinson Eyre Architects. The envelope is made with a membrane made of polyester fiber coated with PVC. The membrane is stretched over a curved tubular structure in aluminum so as to assume a wavy and jagged shape. On the completely white facades there is a contrast of light and dark color (by shadows) that highlights the shapes drawn by the designers.

Among claddings made with composite materials there is the Seeko'o Hotel in Bordeaux, 2007, by Atelier King Kong. The building envelope, made of Corian ©, is completely white. The building is so completely divorced from the context: almost an alien in shape and color.

Among the envelopes with smart materials there is La Defense Offices in Almere (NL), 2004, by UNStudio. The insulating glass facades are integrated with dichroic film produced by 3M that changes color according to the angle of incidence of sunlight. The facades then veer from green to red and vice versa, creating a contrast of simultaneity.

> The contrast of simultaneity is the phenomenon by which our eye, subjected to a given color, requires at the same time – simultaneously - the complementary color, and not receiving it, it creates it by itself (Itten, 1961: 52).

2.2 The special case of media and smart façades[2]

The research also included the architectural media and smart façades.

The case study analysis has shown a different color performance of these façades, probably due to the used technology.
For the media façades category were analyzed architectures whose envelope was bright and made with digital technologies. In particular, we have analyzed the façades designed by the Berlin group realities:united. They use the BIX system inside architectural envelope (for example: KunstMuseum Graz and Spot Facade in Berlin). Than we analyzed the façades made with LED technology, with LED packets or with the mediamesh system.

For the smart façades type, were analyzed façades system with glass panels, with a smart film interposed. In this case were chosen façades with variable color smart materials as the chromogenic material (thermochromic, photochromic, electrochromic, Lcd) and dichroic film.
One of the case studies is the project: La Defense Offices in Almere, described earlier. The characteristic of media façades analyzed is the division of the façade cladding in many lighting components. These components are visible within easy reach in front of the building. When the façade is seen from far away or when the façade is off the surface is uniform.

When the media envelope is switched on, each component becomes a pixel, a pixel in urban dimension that interacts with the environment.

The façade made with the BIX system are different from those covered in LEDs, because the size of the light components is different. The components of the BIX system are bright fluorescent lamps, they are at least 30 cm and transmit white light. Therefore, the media façade works only in two colors: black or white, corresponding to the controls on / off of the lamp. The pixels are big and the façade transmit 20 frames / sec maximum. They are defined *low resolution façades*. The LEDs, however, are very small components and they are placed very close together, they are colored and they transmit images with many frames / sec. They realize colorful and high resolution façades.

Feature of the smart facades is color uniformity. The materials for smart façades are active or inactive, to shield the facades. So, they may be of a single color (blue or gray) when they are active. When the film is inactive we perceive a glass envelope that reflects the surrounding environment.

It is different for dichroic films (pleochromic materials), whose change in color varies according to the solar incidence.

3. RESULTS AND DISCUSSION[1]

Analyzing the data that emerge from the study above we can infer some design strategies that seem to be used by the designers to achieve certain color effects:

- Merger with natural elements of the environment (ground, sky, vegetation).

- Dematerialization of the building (gray, mirrored surfaces).

- Contrast of primary colors (red-blue). For example, between the building and the sky.

- Contrast of complementary colors (i.e. red Vs green). For example, between building and vegetation.

- Combinations of colors only in the facade (multicolored facades).

- Highlighting specific architectural elements (projecting parts, backward elements, etc.).

- Contrast of light and dark to highlight some forms.

- Color totally divorced from the context: to create a "stranger".

3.1 The "non-color" of media and smart façades[2]

From the analysis, that has been synthesized here, we can see the special case of media and smart facades and their relationship with the visibility and color perception. It is difficult to lay down a rule of color design for these façades and find a measure of their interaction with the environment.

The reasons are to be found in the components and materials used. So, summarizing:

- In the low resolution media facades (eg system BIX) the chromatic interaction with the environment is influenced by the color of the cladding components, of their texture, the type of material (eg. blue plastic, white aluminum panel, frosted glass, etc.). Also, you can find a relationship between color, environment and facade materials only when the media system is off.

- The high-resolution media facades (by LEDs) are already a pixel system, like the analysis system used for this research. Elaborating further the image, the mix of thousands of colored pixels gives as results a "non-color". Usually it is black, gray or brown.
- In smart façades, when the system is off, the color effect is given from the reflection on the glass facades, which are therefore neutral (non color). When the system is "on" the result is a "non-color", the cladding is gray, rarely it is blue.

- The facades using pleochromic smart materials (dichroic film), however, may result in a contrast of simultaneity, according to the incidence of sunlight.

4. CONCLUSIONS

As it is widely known to those involved in the environmental chromatic design, color is an essential aspect in the design process and today it can not be overshadowed. For too long the schools of architecture in Italy have put aside this issue despite knowing that we live in an environment full of colors, perhaps today more than yesterday. The contemporary colors are closely related to the materials and technologies that produce them and they can not be used without a proper knowledge of these technologies. Despite the desire of some academy to keep in the corner these studies, now it seems increasingly essential to place them in evidence and to intensify the research efforts in this direction.

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Color appearance of red printing ink for color vision deficiency

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ABSTRACT

In package printing industry, spot color ink generated by mixing base inks has been used more often than cmyk process ink. In particular, red color ink is required not only for designability but also for using to refer notes on many packages. Therefore, it is important to investigate conspicuous red color inks for various illuminant conditions and color vision deficiency. We made red spot color inks which consisted of several base inks, and printed on coated papers using those spot color inks. Observers with normal color vision and color vision deficiency evaluated the redness of the printing samples and their discriminability results from a black background under two illuminance levels (500 lx and 1 lx). The results of evaluation for redness show that the samples whose hue are from 2.5R to 7.5R and high chroma obtain the high score at 500 lx in general. At 1 lx, samples with yellowish red hue and high chroma obtain the high score of redness for observers with color vision deficiency, especially for protan. The results of discriminability from black is more correlated with the lightness of samples at 1 lx than at 500 lx. The samples with high chroma are highly discriminable for both normal and deutan observers. The scores of protan observers for yellowish red hue and high chroma are high at 1 lx as same as the results of redness. Better discriminability for those samples would be due to the higher middle-wavelength (yellowish color) components in the spectral reflectance of those samples.

1. INTRODUCTION

A model color palette for color universal design was provided to be using for cmyk process print, paint, and display (ref.1). In various package prints (e.g. foods, sanitary product), special color such as a corporate color or a product brand color is used. To reproduce the special color, spot color ink which is generated by mixing base inks has been used more often than the process ink. The combination of the base inks is not necessarily unique, and it is common to exist several combinations to reproduce the same color. Package makers have traditionally selected one from among plural combinations with consideration of physical factor (e.g. light resitance). For package design, however, it is important to convey the product image and to inform notes of product to consumers. Red color inks in particular are often used to printing notes of package products. Accordingly, not only criterion with physical factor, but also a psycophysical factor,"Color appearance" is necessary to select the combination. Package products are seen by a lot of consumers with different types of color vision, and under various illuminant conditions. Therefore, it is important to investigate conspicuous spot color inks, especially red color inks for various illuminant conditions and color vision deficiency. In some cases, packages are seen in outdoor in the evening under low illuminance level as well as indoor. It was reported that not only chroma and lightness but hue of red color chips changed with illuminance (Shin *et al*., 2004). (3) Also, the categorical color perception of color vision deficiency was reported (Kagawa *et al*., 2013). They showed that the color categories of ordinary deuteranomals were almost the same as those of normal trichromats, whereas those of extreme deuteranomals were different under 500 lx.

In this study, we investigate how the color appearance of red spot color inks is influenced by illuminant conditions and color vision deficiency.

2. METHOD

We made red spot color inks which consisted of several base inks, and printed on coated papers. Observers with normal color vision and color vision deficiency evaluated the redness of the printing samples and their discriminability from a black background under various illuminant conditions.

2.1 Sample Preparation

Observers made evaluatations in the booth that inside walls were coverd with gray paper. The test color samples presenetd on desktop of the booth illuminated by high color-rendering fluorescent lamps with correlated color temperature about 5000 K. We tested two illuminance levels, 500 lx and 1 lx

The test samples were 37 color prints with target colors that approximated Munsell values and chromas in hues from 10RP to 10R (Table 1). The spot color inks of samples were mixed with base color inks for offset printing (NCP F-GLOSS, DIC Graphics). The mixing formula to reproduce the target colors was estimated by a computer color matching system. We checked whether each target color was inside of printing ink gamut. Colors out of gamut were replaced to printable colors by gamut mapping. We printed on coated papers using those spot color inks with ink proof machine (R.I Tester). We used art coated papers (Mitsubishi Tokubishi Art N), and cut the printed papers to small 75 mm x 45 mm samples. These printed papers were measured by a spectrophotometer (SpectroEye, X Rite).

2.2 Experimental Procedure

We conducted four conditions in this experiment, evaluation for redness and discriminability from a black background under high illuminance level condition (500 lx) and under low illuminance level condition (1 lx). Observers adapted to an illuminant level for 3 min under 500 lx and 20 min under 1 lx. After the adaptation, observers put each test sample on the desktop and evaluated all 37 test samples individually. The evaluation of all samples was replicated three times for each condition. For the evaluation of redness, the observers viewed each sample on a white backgound and scored using five scale. The white backgroud was a white paper without fluorescent whitening agents. The observer scored five and one point(s) to the most and the least reddish sample, respectively. For the evaluation of discriminability from black, the observers viewed each sample on black backgound and scored in the same way as redness. Score five means that an observer percived the sample as the most discriminative, and one means as the least discriminative.

Four protan, four deutan, and five normal trichromat observers participated in the experiment.

Table 1: Target colors of Samples

No.	Target Color	No.	Target Color	No.	Target Color
1	10RP V4.5/C18	12	3.75R V5/C18	26	8.75R V4/C9
2	1.25R V4/C9	13	5R V4/C9	27	8.75R V5/C9
3	1.25R V4/C13	14	5R V4/C13	28	8.75R V5/C13
4	1.25R V5/C9	15	5R V5/C9	29	8.75R V6/C9
5	1.25R V5/C13	16	5R V5/C13	30	8.75R V6/C13
6	1.25R V5/C18	17	5R V5/C18	31	8.75R V5.5/C18
7	2.5R V4/C9	18	6.25R V5/C18	32	10R V4/C9
8	2.5R V4/C13	19	7.5R V4/C9	33	10R V5/C9
9	2.5R V5/C9	20	7.5R V4/C13	34	10R V5/C13
10	2.5R V5/C13	21	7.5R V5/C9	35	10R V6/C9
11	2.5R V5/C18	22	7.5R V5/C13	36	10R V6/C13
		23	7.5R V6/C9	37	10R V6/C18
		24	7.5R V6/C13		
		25	7.5R V5/C18		

3. RESULTS AND DISCUSSION

We present the averaged results from each type of color vision for the evaluation of redness and discriminability on the black background under two illuminance levels.

3.1 Sample Color (Lightness, Chroma, and Hue)

The correlation coefficients of redness and discriminability from a black background with lightness (L^*), chroma (C^*), hue (H^*) were calculated, respectively. The redness evaluation from deutans had some correlation with chroma at 500 lx. At 1 lx, redness evaluations from both protans and deutans had correlation with chroma, and lightness had some correlation with the results of protans and deutans. The results of discriminability from a black background correlated with lightness at both illuminance levels. The correlation of the discriminability with chroma at 500 lx was stronger than at 1 lx. For protans, the results of discriminability correlated with hue at 500 lx.

In results of redness evaluation at 500 lx, the samples from 2.5R to 7.5R and high chroma obtained the high scores. The samples with low lightness obtained higher score for protans than deutans and normal trichromats. At 1 lx, the sample colors with middle or high lightness and high chroma obtained high score rather than the others. Samples with yellowish red hue and high chroma obtained the high score of redness, especially for protans.

Figure 1 shows the hue samples of high chroma which obtained the high score of the discriminability from the black background for deutans and normal trichromats at 500 lx and 1 lx. For protans, the yellowish red hue and high chroma colors obtained high score in the same way as redness. The scores at 1 lx increased with increasing lightness as same as 500 lx. The above inclination to increase was conspicuous than 500 lx; e.g. In case of 7.5R and Chroma 9, No.19 (Value = 4), No.21 (Value = 5), No.6 (Value = 6). The influence of hue at 1 lx upon the discriminability was less than those at 500 lx.

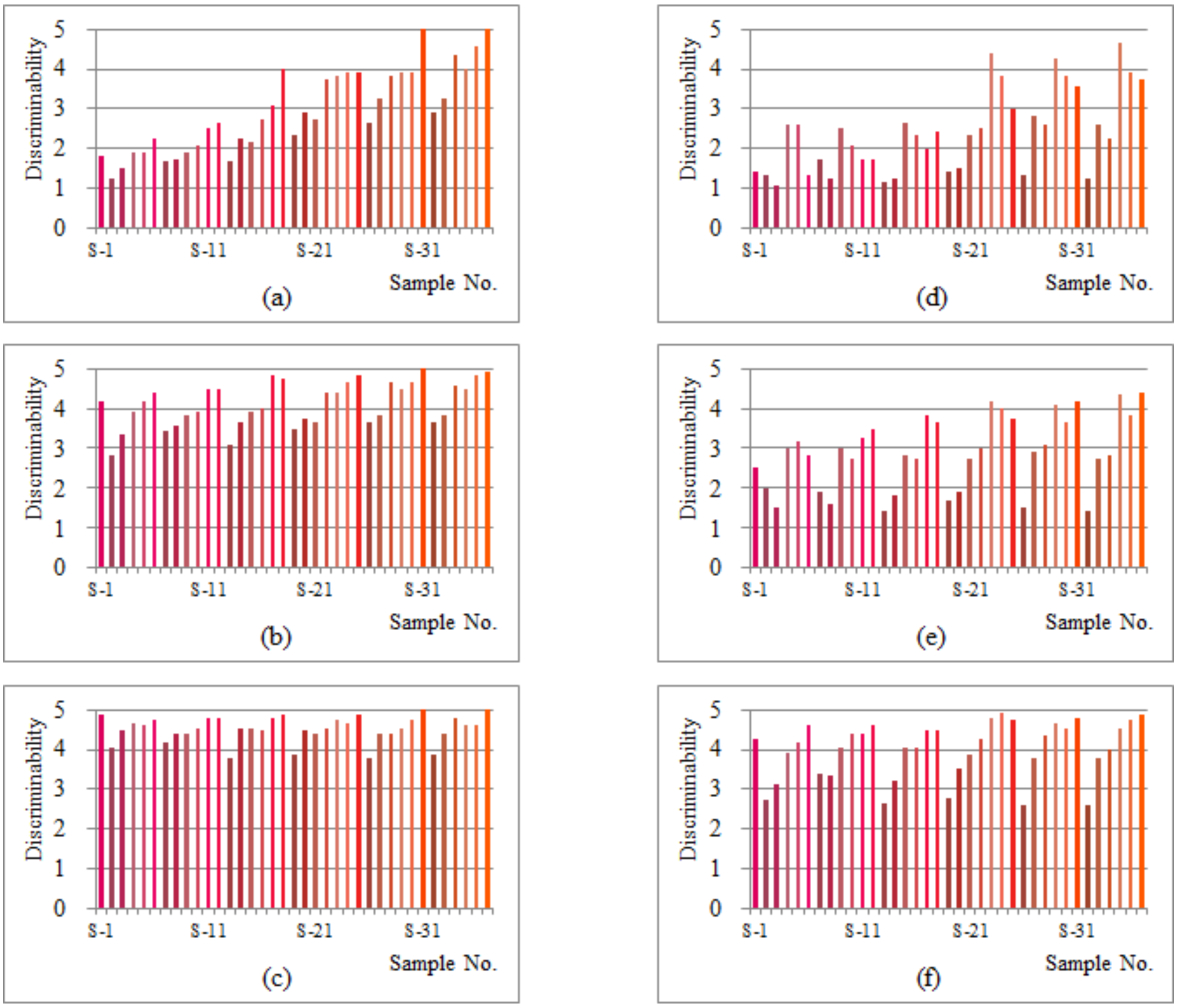

Figure 1: The discriminability from a black background; Left side is for 500 lx, (a) protans, (b) deutans, (c) normal trichromats, Right side is for 1 lx, (d) protans, (e) deutans, (f) normal trichromats,

3.2 Illuminance level

In the preceding, we presented results that evaluation for redness and discriminability from the black background were changed by illuminance level. We investigated the affection of illuminance with samples of high chroma whose hue were from 2.5R to 10R. The shifts of redness and discriminability scores by illuminance level were plotted in Figure 2. The discriminability results of samples from 2.5R to 5R decreased with the shift of illuminance level from 500 lx to 1 lx, whereas, scores of yellowish-red hue colors (8.75R and 10R) shifted less than the other colors.

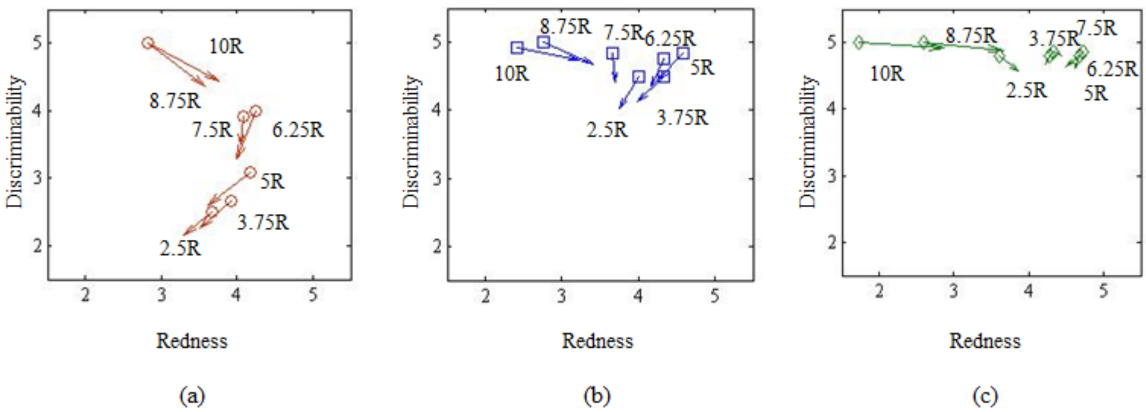

Figure 2: The shifts of redness and discriminability scores by illuminance level (from 500 lx to 1 lx) (a) protan, (b) deutan, and (c)normal trichromats

3.3 Spectral reflectance of sample

As the above result, the discriminability results at 1 lx were worse than at 500 lx for most of samples. However, we also obtained the opposite results, especially in protans, to above in several samples as shown in Figure 1; e.g. discriminability results of No.23 (7.5R6/9), No.29 (8.75R6/9) and No.35 (10R6/9) at 1 lx were higher or the same as those at 500 lx. Therefore, we extracted seven colors each that discriminability results improved or reduced. Those spectral reflectances are shown in Figure 3. The presence of middle-wavelength (yellowish color) components was found in samples with improved discriminability. We consider that the Purkinje shift influenced above tendencies.

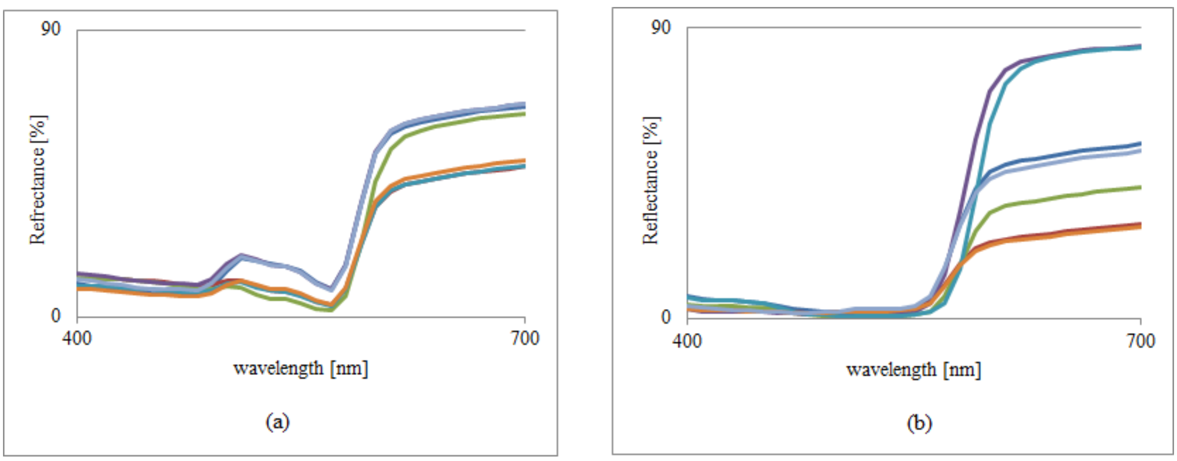

Figure 3: The spectral reflectances of seven colors, (a) improved discriminability, and (b) reduced discriminability.

4. CONCLUSIONS

We investigated the color appearance of red spot color inks by the evaluation of redness and discriminability from a black background in order to find conspicuous package print color inks for various illuminant conditions and different types of color vision deficiency. The redness was tend to vary with observers, though our experimental results showed the samples of around 2.5R to 7.5R and high chroma generally obtained high score at 500 lx. High chroma samples highly scored on the discriminability at 500 lx for deutan and normal trichromats. Above all others, yellowish-red hue samples obtained noticeable discriminability score for protan at 1 lx. Those samples were improved discriminability according to decrement in illuminance level, and the presence of middle-wavelength (yellowish color) components in spectral reflectance. Better discriminability at 1 lx for those samples would be due to the higher middle-wavelength components implying the influence of the Purkinje shift.

Our results suggest that we are able to predict an appropriate red spot color ink for various illuminants, color vision deficiencies, and application usages. In addition, we would investigate more detail of influence by spectral reflectance of inks as a future issue.

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A Study on the utilization of Korean Saekdong Color In the Textile arts

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ABSTRACT

For the arrangement, structure, and ratio of Saekdong, they are typical stripe patterns symbolizing the philosophy and outlook on the universe of Korean people rather than a simple sense of beauty; such can be called Korea's traditional color senses and the harmony of color arrangement featuring moderated modern beauty. Korean people expressed strong aesthetic consciousness of the intention of good omen through Saekdong, the peculiar color sensitivity made by patching cloth of various colors and maintaining it as the traditional color pattern unique to Korean people. The colors most used for Saekdong were the 4 colors of Obang colors excluding black, wherein a mix of various colors were combined with blue, red, yellow, and white to ensure soft color transfers. In particular, the unique sense of rhythm created from the repetitive arrangement of a specified unit amid the asymmetrical natural sense of balance of the left and right of the original colors and the mixed colors is the excellent plastic art element of Korean Saekdong. Therefore, this study was carried out based on the writer's report on studying textile art works of diverse genres to revitalize Saekdong, which shares Korea's identity as well as the aesthetic consciousness of world generality.

INTRODUCTION

Saekdong is is a typical color arrangement that symbolizes today's Korea. The unique color composition and plastic characteristics are products of representative aesthetic awareness wherein the cultural senses inherent to Korean people are condensed and have been closely used during the daily life of Korean people. In particular, the writer has completed modern textile arts expression by reflecting the color sensitivity of Saekdong on various experimental plastic art works such as <The Cord of Life - motif with black(even though excluding black, Saekdong) and white color > done by the writer in the past.

<Work1: Saekdong Image Design – Scarf 05A>

The morphological elements of works are as follows: First, as the relief plastic element of patch work, the work expresses relief form through the plastic art combination and coloring of diversified materials - not the existing needlework technique - based on the plastic section division and patching technique of Korea's wrapping cloth. The writer sought

<Work1: Saekdong Image Design – Scarf 05*B*>

diverse colors of the Saekdong colors reinterpreted on the delicate textile materials and the contemporary plastic expressions in the geometric configuration resulting from the material patching. Second, as a pictorial Saekdong object element, the Saekdong object was assigned as the first accent color of the color planning of the works to express the coexistent energy of life, attempting to reflect the sensitivity of the Saekdong colors on the plastic work as much as possible by extracting strong metaphorical color language from the Saekdong pattern and to compose a with the principal and auxiliary colors and No. 2 and No. 3 accent colors. Third, the existing shape of the large plastic works of Obang colors worked for a long period of time as a linear element combining the Saekdong colors with motif as depicted in the form of line, the symbolic expression element forming the motif. The Saekdong colors were introduced to the monotone motif containing much energy, as a contemporary textile design.

METHOD

The following is < Color Planning Table for Textile Arts > and explains in detail how the Author use ‘Korean Color Palett' for real works to express modern colors of Saekdong. Especially in the color planning for modeling works, They are expressed the energy of life on the works by using the colors of Saekdong cloth to give accents to an entire picture. Besides, proposes composition table of the color arrangement with dominant and secondary colors and work index colors. In detail, the color planning can be divided into 6 types, which are expressed in diagram and particularly summarized by work.

[Type I] The vivid colors extracted from Saekdong colors are arranged as secondary color on the geometric solid and added the 2nd and 3rd contracting accent colors to Saekdong to give the color sensation of Saekdong to the modern modeling work as much as I can.

[Type II] The first, second and third assistant color to the accept colors, which are clear and vivid due to their high chroma used in Saekdong object, through watery color contrast of low brightness and calm color tone or the expressions of scattered color drawing of modern Saekdong colors

[Type III] To create a unique composition with Saekdong colors which are accent colors, It use greyish pastel images in which all of dominant and secondary colors are toned down to express the hidden white image of Korean people.

[Type IV] Unlike other works for which the colors of Saekdong cloth are used as accent color for, Saekdong pattern of multiple colors is arranged on the wide cloth of the first and second accessary color. As dominant color, black and white, which is the colors of motif for mono-tone are mixed to maximize the visibility of the motif.

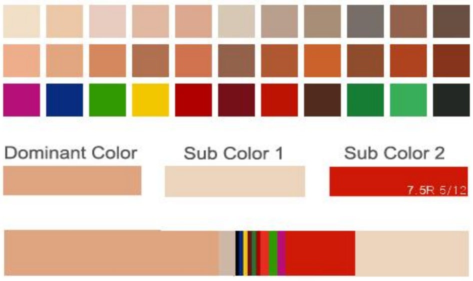
[Type V] The colors of Saekdong fill the entire picture of the work. Being arranged along with accent colors and secondary colors, the numerous paths and traces of Saekdong colors are expressed for piling image in the space

[Type VI] Red and blue, which are two of five cardinal colors are used as dominant and secondary color, respectively, for contrast effect. This contrast elevates the expansibility of image. In addition, the motif pattern in black and white is arranged on the front, composing the picture as secondary color along with white color line that is dominant color. All these are an attempt for multilateral color planning.

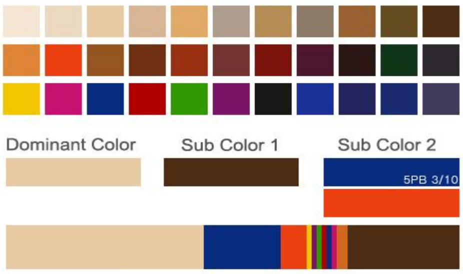
RESULTS AND DISCUSSION

The color planning of modeling works by [Type I~ **IV**] is as follows.

Color Planning – type I

COLOR	Work 1
	

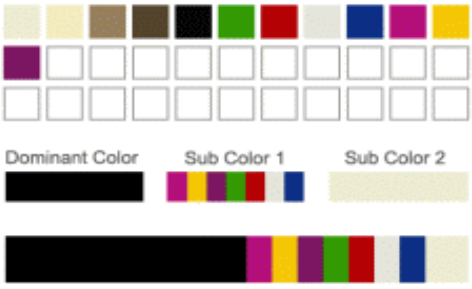
Color Planning - type II

COLOR	Work 2
	

Color Planning - type III

COLOR	Work 3
	

Color Planning - type IV

COLOR	Work 4
	

CONCLUSIONS

One important precautionary point that should not be overlooked in relation to diversified modern textile art works under this study is that it has attempted at the modern plastic expression of the Saekdong colors with the premise that the image of the results should carry unique global competitiveness having specific nationality. To date, there have been many plastic works and prior studies and analysis carried out on colors regarding plastic works and Korean-style image expression. Through the diverse and aggressive plastic experiments carried out on colors unique to Korean people, gone will be the times when such colors might be ignored owing to traditionality.

They also provide an opportunity to use such colors positively as the global color sensitivity contents based on the plastic superiority of the Saekdong colors of Korea. We hope that various color tests and experiments are carried out continuously in the future to modernize the Saekdong patterns.

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Color adjustment for an appealing facial photography

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ABSTRACT

This study investigated the relationship between the color adjustments and preference judgment of facial. Four facial photographs were given and subjects were asked to choose more attractive and likeable photography between a pair of facial photographs displayed in two identical smartphones. All stimuli were adjusted with 5 color adjustments comprised of Lightness, Contrast, Saturation, and a* and b* values in CIELAB color space. Through an orthogonal design, a total of 28 combinations were planned including 3 holdouts. Based on the judgments for the paired comparisons, Conjoint analysis was performed and the impact of each attribute and the levels of within each attribute were identified. Contrast had the biggest impact followed by Lightness, Saturation, and hue values, a* or b*. This tendency was found across all four photographs. The results provide guide to improve the quality of facial photograph, and limitations are discussed.

1. INTRODUCTION

Called as 'Selfie' in the social network services (SNS), a facial photography is one of the popular behaviors of SNS users. Due to a growing concern about more attractive and professional Selfies, most of the SNS are offering image filters. The profile images on Social Network have a characteristic that can be exposed toward unspecified individuals(Zhao, Grasmuck, and Martin 2008), and they are regarded as one of the most powerful ways to express ones' desired impressions on the network(Ellison, Heino, and Gibbs 2006). Studies on self-presentation analysis revealed that people tend to upload their online profile images not actual versions but edited versions which are reflected their own ideal images(Ellison, Heino, and Gibbs 2006). Under this circumstance, the photo editing applications try to meet social network users' demands to change their profile photos. Consequently, the photo editing applications contain filter bundles which modify the image characteristics and thereby improve impressions of photos. In this regard, we tries to find an underlying relationship between the color adjustments that affects judgment of facial photography.

2. METHOD

2.1 Material and color adjustment

We purchased four portrait photos from iStock®, and the four consisted of two males and two females (Figure 1). When selecting the four photography, we intended to avoid the external effect such as background color, clothes(Elliot and Niesta 2008), and the initial facial expressions. Accordingly, we chose neutral facial expression and then removed the background and modified the clothe either in black or white. For the graphical editing, we used the Photoshop CS6.

Figure 1: Original photos of 4 stimuli (from left, male A, male B, female A, female B)

As the color attributes for the adjustment, we manipulated the following five aspects: 1) The Lightness: direct adjustment of L*; 2) Contrast: a sigmoid adjustment to L*); 3) Saturation: multiplicative adjustment to C^*_{ab} at a constant h_{ab}; 4) and 5) a* and b* values: adjustment at a* and b* coordinates in the CIELAB system. What particular in our study was that we articulated the a* and b* indenpendently, whereas most of the related studies grouped a* and b* into several nominal categories. Then we varied the levels of each attribute somewhat differently as presented in Table 1. While altering the levels of color attributes, we basically pursue maintaining aesthetically acceptable quality, and thus we referred to a previous study in that the acceptable range of deviation of color attributes were proposed (Fernandez, Fairchild, and Braun 2005). Subsequently, with regard to the Lightness, Contrast and Saturation, we applied 5 levels, whereas we did 3 levels for both a* and b*. We created the adjusted images in MatLab® 2014b.

Table 1. Summary of the levels of adjustment value on five color attributes.

Color Attributes	Levels				
	(a)	(b)	(c)	(d)	(e)
Lightness	-10	-5	Original	5	10
Contrast	0.03	0.04	Original	0.05	0.06
Saturation	0.8	0.9	Original	1.1	1.2
a* value	-2.5	Original	2.5		
b* value	-2.5	Original	2.5		

In order to reduce the number of combination from the entire factorial designs (1,125 = 5x5x5x3x3) while minimizing the loss of information, we created only 25 combinations by through an Orthogonal Design. After having added another 3 combinations as the holdouts, we prepared a total number of 28 combinations for the subjective assessment. Considering the Selfie context, we displayed the photos on a smartphone whose screen size is 2.4 inches in width and 4.2 inches in height.

2.2 Method

A total of 30 college students composed of 16 males and 14 females participated in experiment. The avrage age of the subjects was 21.57 years with a standard deviation of 3.37 years.

The experiments consisted of two parts. In the first part, we asked the subjects to evaluate each of the four original photography using a set of criteria. The criteria included the following five aspects proposed by Willis and Todorov (2006): Attractiveness, Likeable, Competence, Trustworthiness and Aggressiveness. We intended to identify the baseline of each photography, and subjects made judgments of each photography using 7-point Likert scale (1 = strongly disagree, 5 = strongly agree). In the latter part, we adopted a pair comparison method, and thus provided each subject with a pair of photography displayed in two identical smarphones. Since we prepared 28 combinations, a total of 378 paired comparisons (28*27/2 = 378) were acquired. We requested subjects to choose a more attractive photography than the other within 2 seconds, and all could easily make the decision.

The experiment room was lit with 6500K and illuminance was 650 lx. Under this illumination, the luminosity reflected from a white area in the content image was measured as 203 cd/m^2.

2.3 Results and analyses

Based on the assessments in the first part, we compared the mean differences among the 4 photographs with regard to the 5 criteria, and found that there were differences of initial impressions among the four. Repeated measure One-way ANOVA yielded the statistical difference an alpha level of 0.01. For example, in terms of degree of 'Attractiveness', Female A got the highest score(5.23) followed by Male B, Female B, and Male A. Therefore, we should take the individual difference into consideration during the analysis of the data.

Table 2. Mean and standard deviation of the 4 photographs when original. (N = 30)

Attributes	Male A	Male B	Female A	Female B
Attractiveness	4.20 (0.85)	4.93 (1.05)	5.23 (1.10)	4.33 (0.96)
Likeable	4.43 (0.90)	3.97 (1.10)	4.70 (0.99)	5.00 (0.95)
Competence	4.57 (0.97)	5.33 (1.06)	5.27 (0.98)	4.03 (0.81)
Trustworthiness	4.40 (1.00)	4.17 (1.44)	3.87 (1.04)	5.00 (0.87)
Aggressiveness	4.20 (0.81)	5.10 (1.03)	5.73 (0.91)	3.70 (1.06)

Then we accumulated the judgments of paired comparisions, and transformed the data into the rank orders. Based on the 60 cases (30 subjects x 2 sets of photographs) of ranked data, we performed a Conjoint analysis in SPSS® 21 to identify the relevance of each attribute(i.e. relative importance) as well as each level within each attribute(i.e. utility). The following Figure 2 presents the averaged importance values of 60 cases. Among the five color attributes, Contrast had the greatest impact while b* did the smallest one. A

Repeated measure One-way ANOVA confirmed that the averaged values of relative importance were statistically significant [$F(4,236) = 117.42$, $p = 0.00$]. Moreover, a strong positive correlation was found between the ranks of 25 combinations and those of 3 holdouts (kendall's tau = 0.87, $p = 0.00$), supporting a high level of reliability.

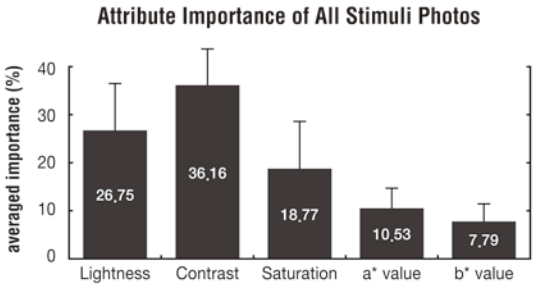

Figure 2: Relative importance of the five attributes.

Futhermore, the utility scores of each of the 5 attributes were revealed (Figure 3), and we formed the best combination as follows: 3.78 + 4.52 + 1.97 + 1.20 + 0.40 = 11.87 (maximum of sum of utility).

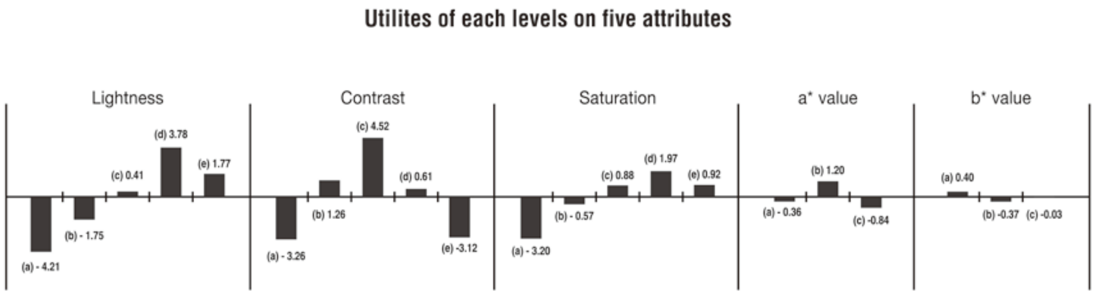

Figure 3: Utility of each level on five attributes

Also we observed quite similar tendency between males and females indicating that the color adjustment can be applied to both genders. In both gender groups, Contrast had the strongest impact followed by Lightness, Saturation, a*, and then b*. The only slight

Figure 4: (Above) Original photos (Below) Adjusted to be the most appealing

difference was found in the utility scores of b*. More bluish female photographs(negative b*) were preferred while more yellowish male photogrpahs(positive b*) were preferred.

In addition, we concerned about the individual difference among the four photographs with regard to the initial impressions. However, the Conjoint analysis yielded similar tendency across the four different faces. This implies that the color adjustment to make a facial photographs to be more attractive can be universally applied to different faces (Figure 4).

4. CONCLUSIONS

This study revealed the relative importance of color attributes for the impressions of facial photography. The empirical study showed that Contrast was the most effective on both female and male photos whereas b* value change was the least. In particular, the most attractive/likeable combination of color attributes on photos was proposed in the following procedure; 5 amount increase of Lightness value, 1.1 multiple amount of Saturation value, original Contrast value, original a* value and 2.5 amount negative shift of b* value. When the utility scores within each attribute were compared, it was found that original contrast was the most preferred. However, further investigation should be carried out with non-professional photographs whose aesthetic quality is not professionally controlled. Nevertheless, a consistent tendency was found across all four photographs, which implies that there is a ground truth with regard to the preference for facial photographs. In a future study, the empirical study should expand to include different initial quality of the photographs and different ethnic groups not only as stimuli but also for the judgment.

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Understanding popular relationships among colors through the network analysis for crowd sourced color data

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ABSTRACT

This study makes a unique attempt to adopt Social Network Analysis(SNA) in order to exploit the potential of the crowd sourced large-scale color data. We anticipate understanding the trend of color combinations and the way of generating harmonious color schemes. Basic concepts in SNA are introduced along with the method of constructing a color network from the existing color database called Adobe Kuler®. In relation to the characteristics of SNA, the implication of adopting SNA is discussed while demonstrating its benefits through findings from the network analysis of a color database. Various ways of visualization of the color data are suggested to illustrate the difference among them. In addition, quantitative metrics are calculated which identify the relative importance of individual colors and the entire structure of a network. The result reveals key players of a color network and subgroups of colors which are harmonized well to each other.

1. INTRODUCTION

Utilizing a harmonious color scheme is often essential to make an aesthetically pleasing art work and design. In order to support a proper color choice, there have been studies that are focused on developing algorithms or tools to generate a set of color (Shen et al. 2000, Wijffelaars et al. 2008, Hu et al. 2014). However, constructing a satisfied color scheme is still challenging due to the limited practicality and weak theoretical background of existing models. In this regard, this research aims to investigate patterns of color combinations through exploring the latent relationships among colors in color schemes. A network analysis was adopted to examine the relationship of colors that are generated by crowd, and to identify key players of the color combinations and the subgroups that consist of closely related colors.

2. APPLICATION OF SNA FOR A LARGE-SCALE COLOR DATA

Social Network Analysis (SNA) has been successfully utilized in various fields to understand the structure of a community, a society and even a biological system (Ennett and Bauman 1993, Böde et al. 2007, Blanchet and James 2012). Compared to traditional research methods, SNA focuses on the relationships and emerging structures formed by relationships (Scott 2012). Due to this characteristics, SNA has been supported the identification of new paradigms and latent patterns beneath the structure. Nowadays, a growing number of researches adopt SNA to investigate the structure, determinants, and impacts of relationships between actors. To our best knowledge, however, it has been yet applied to the large-scaled color data, especially a database of color schemes built by crowd. A color scheme can be easily interpreted as relational data among colors that belongs to a same scheme. In addition, Adobe Kuler®, one of the largest color scheme database, provides not only the color schemes but also the ratings for each scheme that are given by numerous users. It is expected that existing color schemes and their ratings can provide relevant guidelines to identify a harmonious combinations of colors that is applicable to a new art work. Thus we made an attempt to explore the color schemes of Adobe Kuler using SNA.

Table 1. Summary of the charcateristics of SNA and its implications on a color network .

Characteristicss of Social Network Analysis	Related SNA metrics	Implications of applying SNA to a color network	Related examples from SNS studies
Quick and easy visualization of big database	-	An easy and intuitive understanding of popular colors (See 4.1)	-
Identifting the relative importance of a social actor depending on the network position	Closeness centrality	Identifying universal colors which are easy to match with diverse colors (See 4.2)	A user who can reach to all other users with fewer steps using a friendship network
Identifying the subgroups of a network according to the relational data.	Modularity	Identifying a group of colors that are often used together in order to construct a color scheme (See 4.3)	A group of users that have intimate and dense friendships with each other

Application of network analysis to a crowd sourced database has several advantages. First of all, SNA enables a quick and easy visualization of large scaled data. Due to the visual properties of color data, an immediate visualization of data facilitates initial analysis and interpretation of the entire dataset. Secondly, network analysis focuses on the relational data, and this focal point is much more appropriate to investigate the compatibility of a color rather than its popularity that can be easily captured and compared by conventional methods. SNA provides quantitative metrics such as closeness centrality that measures the relative importance of a node in the aspect of connectivity a node has. This can be employed to identify universal colors that have been belonged to many color schemes with diverse combinations. SNA also supports a clustering of nodes using a modularity algorithm that identifies subgroups of intimate colors based on the relational data.

In conclusion, SNA allows rich and informative analysis to investigate latent but practical knowledge that traditional methods are hard to discover. Table 1 summarizes the characteristics of SNA and its implication on the study of color database with the comparison of examples from Social Network Service(SNS) studies (Perry-Smith 2006, Newman 2006) .

3. CONSTRUCTING A COLOR NETWORK

3.1 Data collection and processing

In order to construct a color network, we utilized 44,986 color themes of Adobe Kuler(Adobe Color CC) which were collected and distributed by O'Donovan et al (2011). We filtered out 7,118 popular color themes whose scores are higher than 4.0 out of 5.0. Then we transformed each color theme into nodes and links data. A node indicates a single color, and a link is a connection between a pair of colors which are included in the same color scheme. Since every color scheme consists of five colors, we were able to extract five nodes and ten links (10= (5 x 4)/2) from each color scheme.

In addition, the RGB scores as it was initially crawled were mapped into the CIE1976L*a*b space. The L, a, b scores were rounded off to every 5(for example a color with L:71, a:14, b:13 was transformed to L:70, a:15, b:15). Consequently the color quantization aggregated multiple colors into one, and helped to construct a concise and denser network.

3.2 Visualization in Gephi®

Utilizing the quantized Lab values of Adobe Kuler data, a color network with 4,922 nodes and 26,401 edges was generated. An opensource software Gephi was utilized in order to visualize the network and anlyze it. Figure 1 shows a visualized color network which is composed of colors that are used more than 50 times.

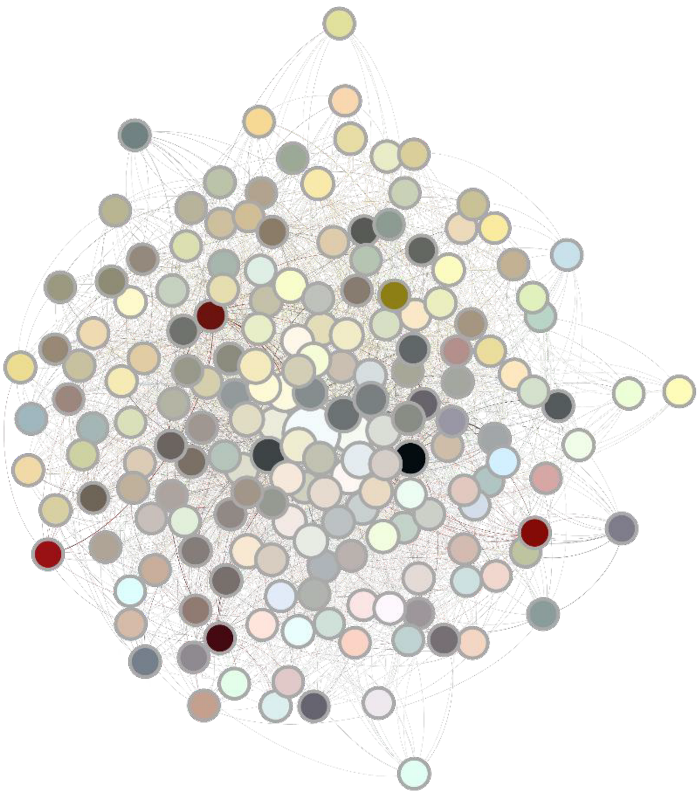


Figure 1: A color network of colors which are utilized more than 50 times

4. FINDINGS FROM THE NETWORK ANALYSIS

4.1 Identifying key players through a visualized network

As previously mentioned, SNA has notable characteristics and advantages that are different from other research methods. First, it provides an effective way of visualization which enables an intuitive understanding of the entire data. Figure 2 shows three networks which utilized the same data but devised different filtering criteria to emphasize the key players of a color network. The left network provides a look of network that are composed of colors utilized more than 20 times (degrees). It covers 37.85 % of the entire links, and shows the general tendency of the color utilized by crowd. The middle one shows popular colors that are utilized more than 70 times. As shown in the graph, most of reddish colors appeared in the low range of L, whereas bluish colors more frequently had higher L values. The right figure was generated by applying the criterion of degrees more than 200. In this case, only a few colors are visualized, and it is really easy to identify the extremely popular colors that are frequently utilized throughout the database. To summarize, SNA provides an easy and effective way of representing the data while investigating the relationships with diverse perspectives. It also provides an intuitive view to compare more than two different color networks. Especially when it combines with time-dependent data, it is expected that the trend change of popular colors can be traced and compared easily using the color network.

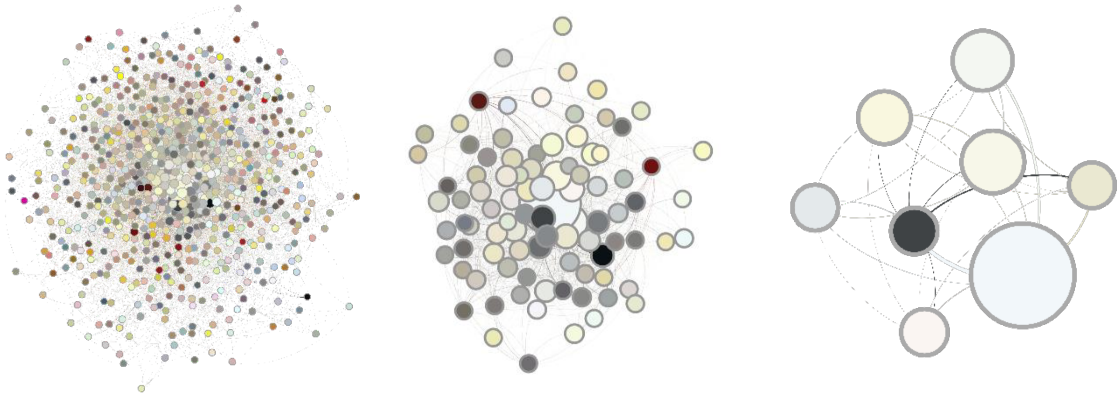


Figure 2: Networks with different filtering criteria - nodes of 20, 70, 200 degrees respectively

4.2 Identifying universal colors using a closeness centrality measure

A color scheme is often constructed with more than 2~3 colors. Hence, it is important to identify colors that can be universally matched with other colors instead of capturing single color with a extreme popularity. In this regard, a color which has a closer relationship with other colors is more meaningful than a color which has been frequently used as a member of a color scheme. The measure of closeness centrality relates to the concept of universal match, and it calculates the average distance from each node to every other nodes in the network. For instance, the value 2 of closeness centrality indicates that the node can reach to other nodes within two degrees in average. The higher closeness centrality implies that a color can be connected to other colors with a shoter distance, and it increases the possiblity that a color belongs to various color schemes. Therefore, a color with a higher closeness centrality can be regarded as a universal one which is compatable to any combinations.

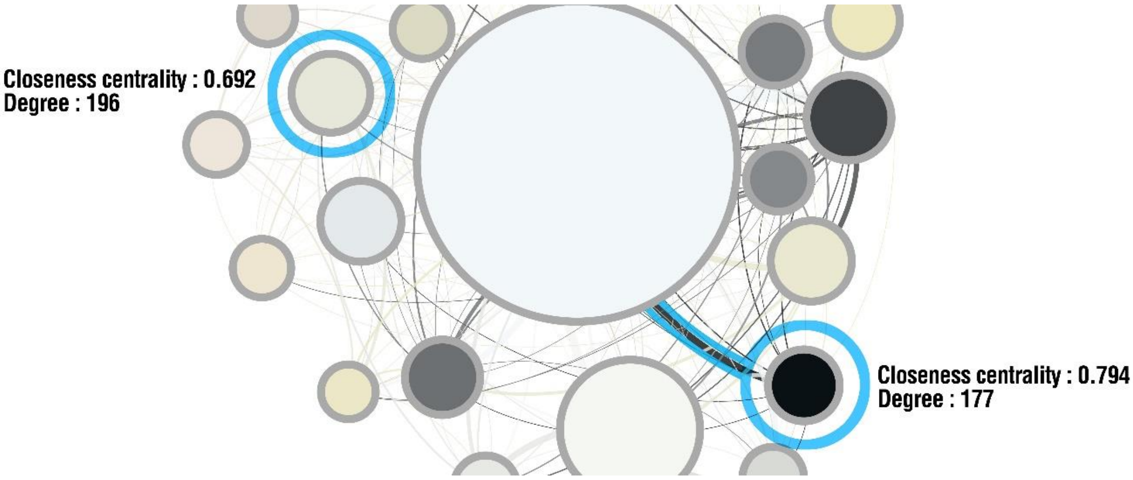


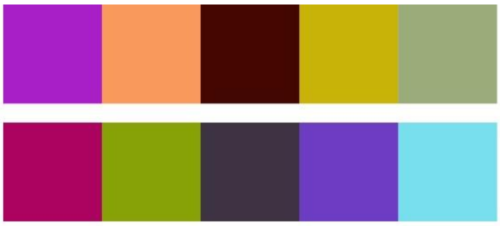
Figure 3: A partial network to compare two colors with different closeness centralities

In a network, colors which show higher closeness centralities often overlap with the popular colors which are utilized more frequently than others, but not always the same. Figure 3 shows two colors in a network with a closer look; the highlighted color on the right side of the network represents a color with a higher closeness centrality (0.794) whereas the left one represents a popular color utilized more frequently but less central (0.692). As shown in the graph, the color with higher centrality has strong relationships with other colors that are popular as their size represent. However the left one with a lower centrality value has relatively less links with other popular colors. The strong connectivity with other popular colors increase the possibility that the right color reach to other colors to construct various combinations. In general, colors with remarkable centralities have extreme L values and lower chromaticities throughout the entire graph.

4.3 Identifying groups of harmonious colors using a Modularity measure

The modularity algorithm looks for nodes that are more densely connected together than to the rest of the network (Newman 2006). The nodes that belong to the same modularity group has a strong relationship with each other because they have been frequently utilized in the same color scheme together. Therefore the modular membership of a color can be employed to construct a color scheme which has been proved as harmonious combination by numerous users. As shown in the Figure 4, color schemes that consist of colors from the same modular groups are relatively more harmonious than schemes composed of colors with different modular memberships.

(a) Colors from the same Modularity group



(b) Colors from the different Modularity group

Figure 4: Color schemes that are generated using the Modularity of colors

5. CONCLUSION

In this study, Social Network Analysis has been adopted in order to explore the crowd-generated color big data. We have discussed the method to construct a network using the exsiting color database, and have introduced relevant metrics and methods that are applicable to the color data. The constructed network was analyzed and interpreted by visualizing it with different filtering criteria, and by calculating network measurements such as closeness centrality and modularity. The measurement of closeness centrality reveals that colors with extreme L values and low chromaticities are more compatable with other colors. We also generated color schemes by employing the modularity memberships of colors, and the colors from the same modular groups produeced more harmonious color schemes. In conclusion, the network analysis provides a noble way of investigating color data in the perspective of relatinships among colors, and suggests findings that conventional methods are hard to reveal. However this study is intended as a priliminary research to introduce the implication and benefits of applying a network analysis. For further studies, it is required to develop relative analysis methods and verify its significance in order to enhance reliability and practicality of network analysis in color studies.

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Eliciting the Color Bizarreness Effect Using Photographs

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ABSTRACT

Color typicality has seemed to affect on performance of a picture memory task. When an object is typically colored, the color is remembered more accurately than when it is atypically colored. In contrast, incongruent stimuli have been found to increase attention, resulting in higher performance on memory tasks compared with congruent stimuli, the so-called "bizarreness effect". The previous study by these authors investigated the color bizarreness effect in line drawings. The current study manipulated the object color of photographs, rather than that of line drawings. We expected that the strangeness of the bizarrely colored stimuli is larger in photographs than that in line drawings. The objects pictured were exactly the same as those in the previous study, which found a color bizarreness effect with line drawings. The participants in this study comprised 30 university students. In an initial learning session, 28 photographs of objects were presented one at a time. They were colored in typical colors (e.g., yellow banana, purple eggplant) or bizarre colors (e.g., blue banana, orange eggplant). The recall performance results did not show a bizarreness effect or a typicality effect. Why the bizarrely colored photographs did not produce color bizarreness effect is discussed. Previously, the authors examined the color bizarreness effect using line-drawings. The procedure was exactly the same as this current experiment except that the stimuli were line-drawings, not photographs. That experiment did produce bizarreness effect. An ad-hoc analysis found that the strangeness of the filler stimuli, that is, typically-colored stimuli, affected the bizarreness effect; because the typically-colored photo stimuli seemed to be a little unnatural, bizarreness effect decreases. This mechanism for the color bizarreness effect can be applied to create striking text or advertisements.

1. INTRODUCTION

The so-called bizarreness effect is the theory that people have better memory for bizarre items as compared to common items, a finding referred to as the bizarreness effect (Geraci, McDaniel, Miller, & Hughes, 2013). Many of the studies on this theory have used bizarre images or sentences as stimuli. However, some studies triggered this effect using pictures (e.g., Gounden & Nicolas, 2012), advertisements (e.g., Subbotsky & Matthews, 2011), or personal information (e.g., Brandt, Gardiner, & Macrae, 2006).

The mechanism of the bizarreness effect has yet to be clarified, but one of its underlying factors is that bizarre stimuli attract attention. Another factor is that bizarre or unexpected items activate particular encoding processes. When the event is more elaboratively processed, bizarre items are encoded with a richer set of cues that are especially useful in retrieval (McDaniel, DeLosh, May, & Brady, 1995).

The present study investigated the mechanism producing the color bizarreness effect. While color typicality evidently affects performance of picture-memory tasks, some studies have reported that when a line drawing is typically colored, it is more accurately remembered than when it is bizarrely colored (e.g., Morita, 2013; Ratner & McCarthy, 1990). In such cases, it is possible that the color bizarreness effect scarcely occurs. In contrast, we found a color bizarreness effect with line drawings as participants recalled more bizarrely colored line drawings than commonly colored ones (Morita & Funakoshi, in press).

Our present study used exactly the same objects as in the previous study (Morita & Funakoshi, in press), but showed them in photographs rather than line drawings. We mentioned above that some studies found a color typicality effect for pictures; however, few have examined the color bizarreness effect. Thus, we arranged conditions to induce the bizarreness effect. We examined whether we could find the color bizarreness effect when using photographs.

2. METHOD

2.1 Participants

The participants in this study were 30 university students, and the experiment consisted of small groups of one to five participants.

2.2 Stimuli

We selected 28 objects based on the our previous studies that used line drawings (Morita & Funakoshi, in press). We then chose photographs of the objects from a database of psychological photographs and websites.

Of the 28 objects, 12 were assigned to target stimuli, which were were colored with either a common or bizarre color. Another 12 objects were assigned to filler stimuli. The bizarreness effect can be expected to be larger when there are more common items employed. For example, Hirshman, Whelley, & Palij (1989) found that the effect occurred when there were four bizarre sentences and 12 common sentences, but not when there were 12 bizarre sentences and four common sentences. To prevent primacy and the recency effect, the remaining four objects were assigned to dummy stimuli, which were presented as the first and last items on the list. Target items were counterbalanced across participants. A participant was presented six bizarrely colored targets, six commonly colored targets, 12 commonly colored fillers, and the dummy stimuli.

To compare the effect, the bizarre color and the common color of these stimuli were the same as in Morita & Funakoshi (in press) using line drawings. Adobe Photoshop was used to color the photograph stimuli (Figure 1).

Figure 1: Examples of commonly colored and bizarrely colored stimuli.

2.3 Experimental Procedure

The experiment consisted of a learning session and a free recall test session. In the initial learning session, 28 photographs of objects were presented one at a time by PowerPoint. One trial consisted of a gaze point (1 sec), photograph of the object (2 sec), and the object name attached to the photograph (1 sec). Participants judged whether it was easy to identify the object, and rated on a three-point scale. After viewing the 28 stimuli, participants were made to perform to a distraction task; spending 2 minutes answering a questionnaire. In the last test session, participants were asked to recall the names of the objects presented in the learning session.

3. RESULTS AND DISCUSSION

Figure 2 shows the mean proportions of recall of the common and bizarre targets. The mean recall rate of filler stimuli was 56.7%. A *t*-test found no significant difference between the recall performance under two conditions; the bizarreness effect did not occur.

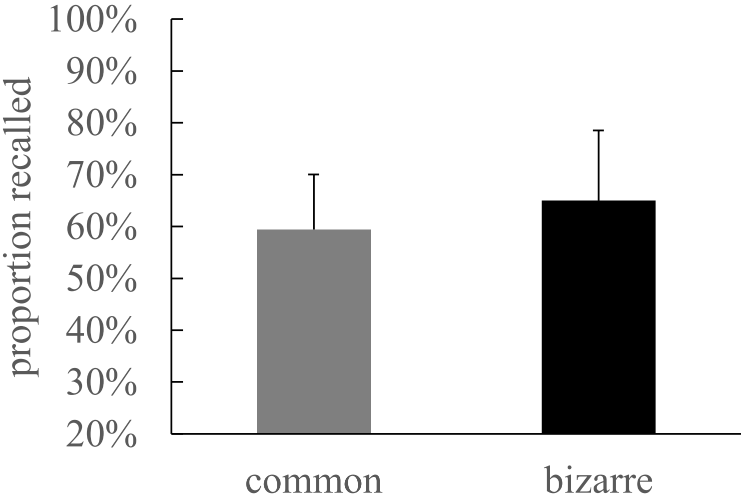

Figure 2: Mean proportion of recall of commonly colored and bizarrely colored stimuli.

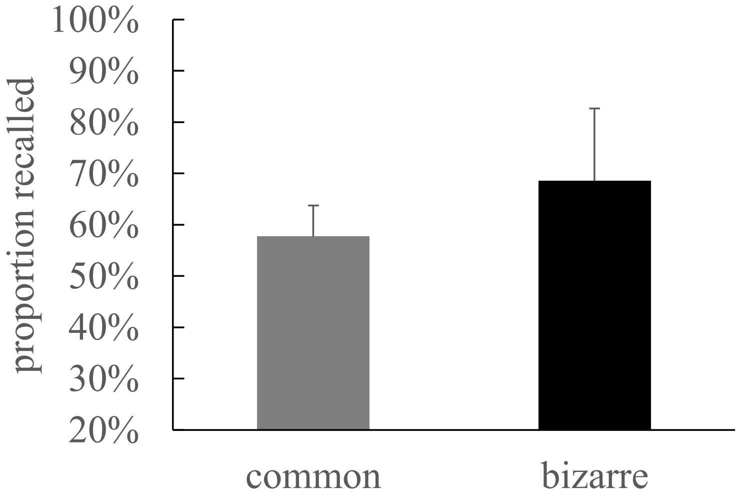

Figure 3: Mean proportion of recall of commonly colored and bizarrely colored stimuli excluding five participants.

However, five participants had a recall rate of below 50% for all stimuli. It is possible these five did not perform the task sincerely. Thus, we analyzed the recall rate for the target stimuli again, excluding these five participants' data (Figure 3). A *t*-test found that bizarrely color targets were recalled marginally better than commonly colored ones.

The study's objective was to investigate whether the color bizarreness effect could occur under conditions arranged to induce the bizarreness effect. The current study used photographs, expecting that the strangeness of the bizarrely colored stimuli would be greater this way as opposed to using line drawings.

The results showed no significant difference between common and bizarre colors. When excluding five participants from apparently underperforming participants, the bizarreness effect was found to occur at a marginal level. Though this experiment was conducted under conditions for inducing the bizarreness effect, the effect seldom surfaced.

In comparing our present and past studies, we note the procedure was exactly the same except the previous stimuli were line drawings rather than photographs. Ad-hoc analysis found that somewhat strange attributes of the filler (typically colored) stimuli affected the bizarreness effect. This was because the typically colored photo stimuli seemed slightly unnatural, and thus the bizarreness effect decreased.

This experiment added insight about the mechanism of the bizarreness effect. We suggest that the process differs between the differently colored objects. Rappaport, Humphreys, & Riddoch (2013) reported that a search for a common color-form conjunction was uniquely efficient. That study suggested that learned bindings can be computed with minimal attentional limitations. In contrast, the search for bizarrely colored objects was slow, consistent with serial attention being required to distinguish targets and nontargets. Here we suggest that bizarrely colored stimuli need additional processing with attention. This additional processing is found to produce the bizarreness effect and, thus, observance of the color bizarreness effect should come as no surporse. In contrast, memory performance is enhanced to the extent that the context forms and integrated unit with the target. A common object will yield superior memory performance because a more elaborate trace is laid down and because in such cases the structure of semantic memory can be used more effectively to facilitate retrieval (Claik & Tulving, 1975). This rich elaboration is indicated to produce a typicality effect.

4. CONCLUSIONS

In this experiment, neither of these two effect occurred clearly. We could not conclude that bizarrely colored objects are easier to remember. It seems to be difficult to produce the bizarreness effect using color manipulation. This may be dependent upon the color-shape conjunction or strangeness of the color.

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Texture in Color Emotions

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ABSTRACT

Regarding the visual sensation much effort is put into investigating so-called color emotions, building the models by selecting emotion scales and through them assessing human reaction to selected colors. Most of the previous studies had recorded color emotions in subjects viewing uniform color patches. However, when dealing with the real world objects, perception of the color is usually connected with the perception of objects surface properties i.e. texture. In this work we had done a pilot study to assess and possibly describe the effect of texture on color emotions and also to select a set of attributes which can be appropriate for describing the reaction to the texture.

1. INTRODUCTION

There are an extensive number of studies that tried to capture and model the effect of color on human emotions (Gao and Xin, 2006; Ou et al., 2004; Ou et al, 2012, etc.). In these studies solid colors are used as stimuli, while the emotion scales are based on pairs of words, usually adjectives, with the opposite meaning (for example: heavy-light, modern-classical, clean-dirty, masculine-feminine, etc.). As seen from these examples, adjectives used to describe emotions are rather opinions and descriptions of specific reaction to a certain color and the effect it produces. Even though these descriptors do not capture the essence of emotions, they do provide very important information about human reaction to a certain color. Hence, for the purpose of our study we will adopt the term color emotions for describing the reaction to the colored sample, in general.

It is stated that color can be perceived differently, and consequently evoke different emotions, if it is combined with the texture (Zhang and Wandell, 1996). Lucassen et al. (2011) show that "texture fully determins the response on the hard-soft scale and plays an important role in decreasing weight for the masculine-feminine, heavy-light and warm-cool scales." This study was done with synthesized images, where all the samples were visible during the decision process.

The aim of this study was to provide us with some basic information for better understanding of the effect that texture has on human reaction to color. In this part of a study we decided to use a limited number of natural textures. We started testing whether the adjectives used in the color emotion studies are actually appropriate when dealing with textures, so we conducted a survey on 94 respondents of different nationalities. The method and some preliminary results are presented in the next sections.

2. METHOD

2.1 Selection of the Color Centers and Texture Samples

For the purpose of our study thirty chromatic and three achromatic color centers were chosen. Samples had L^* values of 20, 50 and 80. In case of the chromatic samples, h_{ab} was 18°, 90°, 162°, 234° and 306°, while C^*_{ab} was chosen to be the maximum and half the maximum value in sRGB color space. For the hue centers, the above-defined angles represent better the unique hues (Kuehni, 1979).

Next step was defining the textured samples. The goal was to define a set with a reasonably low number of them with enough of the variance regarding texture strength. Samples were chosen from the KTH-TIPS and KTH-TIPS2 database (Mallikarjuna et al, 2006; Fritz et al, 2004) by taking into account the results presented in Gebejes et al (2012; 2013), where GLCM method (Haralick et al., 1973) was used for the characterization of the samples. Since the Homogeneity parameter was shown to have the best correlation with visual perception (Gebejes et al, 2012) five textured color images were selected according to their Homogeneity values (0.571, 0.696, 0.787, 0.869 and 0.949), as seen in Fig. 1. Please, note that for the solid colors Homogeneity takes value of 1. Among some different possibilities, visual appearance of the textures was taken into account in the final decision. Thus, a total of 198 samples (combining 33 color centers with five textures, plus the solid colors) were generated.

Figure 1. Textured color images ordered by decreasing Homogeneity.

2.2 Color to Texture Fusion

Color to texture fusion was performed in CIE LCH color space. It is assumed that resulting hue does not depend on the hue of the source image, while lightness and chroma are computed from both the source image and the target color as in (Milic et al., 2010). Thus, hue channel corresponds to the selected target hue, while lightness and saturation channels were normalized with the respect to the mean values of the source image as:

$$P_t^i = P_t + \left(P^i - P_{mean}\right) \qquad (1)$$

where P_t^i is the target lightness/chroma of a pixel i, P_t is the lightness/chroma of the target color, P^i is the source lightness/chroma of a pixel i and P_{mean} is the mean value of the lightness/chroma of the source image. Fig. 2 shows the results of color to texture fusion for the 5 considered textured images in the case of medium-lightness, saturated blue center (L^*=50, C^*_{ab}=39, h_{ab}=234°).

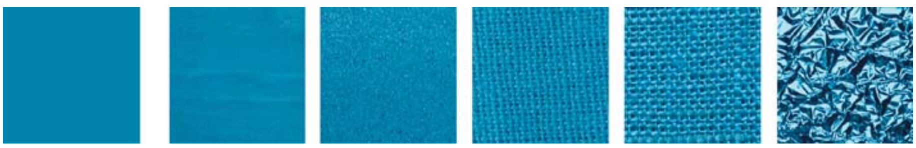

Figure 2. One of the blue target colors and resulting images of the color to texture fusion for all the textures considered in Fig. 1.

2.3 Scales for Texture Emotion

We conducted a survey with the goal to define the most appropriate scales for assessing emotions related to textured samples. The basic idea was to obtain responses from people belonging to different nationhood, and that words pairs used were the most "universal" as possible – meaning not culturally dependent. Our examinees were asked to imagine some texture(s) and to describe, with ten adjectives, their emotions and sensations toward it. In total, we obtained the responses from 94 people. Most of the examinees were from Spain and Serbia (34 of the both nationhood). The rest of the group contained Hungarians, Norwegians, Americans, German, Italian, Romanians, Portuguese, Dutch, Irish, Russian, Bulgarian, Indian, French and Israeli. Questions were posed in English and, due to the large number of examinees from Spain and Serbia, also in Spanish and Serbian. Adjectives obtained in Spanish and Serbian were translated into English and were assessed by language professors.

2.4 Task of the Observers

In this part of the work 26 observers participated 16 females and 10 males, with ages ranging from 21 to 58 and with normal color vision (tested with the Ishihara Color Vision Test).

The 198 samples were presented in dark viewing condition on a LCD monitor (HP 2510i of 25" of the size and operated with a resolution of 1920x1080 pixels). Monitor was calibrated with Eye-One Display colorimeter by taking into account the chromacity coordinates of the sRGB color space. Accuracy of color patches displayed on the screen was measured by the Photo Research SpectraScan PR-704 spectroradiometer. The luminance of the referent white of the screen was 105 cd/m^2. Samples were observed against a neutral background as shown in Fig. 3. The size of the color patches displayed on the LCD screen was 115x115 mm, while the distance of observation was around 50 cm; no chinrest had been used. Thus, the CIE 1964 Supplementary Standard Observer has been assumed according to the samples size and observers' position.

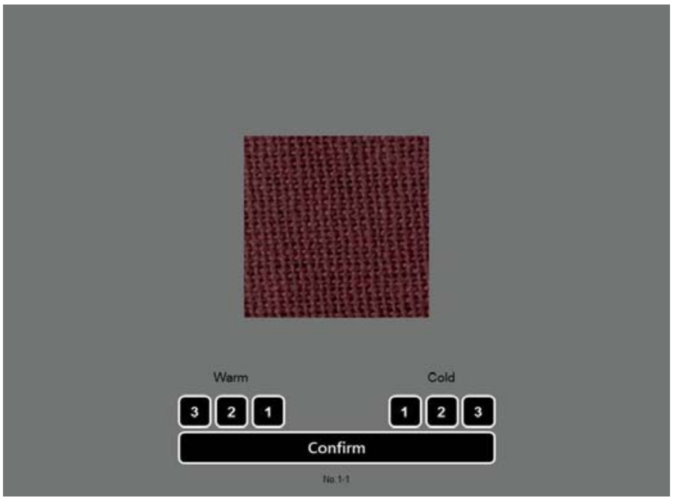

Figure 3. Screenshot of the observers' task

Previous to each session, the observers were adapted to the background conditions for two minutes and adaptation between samples displaying was of 1 second. For each displayed sample, the observers were asked to select one of the words of the pairs and give a score between 1 and 3. Taking warm-cold as an example, numbers 1 to 3 represent the intensity of the reaction, either warm or cold, where 1 means 'slightly' and 3 means 'very'. Value zero was not allowed. For each displayed sample, the answer for two of the words pairs was asked consecutively. The experiment was divided into 3 sessions; one for the words pairs soft-hard and warm-cold, another for smooth-rough and heavy-light, and other for natural-unnatural and like-dislike. Each session lasts for around 30 minutes. Observers performed the sessions in random order and different days.

3. RESULTS AND DISCUSSION

In assessing the results of the survey it was noticed that most of the responses were actually descriptions of texture surface roughness. Overall, we obtained 430 different adjectives where only small amount of them can be regarded as emotional reactions. The words with the highest frequency of the appearance were: soft (12.3%), rough (10.2%), cold (5.8%), warm (5.8%), smooth (4.7%), even (4.7%), hard (3.3%), and pleasant (2.8). It can be seen that among the most frequently used adjectives there are words with somehow opposite meaning (*soft-rough, cold-warm*). This is similar, but not completely in accordance, with the pairs used in color emotion studies (Ou et al., 2004): *warm–cool, hard–soft*.

Following scales were chosen among those with the highest frequency: *soft-hard, warm-cold,* and *smooth-rough.* Besides these, we included two pairs that are frequently used in the color emotion studies and were also found among the responses of our examinees: *heavy-light* and *natural-unnatural*. Additional scale describing preferences is also used in the form *like-dislike*. Thus, in total we chose six pairs of words: soft-hard, warm-cold, smooth-rough, heavy-light, natural-unnatural and like-dislike. Chosen scales can be divided into 3 groups according to the primary potency factors (Ou et al, 2004); *Like-dislike* and *natural-unnatural* can be categorized as evaluative factor, *soft-hard, smooth-rough* and *heavy-light* as potency, while *warm-cold* as activity factors.

The inter-observer variability was computed with a modified version of RMS:

$$RMS = \sqrt{\frac{\sum_i \left(x_i - \bar{x}_i\right)^2}{N}} \qquad (2)$$

where x_i represents an observer's color emotion response to the stimulus i; x_i represents the mean value for all observers within the group for stimulus i; N is the total number of stimuli. Finally, we average over the 26 observers. The lower the RMS value, the more the observers' responses agree with each other within the group and thus, the more accurate the responses.

Table 1 summarizes the test results, which are similar, though slightly lower than in previous works of color emotions (Ou et al., 2012). Considering all the samples, the warm/cold responses were the most accurate within the group, while the like/dislike and natural/unnatural, the evaluative factors, the least. This is also in agreement with the previous works (Ou et al., 2012). The stronger textures (less homogeneous) produce higher variability for all the scales except soft/hard. It seems that texture in some way helps observers to decide about soft/hard but scatter the responses for the rest of scales.

Torgerson's law of categorical judgment was used to convert the raw data (with scales ranging from -3 to 3) into z-score related scale values. Table 2 shows the Pearson correlation coefficient between the emotion scales.

Table 1. *Inter-observer variability RMS values for the six color emotion scales.*

Homogeneity	Soft/ Hard	Warm/ Cold	Smooth/ Rough	Heavy/ Light	Natural/ Unnatura l	Like/ Dislik e	Mean
0.57	1.06	1.22	1.25	1.83	1.25	1.72	1.39
0.70	1.61	1.59	1.80	1.66	1.76	1.65	1.68
0.79	1.47	1.57	1.68	1.50	1.79	1.66	1.61
0.87	1.03	1.39	1.05	1.27	1.64	1.68	1.34
0.95	1.48	1.37	1.56	1.36	1.59	1.59	1.49
1 (solid)	1.84	1.40	1.53	1.52	1.62	1.49	1.57
All	1.51	1.45	1.60	1.58	1.65	1.66	1.58

Table 2. Pearson coefficient for the emotion scales.

	Soft/ Hard	Warm/ Cold	Smoot/ Rough	Heavy/ Light	Natural/ Unnatura l	Like/ Dislike
Soft/Hard	1	0.5783	0.6131	-0.7232	0.2898	0.3969
Warm/Cold	0.5783	1	0.2278	-0.4175	0.2901	0.4467
Smooth/Rough	0.6131	0.2278	1	-0.2996	0.1381	0.1235
Heavy/Light	-0.7232	-0.4175	-0.2996	1	-0.0055	-0.1739
Natural/Unnatura l	0.2898	0.2901	0.1381	-0.0055	1	0.6597
Like/Dislike	0.3969	0.4467	0.1235	-0.1739	0.6597	1

From Table 2 it can be deduced that the chosen emotion scales are quite independent. The higher correlation (-0.7232) appears between two potency factors heavy/light and soft/hard, in a negative way. The more heavy a stimulus appears the harder it is perceived, which seems logical. The next higher correlation (0.6597) is between the two evaluative factors, like/dislike and natural/unnatural, in a positive way. Then, the more natural stimulus appears the more it was favored, as could be expected. The fewer correlated scales are natural/unnatural and heavy/light, with a coefficient of -0.0055.

4. CONCLUSIONS

A textured images set to perform an experiment about texture emotions, had been generated according to perception dissimilarity: 198 samples, mixing 6 different textures (one of them is the case of solid color) with 33 color centers. Furthermore, specific emotion scales for the study of texture emotions had been developed. Preliminary results, with 26 observers, indicate a good inter-observer variability, in agreement with previous works, and a good selection of the chosen emotion scales, which are independent.

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Individual's Color Preference and Personality of Feeling Active and Passive Good Emotion, Pleasantness and Comfortableness

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ABSTRACT

We investigated relationship between individual's color preference and his/her personality of feeling pleasantness and comfortableness, that is, active and passive kinds of good emotion. A hundred university students answered the degree of liking of twelve basic colors; red, orange, yellow, yellow-green, green, blue, purple, pink, brown, white, black, and gray. In addition, they were asked to read six short sentences, three of which depicted pleasant affairs (P sentences) and the remaining three depicted comfortable affairs (C sentences), and to answer how strong he/she will feel good emotion presented as ten emotional words. Based on an exploratory analysis of the data, we selected two emotional words ('glad' and 'excited') as indicators of pleasantness, and two words ('relieved' and 'relaxed') as indicators of comfortableness. Correlation analysis and multiple regression analysis between the degree of liking each color and the degree of feeling these indicator words showed that the individual who is sensitive to pleasantness on P sentences tends to like black and purple, and the individual who is sensitive to comfortableness on C sentences tends to like orange, green, and yellow-green. These colors were suggested to have some association with our active and passive aspects of good feeling.

1. INTRODUCTION

Color preference is one of the most intriguing topics in the field of color psychology. The underlying idea of the color preference research as a subject of psychology would be that a certain color makes a certain person feel good for a certain reason. Thus, researchers try to clarify 'what color' is preferred by the individual having 'what personality and/or attribute' for 'what reason.' Indeed, anyone has some color(s) associated with good feeling.

Kuno, Ohno, and Nakahata (1987) proposed, in the field of thermal sensation, that our good feeling could be distinguished into two types, active one and passive one. The active good feeling is called pleasantness, which is characterized by activeness, change, and surprise. For example, when we move from the extremely hot open air to an air-conditioned room, we would feel excitingly good, that is pleasantness. On the other hand, the passive good feeling is called comfortableness, which is characterized by passiveness, stability, and ordinariness. For example, when we stay in a room neither hot nor cold (in other words, not being conscious of the room temperature), we would feel calmly good, that is comfortableness. Though the original idea by Kuno et al. (1987) stems from the thermal comfort research, Takahashi (2003) discussed that the distinction between pleasantness and comfortableness could be applied to visual comfort, and even to more general concept of human's good emotion and sense of well-being.

In the present study, we take the first step to investigate possible relationship between individual's color preference and his/her personality of feeling pleasantness and comfortableness. It was aimed at contributing to our better understanding of the color preference in the light of an untouched factor of its psychological process.

2. METHOD

2.1 Participants

A hundred university students, forty-five males and fifty-five females, participated in our research. Their mean age was 18.5 years old (SD = .56).

2.2 Procedure

All data were collected through questionnaire. The questionnaire was composed of two parts. The first part included twelve visual analog scales on which participant answered his/her degree of liking of twelve basic colors; red (5R 4.5/14), orange (10R 6/11), yellow (5Y 8.5/12), yellow-green (5YG 6.5/9), green (5G 4.5/10), blue (2.5PB 4/11), purple (10P 4/11), pink (5RP 6.5/9), brown (7.5R 4/6), white (N9.5), black (N1.5), and gray (N5.5). These colors were presented as printed color chips (6 mm × 16 mm). Participants drew a slash, according to the degree of liking each color, on the line with the left-end indicating 'don't like at all (0% liking)' and the right-end indicating 'like the most (100% liking)' (Figure 1).

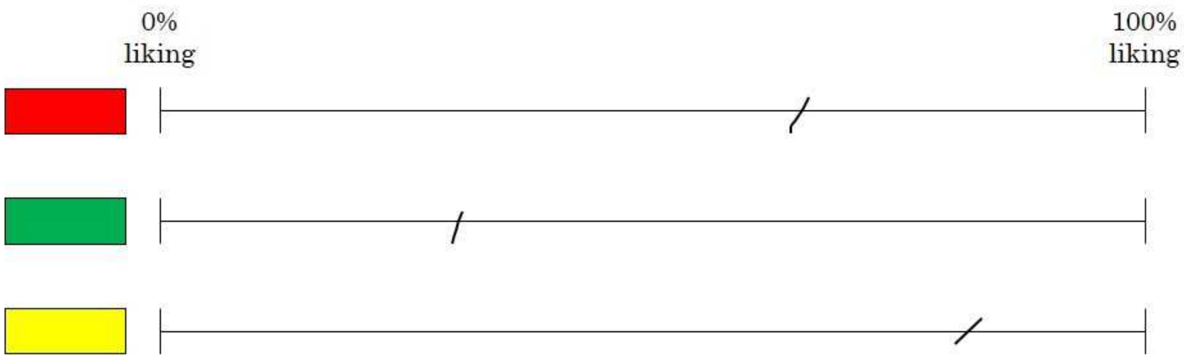

Figure 1: Samples of the visual analog scales.

The second part showed participants six short sentences, each of which depicted good affair. Three of them depicted pleasant situation (P sentences), and the remaining three depicted comfortable situation (C sentences) (Table 1). For each sentence, participants were asked to imagine how strong he/she will feel emotions presented as ten emotional words, and answer the degree on 11-point scales (0: 'don't feel at all' – 10: 'feel the most'). Five of ten words intended to measure the pleasant feeling; 'glad,' 'wakening,' 'pleasing,' 'delightful,' and 'excited.' Another five intended to measure the comfortable feeling; 'relieved,' 'heart-warming,' 'calm,' 'comfortable,' and 'relaxed.

2.3 Data processing

As for results of the visual analog scales, position of the slash was measured and converted

Table 1. Brief sentences depicting imaginary good affairs. Please note actually richer Japanese expression was given so as to emphasize pleasant or comfortable situation.

P sentences	P1: Cool the flushing body by the blast of cold air.
	P2: Win a prize of 5,000 yen in the lottery.
	P3: Notice cherry blossoms in full bloom.
C sentences	C1: No problem was pointed in a health examination.
	C2: Stay relaxed in a moderately air-conditioned room.
	C3: Take a walk through the trees on the plateau.

into the preference score ranging from 0 (the left-end) to 100 (the right-end). Ratings for each emotional word were averaged for three P sentences (P1, P2, P3) and for three C sentences (C1, C2, C3) in each participant.

3. RESULTS AND DISCUSSION

3.1 Preference scores

Mean preference scores for each color, separately for male and female participants, are shown in Table 2, which are ordered by the grand mean (for all participants). Compared to our previous data (Takahashi and Hanari, 2008), a drop of black's score, which was formerly 73.4 and ranked first, is remarkable. Otherwise almost the same sketch was replicated. As for the sex difference, pink and yellow were liked more by females than by males, which was the case in the previous data.

Table 2. Mean preference scores in all, male, and female participants. ** $p < .01$

	White	Blue	Red	Black	Yellow	Orange	Y-G	Green	Pink	Purple	Gray	Brown
All	79.9	72.3	69.2	66.2	65.1	64.6	60.3	58.8	58.2	54.5	52.7	44.7
Males	76.6	71.8	67.4	62.7	56.8	66.1	60.7	61.0	49.6	57.1	57.1	44.6
Females	82.6	72.6	70.7	69.1	** 71.8	63.4	60.0	57.1	** 65.2	52.3	49.2	44.8

3.2 Color preference and feeling pleasantness and comfortableness

Using data of all participants, mean ratings for each emotional word were compared between P sentences and C sentences. As the results, ratings for 'glad' and 'excited' were found to be higher for P sentences than for C sentences ('glad': P 8.04, C 6.02, 'excited': P 6.50, C 4.45). Thus these words were chosen to be pleasantness indicators, and the mean of these ratings for three P sentences was calculated in each participant to show his/her pleasantness sensitivity (P score). Contrarily, ratings for 'relieved' and 'relaxed' were found to be higher for C sentences than for P sentences ('relieved': P 4.91, C 7.07, 'relaxed': P 5.17, C 6.98). Thus these words were chosen to be confortableness indicators, and the mean of these ratings for three C sentences was calculated in each participant to show his/her comfortableness sensitivity (C score).

Next, correlations between each participant's P score and C score and his/her preference

Table 3. Correlations between P and C scores and color preference scores. ** $p < .01$, * $p < .05$

	White	Blue	Red	Black	Yellow	Orange	Y-G	Green	Pink	Purple	Gray	Brown
P score	.034	.113	.071	.416**	.062	.119	.068	.132	.063	.282**	.191	.052
C score	.211*	.197*	.214*	.151	.252*	.376**	.311**	.364**	.113	.146	.107	.116

scores for each color were obtained. As shown in Table 3, P score was positively correlated with black and purple, whereas C score was positively correlated with orange, green, and yellow-green. These results were also supported by the multiple regression analysis with P score and C score as explanatory valiables and the preference score for each color as a target valiable. It was shown that black and purple preferences were significantly regressed by P score; standardized partial regression coefficient (β) was .442 ($p < .001$) and .275 ($p < .05$), respectively. And, orange, green, and yellow-green preferences were significantly regressed by C score; $\beta = .419$ ($p < .001$), .395 ($p < .001$), and .365 ($p < .001$), respectively.

4. CONCLUSIONS

The present study investigated relationship between the color preference and personality of feeling good emotions, and found that pleasantness-sensitive individual tends to like black and purple, while comfortableness-sensitive individual tends to like orange, green, and yellow-green. Considering that preference for any colors did not correlated with both P score and C score, pleasantness and comfortableness would be clearly distinguished from each other in terms of the color preference, each having unique psychological mechanism related with the preference for certain colors. Roughly speaking, orange, green, and yellow-green would be categorized as 'nature colors,' having peaceful impression that might be loved by comfortableness-sensitive people. Contrastingly, purple would have somewhat artificial and surprising impression that might have affinity with pleasantness-seeking. Relationship between black and pleasantness seems not to be easily explained. In the next step, individual's reason for liking those key colors should be examined to understand psychological process of the color preference more deeply.

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Colour Emotions for Antioxidant-Enriched Virgin Olive Oils

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ABSTRACT

This work looks for relationships between 9 specific colour emotions applied to a set of extra virgin olive oils which have been coloured by using a lutein and ß-carotene enriched extract from microalgae. 6 extra virgin olive oils have been coloured with 2 different concentrations of this colorant obtaining a total of 18 different samples. 20 non-expert Spanish observers were asked to describe the colour appearance of the samples using 9 different pairs of adjectives (Aromatic-Odourless, Bitter-Sweet, Fresh-Rancid, Healthy-Unhealthy, Like-Dislike, Natural-Artificial, Spicy-Non spicy, Tasty-Insipid and Textured-Smooth). Results of spectroradiometric measurements performed under the same conditions than visual observations showed that increasing concentrations of the colorant changed the colour of the sample towards a reddish hue. The microalgae antioxidant-enriched colorant changed the colour of the olive oils mainly in hue, in such a way that, on the average, more than 70% of the total CIELAB colour-difference between pure and lutein and ß-carotene enriched virgin olive oils was a hue difference. Torgerson's law of categorical judgment was applied to the results in our colour-emotion experiment showing that there is a high correlation between some pairs of emotions whose meanings are more related to colour preference (Fresh-Rancid, Healthy-Unhealthy, Like-Dislike, Natural-Artificial and Tasty-Insipid). Bitter-Sweet, Spicy-Non spicy, and Textured-Smootj are not correlated with any other emotion. Finally, combining results from colour measurements and colour-preferences we found that if the samples are too reddish their appearance tends to generate a dislike emotion. Therefore, virgin olive oils with high CIELAB hue-angles (greenish hues) seem to be the most appropriate ones to be enriched by these extracts from microalgae.

1. INTRODUCTION

The amounts of carotenoids that are found in human tissues are almost exclusively from dietary origin, mainly from fruits and vegetables, or from supplements. It has been reported that the uptake of ß -carotene reduces the risk of age-related macular degeneration (Teikari, J.M.: 1998). In addition, it has been shown that olive oil with extract from microalgae known as *Scenedesmus almeriensis* brought changes in olive oils, quality, composition, colour and stability giving. Therefore, olive oil with an addition of microalgae extract could be a good convoy to improve and enhance the intake of carotenoids in a daily basis (Limon, P: 2015). Although this change in colour may not change its taste or smell, the subjective perception of these factors can change (Zellner, DA: 2003) and colour emotion techniques help to quantify the expectation of a product when it is perceived by human eye (Wei, S: 2014).

This work has two main objectives. Firstly, we want to analyse how does the colour of virgin olive oil changes when we add lutein and ß-carotene enriched extract from the Scenedesmus almeriensis microalga. Secondly, we want to check how does the human perceived this change in colour by using colour semantic methods (Ou, L: 2004).

2. METHOD

Six samples of different extra-virgin olive oils have been selected, five of them obtained in the same harvest season: Fuenroble, Santuario Mágina, Oro de Bailén, Castillo de Canena and Melgarejo 1; and another one from the previous harvest season Melgarejo 2. For each one of these samples we have prepaired three different samples by adding different concentration of extract of microalgae: 0.00 mg/ml (A), 0.10 mg/ml (B) and 0.21 mg/ml. A total of 18 samples have been used, 6 oils × 3 concentrations. Each one of the samples was poured into bottles with dimensions of 1.5 cm X 1.5cm X 6.0 cm and a capacity of about 20 ml. These bottles have rectangular prism shape and their flat faces allow having an homogenous colour of the oils, this fact makes easier their colour measurement and their colour perception. All the samples were kept in a controlled environment during all the experiment.

Colour measurement of the samples has been made placing the samples in a Verivide Portable cabinet (Verivide, Leicester, United Kingdom) using a D65 light source simulator, the walls of the cabinets were covered by white non fluorescent paper in order to avoid shades in the samples and have a lighter background behind the samples. The colour was measured using a Konica Minolta CS2000A spectroradiometer (Konika Minolta, Nieuwegein, Netherlands) in the same position that the observers performing the visual experiment (figure 1). Tristimulus values were computed assuming CIE64 standard observer. Three replicas of the measurements were made.

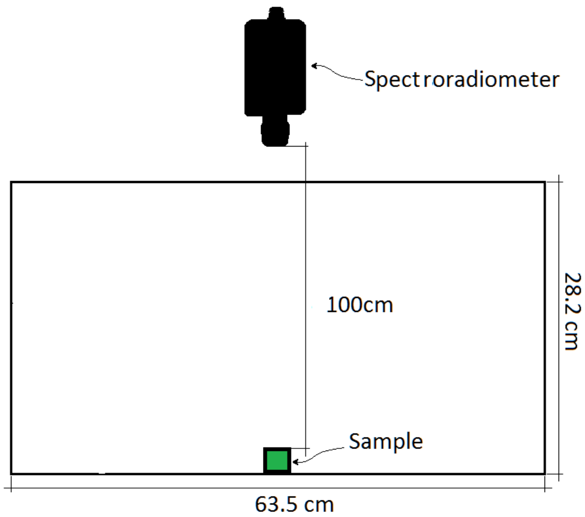

Figure 1: Geometry of the colour measurement of the samples

20 Spanish observers were asked to describe each one of the samples following 9 pairs of opposite descriptors: Aromatic-Odourless, Bitter-Sweet, Fresh-Rancid, Healthy-Unhealthy, Like-Dislike, Natural-Artificial, Spicy-Non spicy, Tasty-Insipid and Textured-Smooth. These 9 descriptors were obtained from 15 interviews to olive oil tasters, trying to describe olive oil appearance in an appropriate way.

For each pair they had to choose one of the descriptors and after that they had to decide if that descriptor describe the oil as “a little”, “moderately” or “very”. For example, an oil can be described as: *moderately aromatic, a little bitter, very rancid, moderately unhealthy, very dislike, very artificial, a little tasty and very textured*. Each one of the samples was shown to each observer 3 times, in the same conditions as it was measured by the spectroradiometer, following a random order. A total of 1080 judgements were made (20observers ×18 samples×3 replicas).

Torgerson’s law of Cathegorical Judgement was applied to the mean of the answers of the observers. This law allow us to create psycophysical scales where each z score means the intensity in which a stimulus is percieved inside that emotional scale.

3. RESULTS AND DISCUSSION

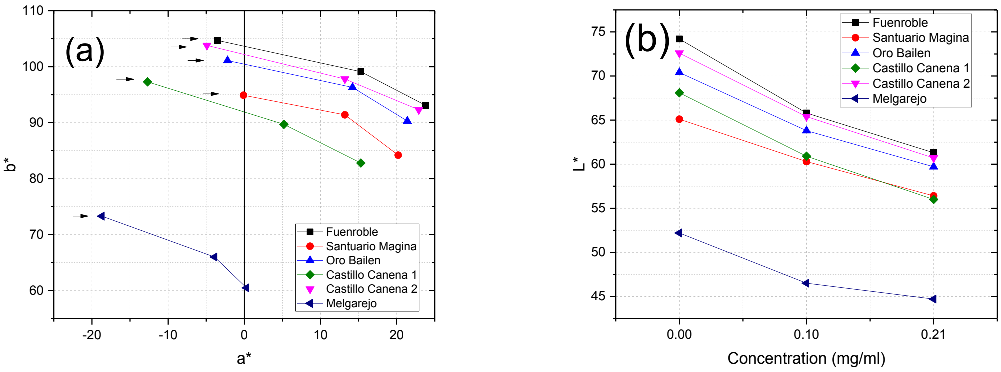

*Figure 2: Colour coordinates of the samples changing the concentration of microalgae extract. (a) Plane a*b* (black arrow indicates direction of color change when extract concentration is increased). (b) Lightness dependence with concentration.*

Figure 2 shows results corresponding to colour measurements. In figure 2 we can see that adding lutein and ß-carotene produced a decrease of lightness L^* and b^* coordinates and an increase of a^* coordinate. In Table 1 we have summarized colour change of the oils from pure extra-virgin olive oil to oils with the 2 concentrations of microalgae extract. Second and third columns in Table 1 indicate a high colour change, clearly perceptible by human observers with normal coclor vision. Last column indicates that the colour change is mainly due to a hue change. Combining data from Figure 2 and Table 1 we can conclude that enriching the oils with lutein and ß-carotene extract makes the oils become more reddish and darker. All the oils except Melgarejo (the greenest oil) undergo a color change from yellow to yellowish-orange hues.

Table 1: Mean colour change from pure extra-virgin olive oils in CIELAB and CIEDE2000 units. Three last columns show percentage of change in Lightness, Chroma and Hue in CIELAB units.

Change	ΔE_{00}	ΔE_{ab}	$\%\Delta L^*$	$\%\Delta C^*_{ab}$	$\%\Delta H^*_{ab}$
From 0.00 mg/ml to 0.10 mg/ml	10.5	18.8	12.4	10.7	76.9
From 0.00 mg/ml to 0.21 mg/ml	16.4	29.2	13.2	15.3	71.6

Results from visual experiment are summarized in Table 2. In this table we have correlation coefficents between *z* scores of different emotions. We can see that there are a high correlation between Fresh-Rancid, Healthy-Unhealthy, Like-Dislike, Natural-Artificial and Tasty-Insipid. That means that when an oil is perceived as Fresh it is perceived also as Healthy, Natural and it likes. This result agrees with the meaning of these descriptors, all of them are related with preferences and can be interpreted as like-dislike. The remaining emotions are descriptors that are related with taste and smell but for observers who are not olive oils experts they do not give a value of preference to the oil.

Table 2: Correlation coefficient (r^2) of z scores obtained from colour emotion experiment. Yellow cells show correlation coefficients greater than 0.8.

	Aromatic Odourless							
Bitter Sweet	0.02	**Bitter Sweet**						
Fresh Rancid	0.68	0.06	**Fresh Rancid**					
Healthy Unhealthy	0.73	0.05	0.98	**Healthy Unhealthy**				
Like Dislike	0.71	0.04	0.96	0.98	**Like Dislike**			
Natural Artificial	0.73	0.03	0.98	0.99	0.98	**Natural Artificial**		
Spicy Non Spicy	0.00	0.66	0.19	0.19	0.16	0.16	**Spicy Non spicy**	
Tasty Insipid	0.87	0.00	0.83	0.87	0.86	0.86	0.05	**Tasty Insipid**
Textured Smooth	0.05	0.43	0.43	0.40	0.39	0.39	0.78	0.19

Emotional responses corresponding to the pair of emotions Like-Dislike are plotted in Figure 3, in left axis we can check the z-score and in right axis we can see the linguistical meaning of the z-scores . The oils are percieved as less liked when the concentration of microalgae additive increases for most of the samples, and this trend is very similar for the emotions well correlated with Like-Dislike. If we add an additive that makes the oil more reddish, the olive oil is percieved as less natural and it does not like. There is only one exception, the oil Melgarejo follows an opposite trend to the other samples: when the concentration of lutein and ß-carotene increases, the emotion “like” increases. The explanation to this behaviour can be explained with colour measurements (figure 2). This sample is the only one in which its colour goes from a greenish colour to a yellower and the rest of the samples go towards a reddish colour.

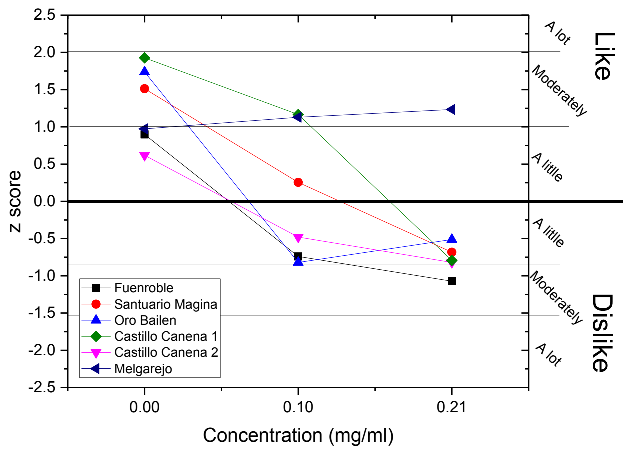

Figure 3: Emotional responses for each sample in scale Like-Dislike. Right axis and horizontal lines shows the linguistic term associated to each z score.

4. CONCLUSIONS

Colour measurements show that adding lutein and ß-carotene enriched extract from microalga Scenedesmus almeriensis to extra virgin olive oils produces a change in colour of the oils. That makes them decrease slightly in their chroma and lightness, and produces a high decrease from greenish or yellow to reddish. The obtained colour differences are far from a just-noticeable colour difference, the change in colour being clearly perceptible by human eye.

From the studied descriptors by a colour-emotion experiment some of them are highly correlated. The meaning of these emotions can be related to the terms Like-Dislike. From the 6 studied oils there is only one that is liked more when we add extract from microalgae, because it changes from green to yellow.

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A Study on Difference in Color Sensibility Judgment between Professionals & Non-Professionals

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ABSTRACT

This study conducted a subjective evaluation experiment on 35 kinds of single colors on 43 sensibility adjective scales to compare the contribution of hue and tone to color sensibility judgment in both professionals and non-professionals. As a result, it showed that professionals had higher acuity for color sensibility than non-professionals and it was not hue but tone that made greater contribution to color sensibility judgment. Besides, it was identified that professionals held dominance over non-professionals in such a tendency, corresponding to findings of precedent studies suggestive of stronger contribution of tone than hue.

1. INTRODUCTION

There are 3 basic attributes of color as criteria for feeling and judging color sensibility, in other words, hue, value and chroma. It may be expressed as a three-dimensional color system of hue × value × chroma, particularly as the Hue & Tone system that is defined as a 2-dimensional hue × tone through combining value and chroma as the tone. As such, separating value and chroma from hue results from the fact that value or chroma is more effective and easier to feel and express a variety of color sensibilities than hue.

There are many comparative analytic studies on the color image and sensibility that separated hue from tone. Reports mention cases of inducing color image or sensibility both by hue and by tone but many raise an opinion that tone makes a dominant contribution over hue (Suk & Irtel 2010, Lee, Sa & Chung 2012). On the other hand, according to the research by Suzuki & Nakatani (1990) suggesting that there is a difference in response to hue and tone among certain groups, practitioners in art and design fields showed a difference in the structural factor for color sensibility since they were good at rousing various kinds of sensibilities by colors compared with general people, reacting to tone more strongly rather than hue.

Considering such points above, setting people as two groups, professionals and non-professionals based on the number of experiences in art, color and design fields, this study aimed at examining about what contribution hue and tone make to color sensibility through the inter-group comparison in terms of their difference and commonness.

2. METHOD

2.1 Evaluation scales

As for the evaluation scales, this study organized 43 monopolar scales as 7-step each using sensibility adjectives systemically selected from the previous study (Lee, Lee & Kim 2012). Table. 1 shows 43 sensibility words extracted from the cluster analysis in the precedent study.

2.2 Subjects

48 subjects participated in the evaluative experiment, composed of 30 female non-professionals (10 persons in their 20s, 30s, 40s respectively) and 18 professionals (9 in their 20s, 6 in their 30s, 3 in their 40s). As for the criterion dividing subjects into both groups, persons who are engaged in color & design business or studies as a major were classified into a professional group and non-majors into a non-professional group. The entire 48 subjects had a normal color perception ability.

Table 1: 43 sensibility words extracted from cluster analysis.

Words extracted from cluster analysis			
mild	exotic	natural	masculine
cool	strong	stylish	luxurious
soft	unique	elegant	charming
pure	sturdy	delicate	eco-friendly
cute	cheery	dynamic	traditional
neat	lovely	hopeful	interesting
deep	casual	classic	high-tech
retro	mature	cheerful	mysterious
light	simple	romantic	sophisticated
clean	sensual	modern	unconventional
bright	modest	emotional	

2.3 Sensibility Evaluation on Single Color

Evaluation scales were created from adjectives (Korean) in Table 1, and subjective assessment experiments were performed using single colors systematically selected from color space. Color stimuli were selected so that a minimum number of stimuli could effectively represent a color space. 35 colors were systematically selected from the PCCS Color System: 6 primary hues and 5 tones for each hue group, and 5 additional achromatic colors. The stimuli were distributed within appropriate range in CIELAB Color Space. Each color stimulus was presented on a medium gray background (L^* = 50) on a LCD monitor. Table 2 shows hue & tone classification for the 35 colors, and CIELAB values obtained from measurement by Minolta CS-1000 Spectroradiometer.

35 colors were randomly presented, and each color was assessed against 43 adjective scales utilizing 7-step evaluation scale. 7-step evaluation scale works as follows: when evaluating against "cold" scale, "7" is checked if coldness was strongly sensed, "1" if no coldness was felt, or "4" for moderate coldness. The viewing distance was 50cm from the monitor, and 10º in visual angle. Each color stimulus was placed at the center of the monitor, and evaluation scales were located beneath. One experiment session took 1 hour 20 minutes including a 5 minute break.

Table 2: Specifications of the 35 color samples.

Sample	Tone	Hue	L^*	a^*	b^*	C^*	h
1	Pale	Red	85.3	5.7	2.7	6.3	26
2		Orange	90.1	3.3	12.6	13.0	75
3		Yellow	90.2	-2.1	16.5	16.6	97
4		Green	85.4	-12.7	6.8	14.4	152
5		Blue	80.5	-1.6	-5.7	5.9	254
6		Purple	80.5	4.2	-3.1	5.2	323
7	Lignt$^+$	Red	77.0	34.7	10.2	36.2	16
8		Orange	85.7	13.9	38.1	40.6	70
9		Yellow	91.6	-1.4	48.7	48.7	92
10		Green	80.0	-22.9	8.6	24.4	159
11		Blue	69.4	1.8	-29.7	29.7	274
12		Purple	71.6	23.4	-16.7	28.8	324
13	Vivid	Red	45.6	60.4	24.4	65.2	22
14		Orange	70.6	42.0	63.7	76.3	57
15		Yellow	83.4	11.0	78.3	79.1	82
16		Green	56.4	-56.7	24.9	61.9	156
17		Blue	45.4	0.5	-44.7	44.7	271
18		Purple	35.4	41.6	-30.7	51.7	324
19	Dark	Red	25.1	28.1	8.1	29.2	16
20		Orange	35.4	14.0	33.3	36.1	67
21		Yellow	40.7	0.7	37.8	37.8	89
22		Green	30.5	-22.1	9.3	24.0	157
23		Blue	20.3	-0.7	-22.2	22.2	268
24		Purple	20.2	19.0	-14.7	24.1	322
25	Grayish	Red	40.7	9.8	3.8	10.5	21
26		Orange	45.8	5.0	11.3	12.4	66
27		Yellow	45.9	-0.7	14.1	14.1	93
28		Green	40.8	-9.9	4.6	11.0	155
29		Blue	35.6	-1.1	-8.7	8.8	263
30		Purple	35.5	8.3	-6.6	10.6	322
31	Achromatic	White	95.1	-0.2	0.3	0.4	124
32		Light Gray	75.7	1.0	-0.6	1.2	329
33		Mid Gray	56.1	-0.1	0.2	0.2	117
34		Dark Gray	35.6	-0.1	0.1	0.1	135
35		Black	15.3	-0.1	0.3	0.3	252

3. RESULTS AND DISCUSSION

3.1 Difference in Emotional Words Used by Among Professionals & Non-Professionals

For professional and non-professional groups, the mean, SD, maximum and minimum values of estimations on 35 colors were calculated for the entire subjects (see Table 3). Differentials of SD, maximum and minimum values show that both groups discerned a color stimulus to some extent. Also, it may be said that professional group has a higher acuity compared with non-professionals since there was remarkably greater standard deviation in professional group.

Table 3: Mean, SD, MAX & MIN for Professionals & Non-Professionals.

	Non-Pro	Pro
Mean	3.70	3.75
SD	0.82	1.20
MAX	5.31	5.98
MIN	2.30	1.91

3.2 Difference Among Professionals & Non-Professionals According to Hue & Tone

This study compared non-professionals with professionals by setting hue and tone as factors for judging color sensibility. In other words, for both groups, it examined whether they are influenced by hue or tone, otherwise by both, what interaction hue and tone have in judging changes of 43 kinds of sensibilities to 35 color stimuli. ANOVA was conducted on 6 (hue) × 5 (tone) × 2 (group) using the mean of color stimulus estimation corresponding to each red, orange, yellow, green, blue, purple hue (6 levels, referred to as a "color factor" hereafter) and that of color stimulus estimation corresponding to each pale, light$^+$, vivid, dark, grayish tone (5 levels, referred to as a "tone factor" hereafter).

Firstly, it showed that hue had no contribution to judging sensibility ($F(5)= 2.160$, *n.s.*). There was no difference in such a tendency between groups (hue×group $F(5)= 0.673$, *n.s.*). On the other hand, this study identified contribution by tone ($F(4)= 32.794$, $p < .001$). Furthermore, groups differed from each other in such a tendency (tone×group $F(4)= 3.742$, $p < .01$). Also, it revealed that there existed interaction between hue and tone (hue×tone $F(20)= 5.485$, $p < .001$), showing no difference between groups (hue×tone×group $F(20)= 1.053$, *n.s.*).

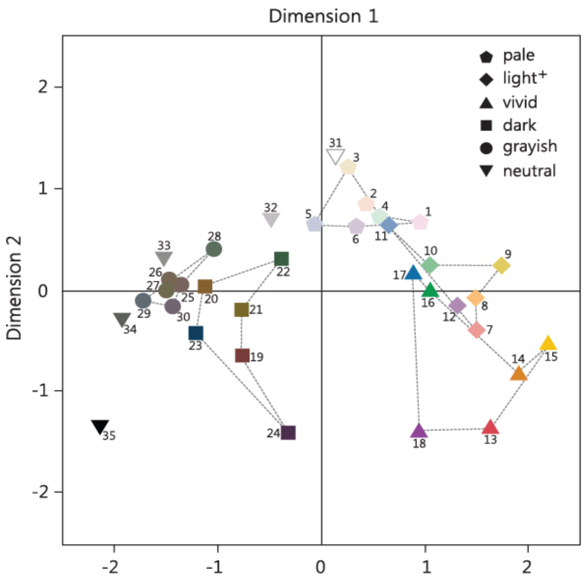

Fig. 1a: MDS plots for non-professionals.

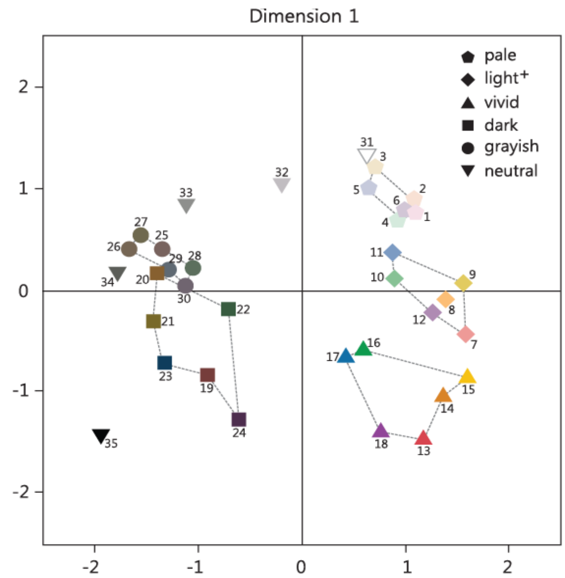

Fig. 1b: MDS plots for professionals.

3.3 Relationship between Color Sensibility Judgment & Tone

Analysis using MDS was conducted to identify what dimension color sensibility judgment has and examine whether professional and non-professional groups have a differed structural dimension based on hue and tone. As shown from a 2-dimensioanl MDS plot in <Fig. 1a>, <Fig. 1b>, research findings showed that there was difference in the distribution of 35 color stimuli between professional and non-professional groups. In <Fig. 1a>, <Fig. 1b>, since similar tones hold together closely in both groups, it showed that objects formed a group by tone rather than by hue and may be interpreted that professional group is more distinct in its degree than non-professionals.

MDS results showed that both professional and non-professional groups formed a dimension of color sensibility judgment based on the tone. Besides, professional group revealed a dimensional structure based on the tone more clearly. Such a result supports ANOVA of the paragraph above that there was difference between both groups by tone factors and suggests that professional group has an advantage in classifying color stimuli by tone through schematization.

4. CONCLUSIONS

In this study, we compared the contribution of hue and tone dimension to color sensibility judgment through subjective evaluation experiment using 43 sensibility adjective scales and 35 single colors, assessing both color professionals and non-professionals. The results were as follows.

Firstly, the color professional group displayed higher acuity for color sensibility judgment than the nonprofessional group, which is attributable to its higher discrimination capability for color stimulus differences and shift in sensibility. Secondly, hue and tone was defined as factors serving as judgment criteria for color sensibility, and their contribution was examined using repeated measures ANOVA. The results revealed that tone was more influential than hue in determining color sensibility, and the amount of its contribution differed between the subject groups. Thirdly, we applied a multidimensional scaling method (MDS) to analyze the structural dimension of color sensibility on hue and tone in both subject groups. The two-dimensional MDS plots in the color professional group revealed the tone dimension much more clearly than the hue dimension, implying a stronger contribution of tone to color sensibility judgment.

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Age Effects on Garments Color Harmony

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ABSTRACT

In order to investigate the age effects on garments color harmony in two-color combinations, 300 color pairs were generated from 24 colors that uniformly selected from CIELAB color space. 59 observers with normal color vision aging from 20 to 79 were divided into two groups according to their ages: junior (20-45 years), and senior (46-79 years). They were encouraged to assess the garments color harmony of the above-mentioned color pairs presented as jackets and trousers on a vicenarian and a quinquagenarian model. The experiments were carried out on a well-characterized LCD monitor with a method of categorical judgment. The color harmony assessments for different age groups on the garments were analyzed.

1. INTRODUCTION

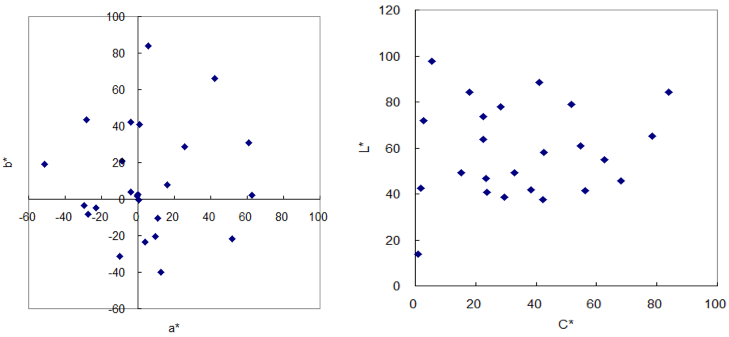
Color conveys different information in our daily life. Two or more color combinations can invoke different color emotion, preference and harmony (*Ou et al. 2012*). The results have revealed that the abstract colors (i.e. colors without any context or specific object assigned) and the specific colors invoke different results. The influence of the application scenarios on the color harmony is an area worth studying, there are some experiments were conducted for juice packages (*Wei et al. 2013*), fashion design (*Luo et al. 2011)* and interior images (*Ou et al. 2011)*. The culture, gender, age (*Ou et al. 2012)* and character of a person also have influences on her/his color preferences, which may be partly related to specific ageing color-vision changes.

In this study, 300 color pairs were generated from 24 colors uniformly selected in CIELAB color space. 59 observers with normal color vision aging from 20 to 79 were organized to assess the garments color harmony of the above color pairs presented on vicenarian and quinquagenarian models. The experimental results were used to analyze the relationships between the mean harmonious/ disharmonious response for different age groups.

2. METHOD

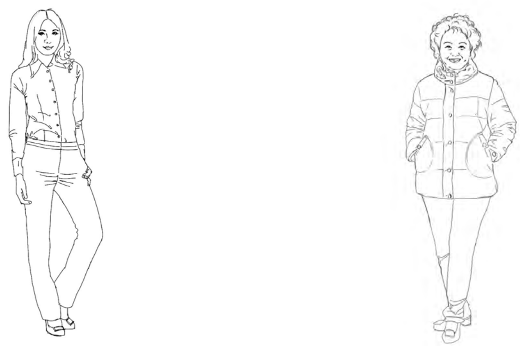
24 colors were chosen to be exhibited on a vicenarian and a quinquagenarian model. It is worth mentioning that some of these colors could not be reproduced on real garments due to the limitation of textile dyestuffs and color gamut actually available. However, they remained in the study considering for the theoretical research. Figure 1 shows the distribution of 24 color centers in the CIELAB $a^*_{10}b^*_{10}$ and $L^*_{10}C^*_{10,\mathrm{ab}}$ planes. It can be seen that these color centers had a good coverage in CIELAB space.

300 color pairs were generated from two-color combinations of the 24 colors as shown in Figure 1. For example, the 1st color was set as the jackets and the 1st, 2nd, 3rd…24th color were arranged as the trousers, respectively, and so on. Considering in daily life, the color combinations for female garments are much more concern than that for the male's and with regards of the experimental workload, only two female models, a vicenarian and a quinquagenarian, were selected as the tested models (see Figure 2). The color stimuli were shown on the screen as garments in irregular patterns and different sizes. The ratios of jackets' to trousers' areas measured in terms of pixels were 69% and 216% for the vicenarian and quinquagenarian model, respectively.



(a) (b)

Figure.1: Distribution of colors selected for the current experiment of garments color harmony in the CIELAB (a) $a^*_{10}b^*_{10}$ and (b) $L^*_{10}C^*_{10,ab}$.



(a) (b)

Figure. 2. Models for the (a) vicenarian and (b) quinquagenarian used in the experiment.

The psychological method used in the experiments by Ou (*Ou et al. 2012*) and Szabó (*Szabó et al. 2010*) has been adopted in the current study as shown in Fig. 3. The background of the monitor and images were set to a gray with L^*, a^*, b^* of 80.78, 1.22, -1.29. In the experiment, each assessment includes 630 judgments for the two models (30 reduplicative for each model) and was divided into six sessions, each including 105 images displayed on the screen of an EIZO CG19 monitor. The approximate duration of each session is about 30 minutes, no time limit for each session. The images presented to the observers were in a random order. 59 Chinese observers (26 female and 33 male) with normal color vision were organized to assess color harmony of the garments. They were divided into two age groups: junior group (31 persons with an average age of 31.0 from 20 to 45) and senior group (28 persons with an average age of 59.7 from 46 to 79), 15 observers replicated the assessments of the 630 images 2-4 times for evaluation of the intra-observer variability. Finally, there are 42 and 40 sets of assessments were gathered for the junior and senior group, respectively. The total number of visual assessments is 630× 82=51660. The intra-observer and inter-observer variability were determined by averaging the root mean square error (*RMSE*) (*Ou et al. 2012*) between each individual data and the overall mean. As a result, the average intra-observer variability was 0.89 and the average inter-observer variability was 2.06.

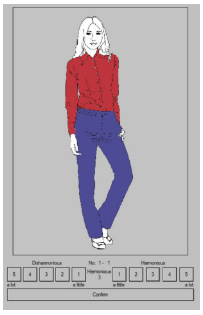


Figure. 3. The experimental layout of the color harmony evaluation

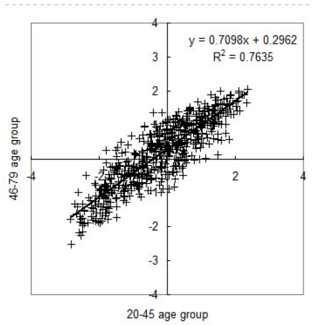


Figure. 4. Observers' responses to garments color harmony of 2 age groups

3. RESULTS AND DISCUSSION

Comparisons were made between observers' responses of different ages for 600 garments color harmony presented on the vicenarian and quinquagenarian models using scatter diagram; the mean scale values for the junior were plotted against that for the senior group (see Figure. 4). Positive and negative numbers mean "harmonious" or "disharmonious", respectively. This indicated that as one ages, although the observers' aesthetical standards for judging garments color harmony have been varied and show some different trends, the junior observers are more "extremes" than the senior observers in their harmonious.

The harmony scores for the 600 garments by the 2 age groups were ranked, the most harmonious and disharmonious garments were shown in Figure.5. For the 2 age groups, the most harmonious garments almost appeared at the vicenarian model and the most disharmonious garments appeared at the quinquagenarian model. Figure.5a and 5b indicated that the less colorful and the cool (green, blue and purple) colors for the jackets, the colors similar to neutral colors for the trousers were easy to arouse harmonious sense. Figure.5c and 5d indicated that the garments with the higher chroma were easy to arouse disharmonious sense, which is not accord with Luo *et al*'s fashion design experimental results (*Luo et al. 2011)* while have some trends with their uniform color patch results *(Ou et al. 2011).*

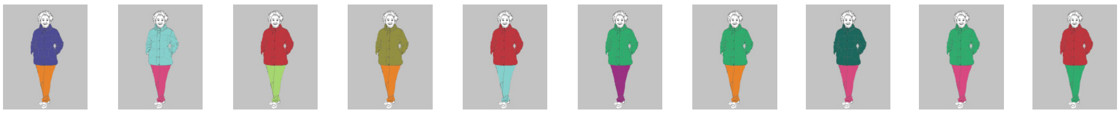
4. CONCLUSIONS

For the same two-color combinations on the garments, all the observers had higher scores to the 300 garments for the vicenarian model than those for the quinquagenarian model. The senior group was more tolerant than the junior group, especially for the harmony assessments of the quinquagenarian model. The model/style and age both have significant influence on the aesthetical standard of garments color harmony.

(a) the most harmonious judged by the junior group

(b) the most harmonious judged by the senior group

(c) the most disharmonious judged by the junior group



(d) the most disharmonious judged by the senior group

Figure. 5. The most harmonious and disharmonious garments for the 2 age groups

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Effects of Color and Aroma of Roasted Tea on the Predicted Taste and Palatability

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ABSTRACT

We can predict the taste of tea by the appearance and the flavor without drinking. Thus it is useful to reveal the multimodal effect of color and aroma on the predicted taste and palatability of tea quantitatively. In the present study, we focused on the roasted tea, because it is one of the most popular tea in Japan and has typical roasted flavor. Visual stimuli and olfactory stimuli: four roasted tea samples those were brewed two hours from 2, 6, 18 and 36 grams of tea leaves (a tea bag) and one liter of water, were evaluated by twenty participants in their twenties. The experiment consisted of three sessions. First, participants observed a visual stimulus without any olfactory stimulus (visual evaluation). Next, they smelled one olfactory stimulus without any visual stimulus (olfactory evaluation). Finally, they observed one of the visual stimuli while smelling one of the olfactory stimuli (visual-olfactory evaluation). Evaluated items were "intensity of color and aroma", "predicted sweetness, bitterness, umami taste, deep flavor, roasted flavor", and "predicted palatability". It was revealed that not only color but also aroma of roasted tea effected on the predicted taste and palatability. Moreover, we tested whether the visual-olfactory evaluation (Z) can be explained the sum of the visual evaluation (X) and the olfactory evaluation (Y) with weighting factors as the formula "$Z = aX + bY$". The results show that weighting factors of "predicted palatability" are $(a, b) = (0.36, 0.41)$. Finally, we compared weighting factors of roasted tea and those of green tea which were calculated in our previous study, and found that olfactory weighting factor of "predicted palatability" in the case of roasted tea is slightly larger than that in the case of green tea ($(a, b) = (0.51,0.49)$).

1. INTRODUCTION

Before drinking tea, the appearance and the flavor must be very important cues. Therefore, it is quite meaningful to reveal the relation between the appearance and the flavor in predicting the taste and palatability of tea before drinking tea. A previous study (Okuda et al., 2013) reported the effect of visual and olfactory "predicted palatability" on multi-sensory evaluation in the case of green tea. Under the condition without the trial to drink, there are few previous researches about the psychological evaluation of drinks. Okuda revealed the effect of visual and olfactory "predicted palatability" on multi-sensory evaluation are nearly equal in the case of evaluation of green tea (Okuda 2013). Roasted tea is also one of the most popular tea in Japan, with characteristic flavor in the roasted process. Thus it is expected the tendency of evaluation in roasted tea is different from the case of green tea. In this study, it was revealed the effect of mono-sensory (visual and olfactory) "predicted tastes and palatability" on multi-sensory evaluation.

2. METHOD

2.1 Visual and Olfactory Stimuli

Visual stimuli and olfactory stimuli were four roasted tea samples those were brewed two hours from two, six, eighteen and thirty six grams of tea leaves (packs of tea bag) and one liter of water. As visual stimulus, each two hundred milliliters tea was poured into a glass, which was six centimeters in diameter, eleven centimeters tall. As olfactory stimulus, each ten milliliters tea was packed in a fifteen milliliters brown bottle (Figure 1).

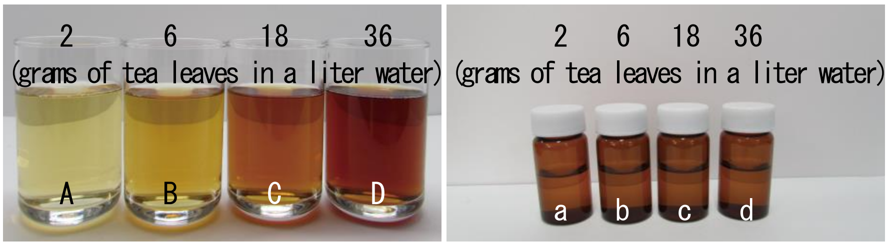

Figure 1: Visual stimuli and olfactory stimuli (roasted tea).

2.2 Procedure

The above stimuli were evaluated by twenty participants (eight women and twelve men) in their twenties. The experiment consisted of three sessions. First, participants observed a visual stimulus without showing any olfactory stimulus (visual evaluation). Next, they smelled one olfactory stimulus without showing any visual stimulus (olfactory evaluation). Finally, they observed one of the visual stimuli while smelling one of the olfactory stimuli (visual-olfactory evaluation). Presentations of stimuli were conducted in the experimental booths (Figure 2). Each booth had a desk and a fluorescent lamp of the standard illuminant D65 on the ceiling. The inside walls and the desk were white (N9). The illuminance of the center of the desk was three hundred lx.

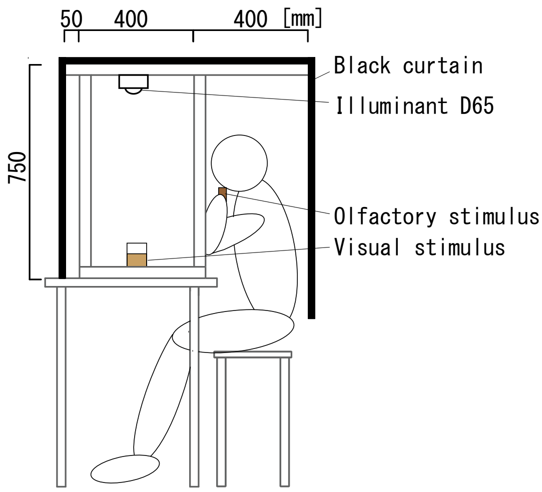

Figure 2:Experimental booth (cross-section view).

Participants evaluated about "intensity of color and aroma" and "predicted tastes (sweetness, bitterness, umami taste, deep flavor, roasted flavor)" on numerical scales of zero to ten, and "predicted palatability" on a categorical scale from ‘very palatable’ to ‘very unpalatable’. Participants were received proper rewards.

3. RESULTS AND DISCUSSION

Figure 3 shows the mean evaluations about "Predicted tastes (sweetness, bitterness, umami-flavor, roasted-flavor and deep-flavor)" and "Intensity of color" in the visual-olfactory experiment. As the color of tea was deep, all evaluations were high except for "sweetness". It may be difficult to evaluate "Sweetness" of tea by only the color. As the aroma of tea was strong, all evaluations were also high, however, the differences between ‘c’ and ’d’were small. In the stimuli combination those were well-matched visually and olfactory, the visual-olfactory evaluations were close to the visual evaluations, as compared among the visual-olfactory evaluations and the visual evaluation.

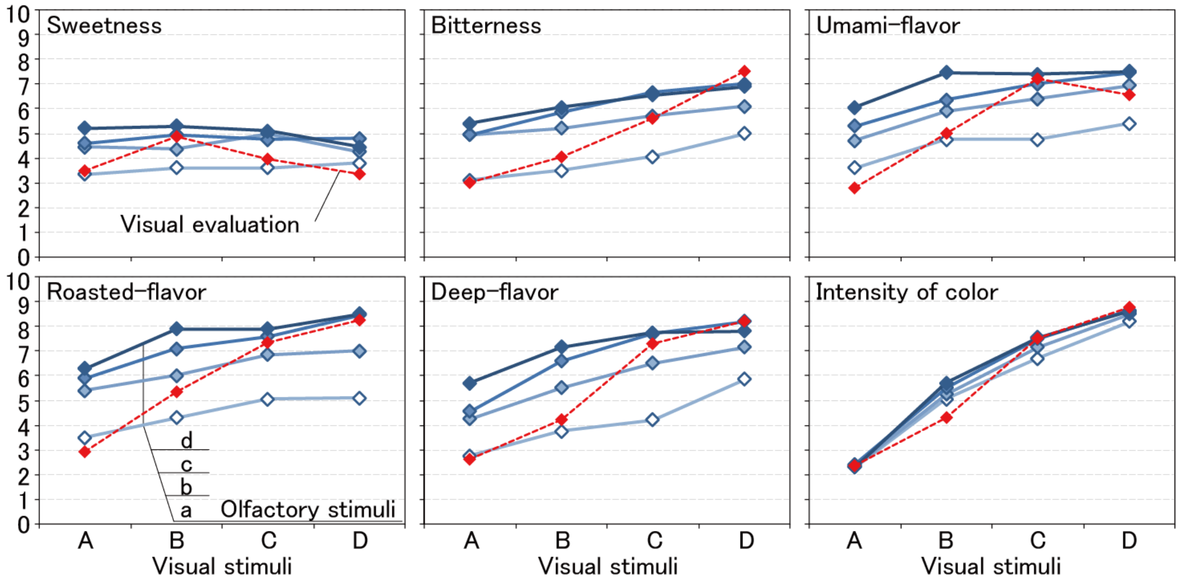

Figure 1. Comparison ’Predicted tastes’ and ‘Intensity of color’ between in the visual-olfactory evaluation and visual experiment.

Figure 4 shows the mean evaluations about "Predicted palatabiluty" in the visual-olfactory experiment. The highest palatability was obtained at ‘C’ stimuli, instead of ‘D’ in the visual stimuli. In the olfactory stimuli, stronger aroma was palatable. As compared among the visual-olfactory evaluations and the visual evaluation, those were close evaluations in the stimuli ‘A’ and ‘D’. However, in the stimulus ‘C’, the visual evaluation was higher than all visual-olfactory evaluations.

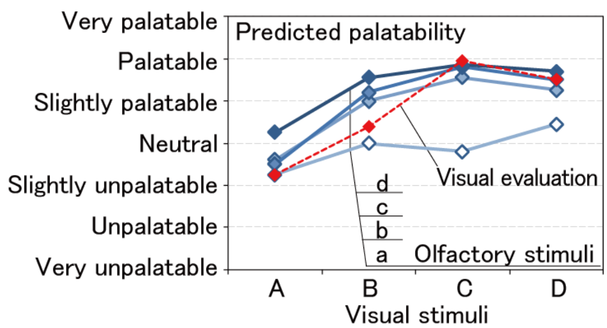

Figure 2. Comparison ’Predicted palatability’ between in the visual-olfactory evaluation and visual experiment.

It was proposed that mono-sensory evaluations, those were the visual evaluation and the olfactory evaluation, decided to the multi-sensory evaluation as below (equation (1)).

$$Z = \alpha X + \beta Y \qquad \textit{equation. (1)}$$

X : evaluation values in the visual experiment

Y : evaluation values in the olfactory experiment

Z : evaluation values in the visual-olfactory experiment

α : contribution ratios of vision

β : contribution ratios of olfaction

Evaluation values (X , Y and Z) were assigned in the equation (1), and contribution ratios α and β were calculated by the least square method (Table 1).

Table 1. Contribution ratios of vision and olfaction in the case of roasted tea.

Evaluation item	α	β	r	α : β
Sweetness	0.15	0.56	0.84	1 : 3.73
Bitterness	0.31	0.57	0.97	1 : 1.84
Umami-flavor	0.38	0.61	0.96	1 : 1.61
Roasted-flavor	0.34	0.71	0.98	1 : 2.09
Deep-flavor	0.44	0.55	0.97	1 : 1.25
Predicted palatability	0.36	0.41	0.90	1 : 1.14

In all evaluation items, high correlation coefficients (‘ r ’) between evaluated ‘ Z ’, and calculated ‘ Z ’ by deciding ‘ α ’ and ‘ β ’ were obtained. It was cleared ‘ β ’ was larger than ‘ α ’ in all evaluation items. This indicates that the olfactory evaluation of roasted tea might have larger effect on the multi-sensory evaluation than the visual evaluation.

Contribution ratios in green tea stimuli (Okuda et al.,2013) were shown in Table 2. Comparing between Table 1 and Table 2, the magnitude relation between ‘ α ’ and ‘ β ’ was almost close except for in "predicted palatability". The contribution ratio might be different between the species of tea leaves, or the matured stages.

*Table 2. Contribution ratios of vision and olfaction in the case of green tea (*Okuda 2013*).*

Evaluation item	α	β	r	α : β
Sweetness	0.26	0.74	0.53	1 : 2.91
Bitterness	0.24	0.78	0.98	1 : 3.31
Roasted-flavor	0.25	0.75	0.96	1 : 2.98
Deep-flavor	0.39	0.62	0.98	1 : 1.59
Predicted palatability	0.51	0.49	0.91	1 : 0.96

4. CONCLUSIONS

We revealed contribution ratios of vision and olfaction cues to multi-sensory "predicted tastes" and "palatability" evaluations. Moreover, we compared contribution ratios in roasted tea and green tea stimuli, and found that they are almost similar except for "predicted palatability".

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A study of relationship between physical value and psychological value in PCCS

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ABSTRACT

The purpose of this study is to examine the effect of psychological Lightness and Saturation on color image by analyzing its tone. This study adopted two methods. First, we investigated the dimensions of the color image; second, we measured the psychological Lightness and Saturation of color. Further, we examined the relation between the dimensions of color image and psychological Lightness and Saturation using a Structural Equation Modelling(SEM). As a result, the correlation relationship was observed between factor scores and physical values. Furthermore, psychological Lightness and Saturation were integrated, their relationship with the dimensions of color image. SEM was performed to investigate these results, and consequently, the relational model of physical value and psychological value was constructed.

1. INTRODUCTION

In colorimetry, color is classified on the basis of three attributes: hue, value, and chroma. These are physically independent, and many color order systems have adopted them; for example, the Munsell system. However, these attributes are not psychologically independent. For instance, in the Helmholtz-Kohlrausch effect, it was observed that lightness perception is affected by chroma. Therefore, it indicates a psychological interaction between value and chroma. Practical Color Co-ordinate System (PCCS) is a color order system developed in Japan, and it comprises three attributes: Hue, Lightness (value), and Saturation (chroma). Moreover, PCCS is characterized by the tone, which is a combination of Lightness and Saturation. Many studies have included three or four dimensions of color image. Our previous study by factor analysis identified two dimensions of color: activity and potency. These factors corresponded with the physical value of color, i.e., potency of Lightness and activity of Saturation in PCCS.

The purpose of this study is to examine the effect of psychological Lightness and Saturation on color image by analyzing its tone.

2. METHOD

This study adopted two methods. First, we investigated the dimensions of the color image; second, we measured the psychological Lightness and Saturation of color.

2.1 Stimuli

The stimuli used were 12 tones (vivid, bright, strong, deep, light, soft, dull, dark, pale, light grayish, grayish, and dark grayish), five hues (2R, 8Y, 12G, 18B, 22P), and five achromatic colors. These were classified into four types. 1) Tone stimuli, with each tone consisting of five hues arranged in a circle, in which the color chip was 3 × 3 cm and the mount was 12 × 12 cm(Fig1); 2) hue stimuli, with each hue consisting of 12 tones arranged in a row, in which the color chip was 3 ×1.5cm and the mount was 5 × 21 cm(Fig2); 3) Gray scale, with five achromatic color steps arranged in a row, in which the color chip was 3 ×1.5cm and the mount was 5 × 10.5 cm(Fig3) ; and 4) single color stimuli in which the color chip was 3 ×3 cm and the mount was 10 × 10 cm(Fig4), with each color being pasted on a neutral gray mount.

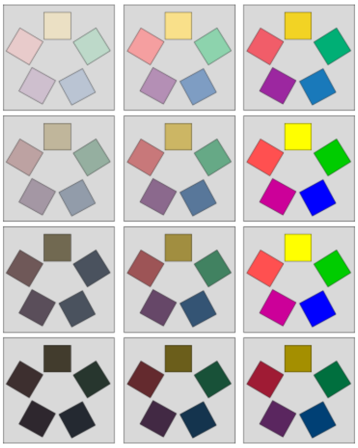

Fig1. Tone stimuli
(There are 12 in total)

Fig2. Hue stimuli
(There are 5 in total)

Fig3. Gray scale

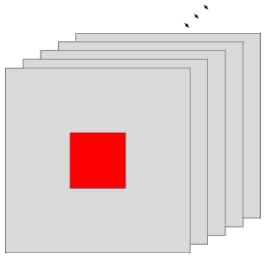

Fig4. single color Stimuli
(there are 65 in total)

2.2 Questionnaire

Two questionnaire type scales were used. First, the semantic differential method (SD method) was used to investigate color image dimensions. Then, the visual analog scale (VAS) was used to measure psychological color lightness and saturation. The SD method had 15 adjective-pair words(beautiful-ugly, clear-muddy, bright-dark, dull-sharp, cheerful-gloomy, loud-quiet, dynamic-static, strained-loosen, light-heavy, gaudy-subdued, soft-hard, blurred-distinctly, warm-cool, preferable-hateful, plain-rich), and had a seven-point scale. The VAS had two adjective pair words(bright-dark and vivid-dull). The questionnaire was presented on an iPad.

2.2 Experimental Procedure

There were 30 participants (8 male and 22 female, average age 21.6 ± 2.0 years) in this experiment. The experiment was conducted in a university classroom under fluorescent light. The participants were divided into four groups, and each group was presented with a different stimuli order and a different adjective pair word order. The subjects were required to look at each color and answer the questionnaire.

3. RESULTS AND DISCUSSION

3.1 Factor analysis

A factor analysis was used to evaluate the results of the SD method. The result of the factor analysis (Maximum likelihood method, *Promax* rotation) revealed four factors (Table1). The factor loadings differ from Osgood's factors(Osgood et.al.: 1964) and

Oyama's factors(Oyama et.al.: 1965). The first factor was Activity. Evaluation and Potency were intermingled in the second factor. The third factor and fourth factors were symbolized imageries, such as shade, and they were based on a combination of stimuli. Furthermore, this tendency was observed in Wakata and Saito (2012). Table2 shows a correlation relationship between factors scores; for example, the correlation between factor 1 and factor 2 (r = .684). The factor analysis showed that the dimensions of color images are not independent.

3.2 Correlation

The correlation coefficients between the VAS value (Lightness and Saturation) and factor scores were calculated (Table3). As a result, a correlation relationship was observed between the Lightness and Saturation(r= .723); it suggested that psychological Lightness and Saturation depend on each other. This result was consistent with the Helmholtz-Kohlrausch effect. Relationships were observed between the VAS values and the factor scores; for example, the relationship between the Saturation (VAS) and factor 1 (r = .896), and the Lightness (VAS) and factor 2 (r = .896). Factor1 is Activity and Factor2 is Potency and Evaluation. The correlation coefficients suggested that the dimensions of color images correspond to psychological values.

3.1 Structural Equation Modelling

The result of the factor analysis and correlation coefficients showed a relationship between the physical value and psychological value in terms of the dimensions of color images. Next, the model of this relationship was built using Structural Equation Modelling (SEM). The model consisted of mainly two parts: first, a factor analysis model of the color images obtained through the SD method (it was based on the resulting *3.1factor analysis* of factor 1 and factor 2). Second, a factor analysis model of psychological Lightness and Saturation was obtained by the VAS. Furthermore, the VAS factor affected the factors of the color image. The result was shown by a path diagram(Fig5). The coefficients were used in standardized values. The following fit parameters were used: Comparative Fit Index (CFI), Goodness of Fit Index (GFI), and Root Mean Square Error of Approximation (RMSEA). As a result, CFI and GFI were high, but RSMEA was observed to be p = 0.099. This

Table1. Factor lodgings (Factor Analysis)

			Fac1	Fac2	Fac3	Fac4
dynamic	-	static	1.002	-.247	.082	-.066
loud	-	quiet	.980	-.310	.130	-.040
warm	-	cool	.649	.131	-.378	-.270
gaudy	-	subdued	.613	.346	.056	-.078
cheerful	-	gloomy	.528	.359	-.051	.035
preferable	-	hateful	-.272	1.028	.011	-.192
beautiful	-	ugly	-.163	1.007	.017	-.071
clear	-	muddy	.001	.622	.182	.271
bright	-	dark	.405	.477	-.164	.078
soft	-	hard	.115	.097	-.672	.176
strained	-	loosen	.072	.042	.616	-.050
blurred	-	distinctly	.315	.254	.572	-.098
dull	-	sharp	.353	.169	.415	.202
plain	-	rich	-.247	-.133	-.148	.789
light	-	heavy	.229	.156	-.344	.451

Maximum likelihood method, *Promax* rotation

Table2. Correlation matrix (between factors)

	Fac1	Fac2	Fac3	Fac4
Fac1	1.000	.684	.082	.400
Fac2	.684	1.000	-.060	.573
Fac3	.082	-.060	1.000	-.273
Fac4	.400	.573	-.273	1.000

Table3. Correlation matrix (between VAS values and factors scores)

	(VAS) Saturation	(VAS) Lightness	Fac1	Fac2	Fac3	Fac4
Saturation (VAS)	1.000	.723	.896	.852	.324	.424
Lightness (VAS)	.723	1.000	.825	.896	-.292	.773
Fac1	.896	.825	1.000	.876	.023	.557
Fac2	.852	.896	.876	1.000	-.157	.795
Fac3	.324	-.292	.023	-.157	1.000	-.612
Fac4	.424	.773	.557	.795	-.612	1.000

model was adopted from the aforementioned parameters. The factor of psychological value showed that the factor influence of Saturation (.973) was greater than that of Lightness (.631). The emergence of this factor depended on Saturation. Therefore, We consider that Japanese「明るい:akarui」is included in「あざやか:azayaka」. Furthermore, the factors of the color image showed a correlation relationship (r =.729). PCCS defines Saturation as a psychological value; Lightness was also similarly defined. This is considered to be related to the structure of this model.

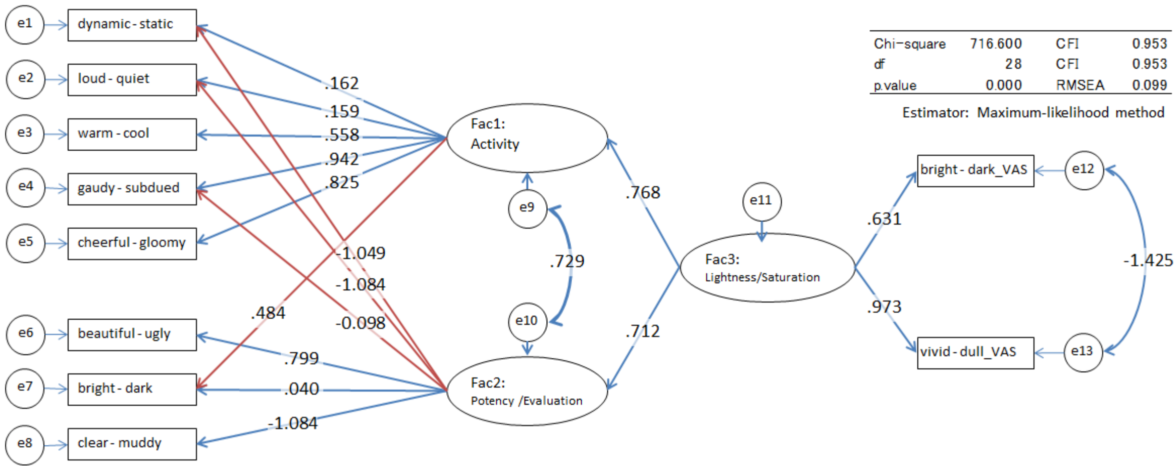

Fig5. Path diagram (SEM)

4. CONCLUSIONS

This study showed that psychological Lightness and Saturation were not independent and suggested the existence of a high level concept common to both variables. Through the use of this concept, a definition for the correspondence between the physical value and psychological value has been achieved.

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Psychological effects of meal tray color on the visual palatability of meals among individuals with low vision – the effect of brightly toned colors

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ABSTRACT

The psychological effects of six meal tray colors (b2, b4, b8, b12, b16, b24 on the Practical Color Coordinate System) on the visual palatability of meals for individuals with low vision were investigated. Images for each tray color were described according to the semantic differential method using 36 antonymic adjective pairs. Participants were divided into either a low-vision group in which subjects wore low-vision simulation glasses or a healthy group with good vision. Using factor analyses, two components, "activity" and "relaxation", were extracted from 36 antonymic adjective pairs. Tray color b8 was positive for both components in terms of visual perception among both low vision and healthy subjects. In addition, b8 showed higher visibility than the other colors. Tray color b8 was the most useful color for visual perception, universal color design, and comfort of the six brightly colored trays.

1. INTRODUCTION

According to the World Health Organization, 347 million people worldwide have diabetes. In such individuals, a lack of control of dietary intake can lead to serious complications, such as diabetic retinopathy, which leads not only to low vision, but also blindness. Although cooking and eating to maintain dietary control under low vision is difficult (Hiroshi T., 2002), most color schemes (Shoko A., 1994, Yuji M. 2009) which represent an important factor in appetite, for tableware made for individuals with low vision only come in combinations of black and white. This study examined the psychological effects of meal tray color on the visual palatability of meals for individuals with low vision.

2. METHOD

Pictures of meals on trays taken with a single-lens reflex camera (Nikon D3000), which was adjusted to white balance selected under the daylight and fluorescent light setting (6500K), were used as samples. The color of the trays was changed using a liquid-crystal display (LCD) while the color of the meals was not adjusted. An image survey of meals on the color-adjusted trays was performed under low vision as described below.

2.1 Sample preparation methods

Pictures of 218 meals which were served for approximately 2.5 months in a nursing home in Japan were taken under D65 using a standard light source device (Macbeth Judge II: Sakata Engineering Co., Ltd.). Meals on trays that created a good color scheme together (not including the dishes on the trays) were selected using the semantic differential (SD) method with the 218 meals divided into seven grades. Sample photos of these meals were then selected.

2.2 Color conversion methods

Pictures of the Practical Color Coordinate System (PCCS) color chart *(Table 1)* were taken under D65 with a standard light source device (Sakata Engineering Macbeth Judge II) using a digital single-lens reflex camera (Nikon D3000). RAW corrections were made using the X-rite Color Checker Classic (Sakata Engineering). The colors of the trays with the meals found to be the most appealing according to the SD method were converted to six bright tones (b2, b4, b8, b12, b16, b24 on the PCCS) using Photoshop (Adobe Systems) on a LCD screen. The legitimacy of color conversion was confirmed using a brightness meter (Konica Minolta CS-2000).

Table 1. Munsel and RGB values of the six tray colors

PCCS color name	Munsel value	RGB value		
		R	G	B
b2	4R 6/12.0	241	93	105
b4	10R 6.5/1.5	247	119	77
b8	5Y 8.5/11.0	242	211	36
b12	3G 6.5/9.0	0	178	117
b16	5B 5.5/8.5	0	143	179
b24	6RP 5.5/10.5	204	92	135

2.3 Image research methods

The subjects were university students (mean age, 21.7±0.76 years; 309 females, 118 males) who sat in front of a LCD screen onto which pictures of the meals and six tray colors were projected. After viewing the pictures of the meals and trays, the subjects answered a questionnaire. All experiments were performed in a room with a fixed fluorescent lamp on the ceiling. The subjects were divided into two groups: a low-vision group in which subjects wore low-vision simulation glasses; and a healthy group without simulation glasses and good vision. The results of the two groups were compared. In this study, two research methods were used. One was the paired comparison method which consisted of looking at two LCD screens at once, while the other method consisted of looking only at one LCD screen. The number of subjects for each method is shown in *Table 2*.The scale of the tray pictures was 60%. Illuminance on each table was 505±11.4 lx, room temperature was 25±1.3℃, and humidity was 57±14.7%. The questionnaire comprised the following three sections: attributes; physical and/or mental condition; and image of tray. Images for each tray color were described according to the SD method, using 36 antonymic adjective pairs. All subjects took part in the experiment at least 1 h after eating.

Table 2. Number of participants by research method and group

	Low-vision group (N/tray color)	**Healthy group** (N/tray color)	**Total** (N/tray color)
Single LCD	31	30	31
Paired comparison method	31	30	31
Total	62	60	122

Table 3. Two components ("activity" and "relaxation") were extracted from the 36 antonym-adjective pairs by factor analysis

Antonymic adjective pairs			**Components**	
			Activity	**Relaxation**
Cheerful	-	Gloomy	0.903	-0.120
Exhilarated	-	Melancholy	0.885	-0.098
Pleased	-	Lonesome	0.872	-0.094
Warm	-	Cool	0.872	0.063
Intimately	-	Lonely	0.872	0.034
Lively	-	Unlively	0.854	-0.205
Conversational	-	Silent	0.841	0.078
Happy	-	Unhappy	0.827	0.190
Energetic	-	Weary	0.825	-0.247
Appetizing	-	Unappetizing	0.804	0.300
Delicious	-	Undelicious	0.777	0.321
Cordial	-	Uncordial	0.776	0.273
Open	-	Closed	0.763	0.052
Fleshly	-	Unfleshly	0.727	0.218
Feminine	-	Musculine	0.631	-0.204
Stable	-	Unstable	0.050	0.812
Calm	-	Excessive	-0.279	0.786
Restful	-	Unrestful	-0.278	0.785
Heartwarming	-	Vigorous	-0.319	0.752
Relaxant	-	Tense	0.157	0.742
Ordinary	-	Original	-0.066	0.724
Natural	-	Artificial	0.162	0.701
Healing	-	Unhealing	0.223	0.701
Simple	-	Decorative	-0.188	0.664
Eigenvalue			10.422	5.520
Cumulative contribution ratio(%)			43.43	66.43
Cronbach's coefficient alpha			0.964	0.899

3. RESULTS AND DISCUSSION

3.1 Single LCD

Using factor analyses, two components, "activity" and "relaxation", were extracted as shown in *Table 3*. Tray color b8 was positive for both components in terms of visual perception for both low vision and healthy subjects *(Figure 1)*. In addition, b8 was evaluated to have higher visibility than the other colors tested.

3.2 Paired comparison method

Tray color b8 was the most clearly visible among both low vision and healthy subjects. B8 among healthy group was evaluated to have a comfortable and restful feeling without garish image, although a bright tone had high value and chroma.

4. CONCLUSIONS

Among the six brightly toned trays, tray color b8 was shown as the most useful color in terms of visual perception, universal color design and comfort.

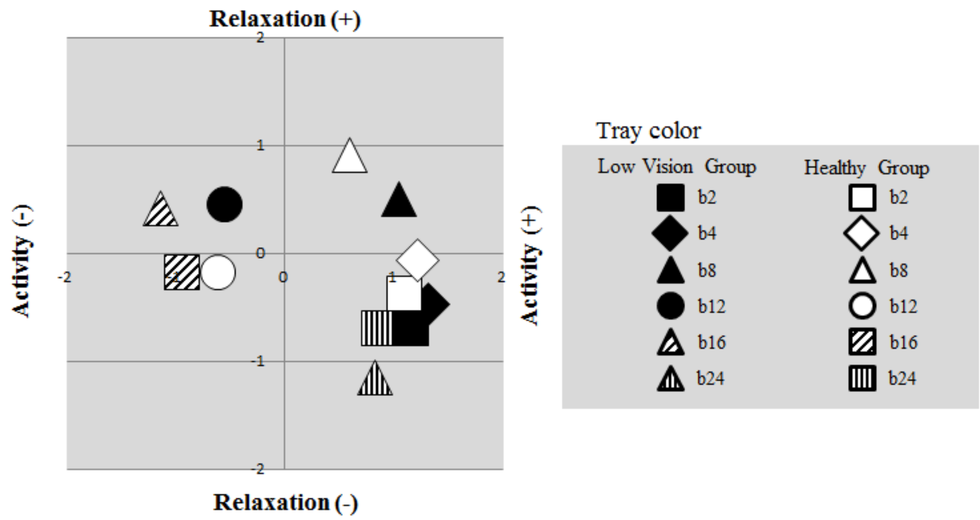

Figure 1. Scores of each tray color for the components "activity" and "relaxation"

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A Comparison Between the Impact of Short and Long Wavelengths of Light on Sleepiness and Mood

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ABSTRACT

It is widely acknowledged that light of a certain wavelength induces alertness, disturbing the duration of sleep. More precisely, among the wavelengths, short wavelength light (blue light) exerts a greater stimulus on circadian rhythm, compared with long wavelength light (red light). Previous studies have demonstrated that blue light exposure impacts on nocturnal alertness, suggesting the impact of chromatic light on the quality of sleep. On the other hand, some investigations have suggested sleeping in blue room is better for sleep rather than red room. Therefore, based on the contradiction, the present study was designed to figure out the psychological impact of short and long wavelengths light (blue and red light) on sleepiness and mood.

1. INTRODUCTION

Since sound sleep is indispensable for health of body and mind, the increasing number of people who are suffering from sleep problems is a concern, raising questions about how to promote high-quality sleep. One of the factors thought to be associated with high-quality sleep is the bedroom circumstance. Among them, the light illumination of the bedroom is one of the most important factors. Light of a certain wavelength is also known to modify human circadian rhythm. The timing, light intensity and light wavelength, are three important factors for circadian entrainment, which is associated with the sleep and alertness rhythm (Dumont et al., 2007). Many studies have reported that exposure to short wavelength light (blue light) prior to sleep stimulates the circadian rhythm most, impacting on alertness and reducing the quality of sleep (Cajochen et al., 2005). Moreover, blue light exposure at night has also been shown to be a factor contributing to mood disorder (Bedrosian et al., 2013; Dumont et al., 2007).

On the other hand, an investigation examining bedroom color conducted by a hotel company (Travelodge, 2013), concluded that sleeping in a blue bedroom is far more conducive to a good night's sleep than sleeping in a red bedroom. Further, several studies have reported that red is the color which stimulates the sympathetic nervous system (SNS) most, whereas blue activates the parasympathetic nervous system (PNS), producing a calming effect (Jacobs & Hustmyer, 1974; Sakuragi & Sugiyama, 2011). These studies together appear to contradict the findings noted before, although the former studies investigated the light color itself, while the latter investigated the reflection of the color of the walls.

In the present study, we examine the effects of bedroom lighting on night sleep. The present study compares the impact of short and long wavelength lights on both sleepiness and mood, using both questionnaires and a behavioral task to elicit effects.

2. METHOD

2.1 Participants

Ten healthy subjects (5 males and 5 females) aged 23 to 35 years who reported not taking medication and having no visual defects or psychological disorders, participated in the experiment after giving oral consent. The experiment consisted of having subjects exposed to light of both short (blue) and long (red) wavelengths. The experiment was conducted over a two-day period, with one condition being presented on each day. The order of the experimental conditions was determined randomly. The subjects were asked to ensure that they had sufficient sleep on the days prior to the experiment. They were also requested to refrain from vigorous exercise, and from consuming alcohol or caffeine on both days of the experiment.

2.2 Measures

Visual Analogue Scale. The Visual Analogue Scale is an effective way of measuring subjective momentary feelings, such as pain, and sleepiness. (Wewers & Lowe, 1990; Sakuragi & Sugiyama, 2011). The present study used the VAS to evaluate subjects' physical sleepiness and mental state.

Psychomotor Vigilance Tests. Psychomotor Vigilance Tests (PVT) use reaction times to particular tasks to objectively determine sleepiness (PVT; PC-PVT v1.1.0 developed by Biotechnology HPC Software Applications Institute) (Khitrov, et al., 2014). A PVT was administered for 10 minutes after exposure to each of the experimental light conditions in order to measure sleepiness at the behavioral level.

Profile of Mood States. The Profile of Mood States (POMS)-Brief Form Japanese Version was used to assess subjective mood. POMS categorizes mood into six subscales: Tension-anxiety, Depression- dejection, Anger-hostility, Vigor, Fatigue and Confusion. POMS also enables the measurement of changes of mood which occur over a short period of time (Yokoyama, 2006). The present study used POMS to evaluate the change of mood over a period of 30 minutes.

2.3 Apparatus and Procedure

Before being exposed to each experimental light condition, each subject was asked to complete both VAS and POMS questionnaires in order to establish the baseline of sleepiness, mental state and mood. After the completion of the questionnaires, each subject was escorted to a soundproof chamber (length 266cm×width 170cm×height 201cm). In the chamber, the apparatus for presenting the chromatic light was located at the center of the ceiling, directly above the subject's head. Each subject was requested to keep his or her eyes open for the entire duration of light exposure, ensuring the delivery of the chromatic light. Figure 1 shows the image of the experimental environment in which both red light and blue light was presented. Two chromatic light conditions were presented using a blue LED peaking at 462 nm, and a red LED peaking at 630 nm (Figure 2). Each subject received light exposure for 30 minutes. The illuminance of several points in the experimental soundproof chamber was measured; red light: 21.81lx, blue light: 3.22lx at subject eyes' level. After exposure to each lighting condition, respectively, subjects undertook a 10-minute PVT test in the chamber and finally, repeated, in post-test fashion, completing the same VAS and POMS questionnaire used in the pre-test. Figure 3 illustrates the experimental procedure and the data collection activity periods.

Figure 1: Simulated experimental environment of the clamber with red light illumination (left) and with blue light illumination (right).

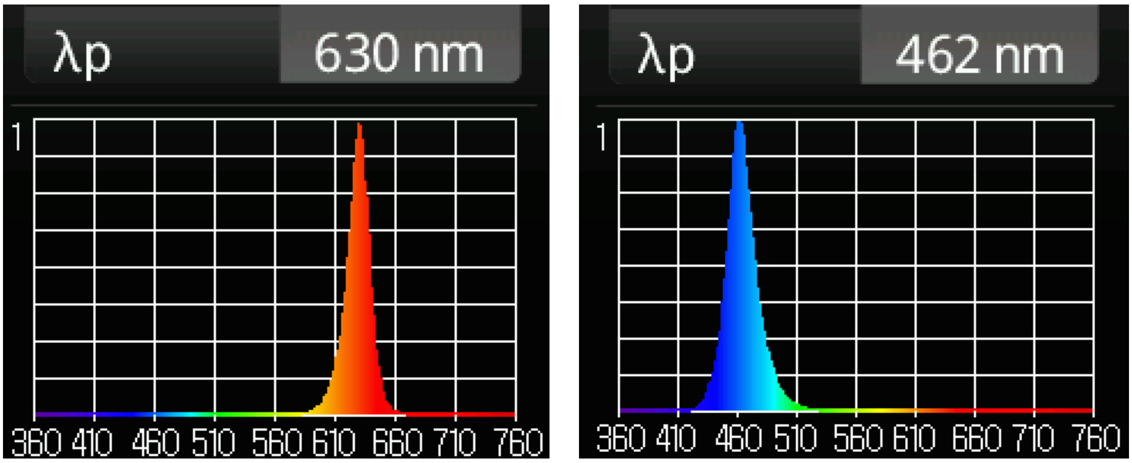

Figure 2: Spectral distribution of red LED light (left) and blue LED light (right).

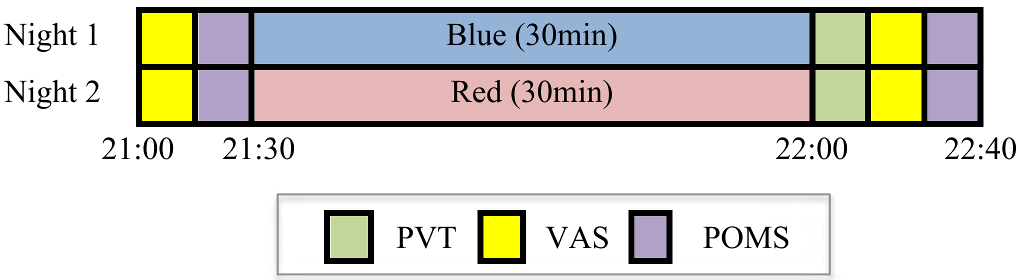

Figure 3: Experimental procedure and data collection times for each subject.

3. RESULTS AND DISCUSSION

3.1 VAS Results

In terms of reported sleepiness, a paired t test revealed significantly increased sleepiness only under the blue condition ($t(9)=-3.485$, $p<0.01$). Both blue and red conditions indicated significant variation in mental state instability (red: $t(9)=2.423$, $p<0.05$; blue: $t(9)=3.692$, $p<0.01$). However, when changes under the red condition were compared with changes under the blue condition, no significant difference was found.

3.2 POMS Results

To establish the comparative impact of light of both long and short wavelengths on mood, a paired t test was used for each subscale. In the Vigor subscale, under both the red condition and under the blue condition, vigor was significantly reduced (red: $t(9)=3.613$, $p<0.01$; blue: $t(9)=3.647$, $p<0.01$). Further, for the Confusion subscale, the reported degree of confusion showed a significant increase only under the blue light condition ($t(9)=-2.717$, $p<0.05$). However, as with VAS, the POMS results showed no significant difference between the red or blue light experimental condition.

3.3 PVT Results

The results of a paired t test showed no significant difference between the red and blue light conditions on sleepiness, as determined by behavioral tasks.

3.4 Discussion

After exposure to blue light for 30 minutes, sleepiness increased significantly (VAS results), whereas red light failed to induce any significant changes in sleepiness. This result is consistent with the statement that the secret to a good night's sleep is to sleep in a blue bedroom rather than red bedroom, as reported by a hotel company (Travelodge, 2013). Meanwhile, the significant increase of sleepiness under blue light condition indicates a discrepancy between the actual outcome and the conclusion of previous studies, that short-wavelength light stimulates the suprachiasmatic nucleus (SCN) most, leading to circadian rhythm disorder and sleep problems. This inconsistency raises the possibility of the existence of other light-sensitive pathways regulating sleep besides the retinohypothalamic tract (RHT).

With respect to mood, both red and blue light exposure contributed to mood instability. However, only under the blue light condition, subjects seemed to become more confused. This result is consistent with the conclusion that blue light leads to mood disorder. Since mood change before sleep also influence the quality of sleep, it is necessary to integrate and compare the reported sleepiness with the impact of mood when evaluating the real quality of real sleep.

Given that the questionnaires and behavioral method have limitations for determining the quality of sleep directly and subjectively, taking into consideration the possibility of other light-sensitive pathways regulating sleep proved by the present study, further study is needed to analyze electrophysiological measures in order to more accurately clarify the impact of different wavelengths of light on sleep.

4. CONCLUSIONS

Exposure to light of a short wavelength (blue light) for 30 minutes elevates nocturnal sleepiness. Mood instability possibly caused by both the short and long wavelengths of light (blue and red light), especially higher confusion led by blue light could influence quality of sleep. These results require further experimental investigation using polysomnographic examinations after exposure to the light conditions used in this study.

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Experimental Study of Common Factors between Impressions of Wall-Paper Colors and Sounds in Living Environments

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ABSTRACT

In order to investigate and extract common factors between the impressions elicited by the change of wall-paper colors and those elicited by the change of sounds in living environments, 30 undergraduate and graduate students were asked to evaluate a model of living rooms with 9 different wall-papers colors by the SD method. Secondly, they were required to evaluate each of four pieces of computer-generated music by the SD method. They were then evaluated by the same SD method regarding their impression of a model of a living room while listening to one of four pieces of music. The data obtained in the three experiments were analyzed by Factor analysis. From among the results of three experiments, two factors, 'pleasant' and 'mild', were extracted. Their possible role in the formation of impressions how colors and sounds relate to the concept of a comfortable living room are discussed.

1. INTRODUCTION

In daily life, psychological impressions are formed through multiple sensory modalities rather than a single sensory modality. The experience of such cross-modal perception is quite natural and common because two or more different sensory modalities usually interact in the brain. This explains why people sometimes associate a paticular color with a certain genre or piece of music. People also often express their memories associated with various colors. Consequently, understanding the relationships between the impressions derived from multiple sensory modalities and the impressions of visual information, especially colors, helps clarify the structure of the impressions derived from multiple sensory modalities. In other words, color may play an important role as a node of cross-modal perception. For instance, Ward et al. (2006) reported that sound-color synesthetes, as a group, tend to see lighter colors for higher sounds. Saito et al. (2013) investigated the harmonious relationship between color and music. They found that changes in the key of music corresponds to changes in the lightness of *PCCS* tone. On the other hand, results indicating that changes in tempo correspond to changes in lightness and saturation in *PCCS* tones from lower levels to higher levels suggest that tempo has a multi-dimensional relationship with lightness and saturation. From a cross-modal point of view, it was also suggested that the components of music can be classified by means of the components of color. To further clarify the relationship between music and color on the assessment of a living room being comfortable or not, the present study investigates the triangulation of these factors in a living environment. In the present study, we investigate factors common to the impressions elicited by the change of wall-paper colors and the impressions elicited by the change of sounds in living environments, using the model of a living room.

2. METHOD

2.1 Participants and Apparatus

The number of subjects who participated in the experiments was 30 undergraduate and graduate students (12 males, and 18 females, ages: mean=21.8 years, SD=1.34). The experimental stimuli were as follows: 1) A model of a living room (Width 500mm x Depth 400mm x Height 300mm) with all of its white miniature interior materials (three sofas, a table, and a curtain) illuminated by *Panasonic* natural white. (See Fig.1) Wall-papers were 9 different colors of the *PCCS* (Practical Color Co-ordinate System), namely: pale tones and grayish tones x 2R, 8Y, 12G, 18B and white. (See Fig. 2 and Fig.3); 2) Sound stimuli: 4 pieces of music composed using our own computer-software in two different octaves of C major, namely C3 major (low) and the second higher octave (high), at two different tempos (BPM=120 and 210). The scores of the four pieces of computer-generated music can be seen in Appendices.

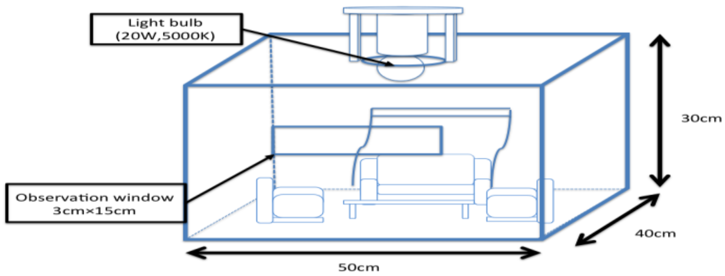

Figure 1: Model of the living room

2.2 Procedure

The participants were asked to look into the model of the living room through an observation window and rate each stimuli on a seven-point scale following the semantic differential (SD) method. In our experiment, 17 adjective-pairs (pleasant-unpleasant, like-dislike, harmonious-unharmonious, ordered-disordered, familiar-unfamiliar, sophisticated-unsophisticated, clear-unclear, soft-hard, cheap-luxurious, nondistinctive-distinctive, cheerful-gloomy, quiet-noisy, bright-dark, gaudy-subdued, warm-cool, calm-restless, feminine-manly) were used. The evaluation was also followed by free comments relating to the first impression, the positive or negative feelings, and the extent of comfortableness, together with some verbal questions, such as feeling free or not, and favorite and disliked

colors.
The study comprised three experiments: First, the participants were asked to give their psychological evaluations of each living-room model by the SD method, and provide free comments. Second, they were asked to evaluate each of the four pieces of computer-generated music by the SD method. Finally, they were asked to evaluate, by the same SD method, each model of a living room while listening to one of the four pieces of music.

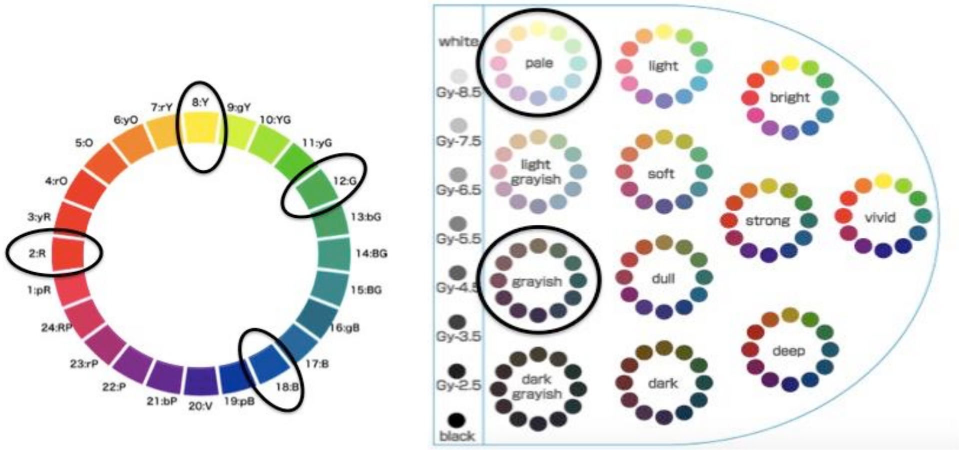

Figure 2: Hues and tones of PCCS used in the experiments

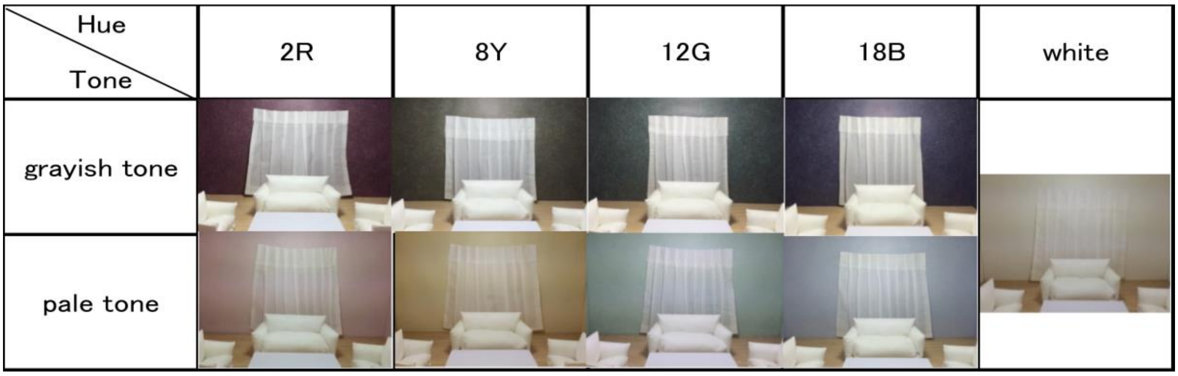

Figure 3: Hue and tone of the wall-paper in the models

3. RESULTS AND DISCUSSION

3.1 Factor Analysis

The data obtained in the three experiments were analyzed independently by Factor analysis (Maximum likelihood method, *Promax* rotation) with two similar factors emerging. Using factor analysis (Major factor method, *Varimax* rotation), a data analysis of all three experiments was repeated, as a result of which two factors, ‘pleasant’ and ‘mild’, were identified. Table 1 indicates factor loadings of the analysis of all of the data from three experiments. As the first factor included the scales of pleasant-unpleasant, like-dislike, harmonious-unharmonious, ordered-disordered, familiar-unfamiliar, sophisticated-unsophisticated, clear-unclear, and soft-hard, it was designated the 'pleasant' factor. The second factor, which consisted of the scales of cheerful-gloomy, quiet-noisy, bright-dark, gaudy-subdued, warm-cool, calm-restless, and feminine-manly, was designated the 'mild' factor. Hence, it is possible that these two factors, 'pleasant' and 'mild', are common to the formation of impressions about a living room being comfortable or not.

Table 1: Matrix of factor loadings

Ajective pairs	Factor	
	PLEASANT	MILD
pleasant-unpleasant	.889	.105
like-dislike	.843	.139
harmonious-unharmonious	.804	.101
ordered-disordered	.735	-.028
familiar-unfamiliar	.725	.283
sophisticated-unsophisticated	.592	-.045
clear-unclear	.563	.242
soft-hard	.457	.440
cheerful-gloomy	.313	.765
quiet-loud	.196	-.731
bright-dark	.470	.725
gaudy-simple	-.108	.664
warm-cool	.340	.609
calm-restless	.522	-.539
feminine-masculine	.155	.509
Contribution ratio	32.5	22.5
Cumulative contribution ratio	32.5	55.0

3.2 Scatter Plot

Fig. 4 below shows a scatter plot of the factor scores of all three experiments. The combination of wall-papers pale in tone appears in the first and fourth quadrants, indicating that no matter what the tempo was, the pleasant and harmonious impression was influenced by the tone of the wall-paper colors, that is, a pale tone was preferred to a grayish tone. As for the impression of cheerfulness and mildness, the tempo of the music seemed to play an important role because while the stimulus combined with a high tempo were mainly scattered in the first and second quadrants, those associated with a low tempo were located in the third and fourth quadrants

3.2 Multiple Regression Analysis

Multiple regression analysis was performed to ascertain the effect of music and wall-paper colors on the impression of the living room. The highest multiple coefficient of determination was 0.311 for 'feminine – manly', indicating that no effective equation of regression was obtained as a whole. However, the partial regression coefficient of the impression only for wall-paper color was higher than that for music. It is suggested that the impression of wall-paper color may be the dominant factor in regard to the conception of a comfortable living room.

4. CONCLUSION

An applied study was carried out to elucidate common factors between the impressions elicited by the change of wall-paper colors and those elicited by the change of sounds in a living environment. Three experiments were conducted and Factor analysis was applied to the participants' evaluations of wall-paper colors of living rooms, relating to sounds, as presented by music of low and high key, and slow and fast tempo. Two main factors, 'pleasant' and 'mild' were extracted from all the experimental data indicating that these two factors feature significantly in the conception of a harmonious living room. Moreover, the results of multiple regression analysis suggest that the impressions of wall-paper colors are related to pleasant and harmonious feelings about a living room. Further studies are required to apply the result of this study to actual living environments.

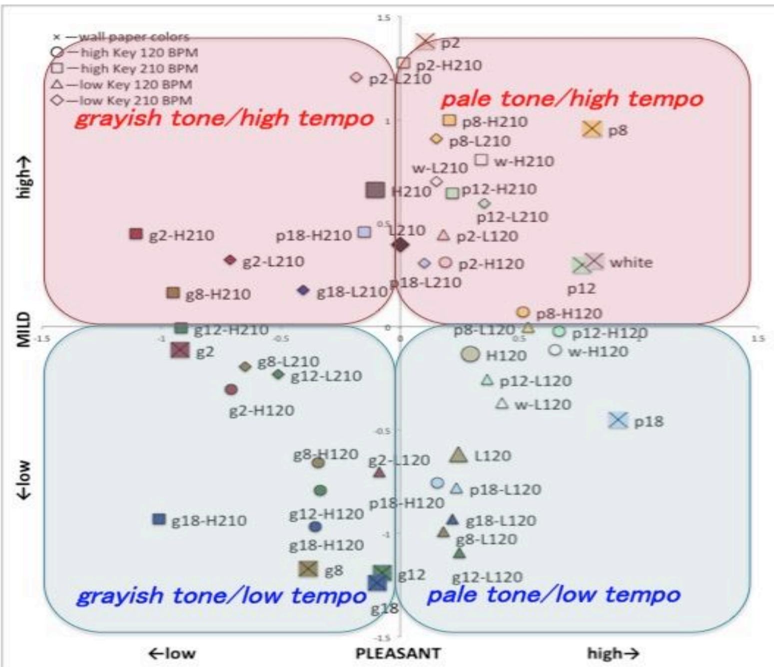

Figure 4: Scatter plot

ACKNOWLEDGEMENT

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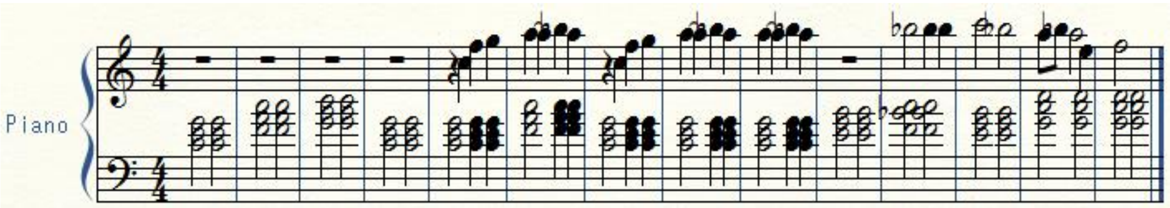
APPENDICES

Appendix 1. The score of the computer-generated music: Higher octave



Appendix 2. The score of the computer-generated music: Lower octave

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The Investigation of Factors Influencing the Impression of Color Harmony

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ABSTRACT

Color harmony has been systematically investigated since 1956 at Budapest using specific pattern samples. To quantify the impression of color harmony, Szabó et al. (2010) developed a CH formula for two and three-color combinations and a harmony rendering index (HRI) quantifying the change of the value of CHF for certain test color sample combinations under the test light source. Ou et al. (2011) developed an additive CF formula for two and three-color combinations and first by using complex images in predicting multicolor harmony. Kuo et al. (2011) developed a pilot CH formula by using textile pattern samples of color images of fashion apparel for two and three-color combinations, and using a psychophysical method of magnitude estimation instead of previous psychological method of category judgment. In Kuo and Wei (2013) CHF performance test study, the results show that test models still cannot have good agreement with model prediction and visual test results of color harmony via textile pattern samples of color images of fashion apparel. The findings indicate that factors influence the accuracy of color-harmony predicting models need to be further investigated.

1. INTRODUCTION

Color harmony is a complex issue and contains a wide variety of factors. Since last centuries, color order systems were developed by Munsell, Ostwald and Itten, and nowadays by Nemcsics to establish harmonic sets of colors. Further studies of color harmony focused on an interrelationship of colors. Judd and Wyszecki defined harmony as “when two or more colors seen in neighboring areas produce a pleasing effect, they are said to produce a color harmony”. There are a number of principles of harmony, such as ‘powerful’, ‘soft’, ‘splendid’, ‘completeness, according to Goethe, ‘order’ according to Ostwald, ‘similarity’ and ‘contrast’ according to Nemcsics and Chevreul, and ‘Balance’ according to Munsell. Color difference-related color harmony as proposed by Moon and Spencer. Other color systems, such as ‘aesthetic uniformity’ by Coloroid system, ‘similarity’ and ‘color perception’ by Natural Color System. Although those principles shared in common regarding color harmony, such as hue, chroma and lightness, but the consistency and predictability of color harmony varied from above mentioned factors.

The recent development in color harmony research adopted CIE colorimetry and psychophysical scaling methods for measuring and modeling color harmony in terms of visual response based on comparisons of a variety of pairs of color consisted of equal hue, or equal chroma, or unequal lightness. Most previous studies on color harmony were typically concerned with whether the color harmony scale can be expressed with a small number of categories, or factors, by using the psychological method of category judgment (Torgerson,1958) or the psychophysical method of magnitude estimation (Kuo, 2007) instead. To modelling color harmony has being studied since 1956 at the Budapest Technical University by Nemcsics (2007). There are advanced color harmony models concerning additive factors that affected predictability, such as light source quality, color emotion, cultural difference, preference, and live-dependency multi-color image test samples, subsequently proposed by Szabó et al. (2010), Ou et al. (2011), and Kuo et al. (2011). However, there still exists a difference among those models in which various types of test color samples and visual experiments were conducted, according to the experimental results analyzed by Kuo et al. (2013).

2. EXPERIMENTAL MODELING OF COLOUR HARMONY

2.1 Two-color Harmony Experiment

In the common two-color harmony experiment, color stimuli consisted of two squared color patches presented side by side, with a gray background (see Fig. 1). These stimuli are generated from selected colors, combining all colors from this set of selected colors. This set also contains monochromatic two-color combinations with the same hue. The test sample colors are selected systematically from the CIE color space containing achromatic and chromatic colors. The experiment is repeated to examine repeatability of observer responses. The same experiment is also used to investigate dichromatic two-color combinations, which consists of two samples of different hue.

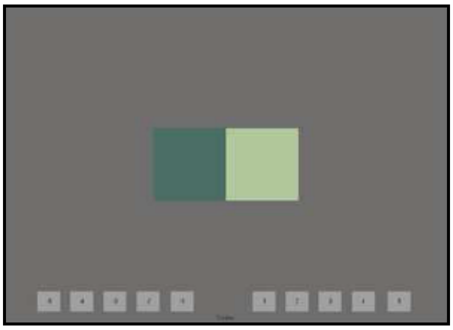
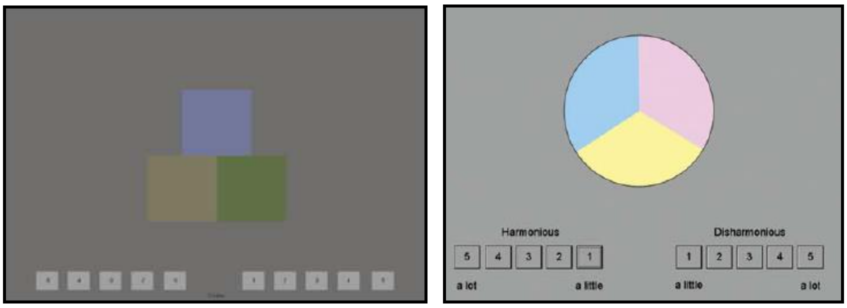


Fig. 1: Example of two-color combination (Szabó et al., 2010)

2.2 Three-color Harmony Experiment

In the common three-color harmony experiment, color stimuli consisted of three squared color patches presented in a triangle position or in a wheel, having a vertex in the middle, with a gray background (see Fig. 2a & b). The three-color harmony experiment arrangement is similar to two-color harmony experiment. The test sample colors are selected systematically from the CIE color space containing achromatic and chromatic colors. Monochromatic three-color combinations are composed form these set of samples, selecting three of them with the same hue. The experiment is repeated to examine repeatability of observer responses. The same experiment is also used to investigate trichromatic three-color combinations, which consists of three samples of different hue.



a **b**

Fig. 2: Example (a) of three-color combination by Szabó et al. (2010); Example (b) of three-color combination by Ou et al. (2011)

2.3 Two and Three-color Harmony Experiment for Complex Color Images

To use complex images of interior decoration (Ou et al., 2011) or fashion apparel (Kuo et al., 2011) as the stimuli (see Fig. 3a & b), there are the latest researches, not only to test two and three-color harmony models, but also to be considered more relevant than a combination of color patches to the art and design practice. Meanwhile, in Ou's study, effect of image configuration and cultural difference are first examined. The results indicate that additive approach, considered as a trichromatic model, is proved effective. The experiment environment including grey background, viewing conditions and data collection methods were the same as those used two and three-color harmony experiments.

a **b**

Fig. 3: Example (a) of image of interior decoration by Ou et al. (2011); Example (b) of images of fashion apparel by Kuo et al. (2011)

3. COMPARISONS OF THE PERFORMANCE OF COLOR HARMONY MODELS

3.1 Stability of Visual Assessment

In Kuo et al. (2013) study, a series of color-harmony assessing experiments are carried out respectively by fifteen observers using the magnitude estimation method. The coefficient of variation (CV%), proposed by Coates et al. (1981), is used to indicate the observer variation. The equation is as follow:

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

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

3.2 The Performance Factor (PF)

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

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

Where CV and γ were proposed by Coates et al. (1981), V_{AB} derived by Schultze and Gall (1971), and r is the correlation coefficient between the two sets of data compared. For a perfect agreement between two sets of data, the PF value should be zero. All estimations of the performance of the color difference formula on predicting visual color differences in the following data analysis are, in terms of PF/4 unit, being able to indicate the percentage error between two sets of data. Meanwhile, the higher the value of PF/4 obtained, the worse the agreement between data sets.

Table 1. Estimation on the performances of the color-harmony models derived by Ou et al. and Szabó et al., and Kuo et al., in predicting visual color-harmony data, H_{v2} and H_{v3} standing for the visual assessing values of the samples with two and three color-combinations respectively, by means of the performance factor (PF/4)

Items \ Values of PF/4 \ Models	Ou's	Szabó's	Kuo's
H_{v2}	191	137	197
H_{v3}	156	115	191
Mean	174	126	194

3.3 Comparisons of the Performance of Three Color-Harmony Models

The performances of color-harmony models, such as model Szabó et al. (2010), model Ou et al. (2011) and pilot model Kuo et al. (2011), in predicting visual color harmony were examined using the experimental visual-harmony data obtained from this study using 162 color images of fashion apparel containing 141 and 21 test samples with two-color and three-color combinations respectively by means of the performance factor (PF/4). The results showed that the model Szabó has the best performance in predicting the visual color harmony among tested models, having the mean values of 126 in the unit of PF/4 as shown on Table 1. However, above test models still cannot have good agreement between model prediction and visual results of color harmony.

4. Discussions and Suggestions

4.1 Agreement of Factors Attribute to Color Harmony

According to previous studies, by Szabó et al. (2010) and Ou et al. (2011), on two and three-color harmony, the test results agree that the factors influence color harmony, that is, ‘equal hue’, ‘equal chroma’, ‘unequal lightness’, ‘high lightness’, and ‘hue preference’. But, it is also found that test results do not show agreement with two conventional principles of color harmony, which are ‘complementary hue’ and ‘equal lightness’ (Szabó et al., 2010; Ou et al., 2011). Obviously, there are other factors that attribute to color harmony need to be taken in account and require further investigation in future research.

4.2 Future Directions for Further Investigation

In Kuo and Wei (2013) study of the performance among three color harmony models using the complex images test samples, surprisingly, the test results show that additive CH model, proposed by Ou et al. (2011), does not have the best performance in predicting visual color harmony, which is different from the test results as reported in Ou’s study. But, indeed, the additive approach opens up a research direction in predicting multicolor harmony whether is more relevant to the art and design practice. There are other factors, such as ‘cultural difference’, ‘light source color quality’, 'color harmony index (HRI)’, proposed by Szabó; ‘context’, ‘image configuration’, ‘color size’, proposed by Ou, and ‘live-dependency complex image’ test samples, proposed by Ou and Kuo. In addition to improve the consistency and predictability of color harmony, there are ongoing researches on Color Rendering Index (CRI) and better uniform color space (CIELAB or CIECAM02) to achieve accordance.

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The hidden image – a strategy to put an unwanted phenomenon in its true light

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ABSTRACT

In the everyday we are surrounded by images and the plethora of visual material is overwhelming us. We do not anymore look properly at images and we assume that what we see is correct. We do not doubt our sight and do not expect that the same image could appear with different colours. This proposal depicts the journey of the exploration of the physical colour phenomenon called metamerism, where a colour pair looks even in a given light situation, but may appear different in a changed light source. In the field of colour most practitioners aim to avoid metameric colour pairs, as it is seen as a problem so far. By contrast, the fascination of the subtle colour change and the interest to work with this 'error', uncovering the potentiality of something that has not previously been appreciated, is a main driver of this research. This research investigates the creation and steering of metameric pairs of colours and their impact upon viewers. Yarns, as the basic material of the fabrics, have intentionally been dyed to be metameric. Knit has been chosen as the medium to create therewith images. The fabrics, thereby created, change colour depending on the switched on 'white' light source and they are revealing hitherto unnoticed visual contrasts. The aim is to give visibility and to lead to a new consideration of this 'trivial' phenomenon. Light breathes life into the colours of the fabrics and the images unveil the phenomenon offering to the audience this wonderful magic of the relativity of colour perception. The interaction of light and colour creates different views of one image and through these artworks metamerism becomes experiencable and the vitality of colours becomes reality.

1. INTRODUCTION

The impetus for this research project resulted from my daily routine as a designer. The zippers I had carefully selected for a knitted cardigan didn't match, and I discovered that this was due to an optical phenomenon called metamerism. It turned out that the colour of a material may appear different under different light sources: when the spectral composition of light changes it can result in differences of the spectral diffuse reflectance of the material surface, causing the initially uniform colour of the material to appear different (Hunt 2011). As in the above example, metameric colours can be a professional irritation and to date, colour metamerism is generally discussed as a problem. This research, by contrast, seeks to explore the poetic and aesthetic experience of this 'unwanted' physical colour phenomenon in order to reconsider its affect, and put in its true light. Through a series of art installations and performances, the project is intended to create and sustain the sense of wonder when metamerism is experienced, allowing an audience to encounter it consciously, and from a new conceptual angle. It is a transdisciplinary exploration of the perception of colours, lighting and environment bringing together the fields of art, science and technology, using the craft of dyeing and knitting. Ideas have been tested in several performances and installations; this paper will outline progress so far, and concentrate upon part of this research journey, the installation "Trilogy of light", a performative installation with three wall-mounted knitted 'canvases', showing three times the same image of a lamp, but with interchanged colours. The work is illuminated by at least two different light sources, switched on and off alternately, and changing at set intervals, thus enabling the images depicted to reveal unexpected subtle colour changes.

2. METHODS, MATERIAL & MEDIUM

This research is situated within art & science (Wilson 2010), therefore the methodology cross-fertilises approaches from various disciplines: it mobilises the science of textile chemistry and physics, knowledge from the humanities, the craft and aesthetic theory of design and visual art, and it uses a mix of qualitative, quantitative and explorative methods. In the twenty-first century, artists, scientists and technologists are collaborating and cooperating with each other on increasingly hybrid inquiries. As well as enabling the specific intentions of this project, the mixed methods enhance links between disciplines, and seek to develop new ways of working and thinking, such that alternative perspectives offer a fruitful way for generating new knowledge.

2.1 Preparation of material: Yarn dyeing

The first part of the research was quantitative, and mainly dedicated to the development of adequate conditions for the dye explorations; it was necessary to generate proper research results to enable preparation of the metameric material. The goal was to find colours, which can be dyed in the manner, that they would look visually the same in daylight D65 but would look different under A and TL84[1]. Knowing that mixed colours tend to be the most metameric, recipes in the range of greyish, brownish and greenish colours have been calculated by the Datacolor System. The research aimed for colour recipes, which would allow three variations responding in a different way to the fixed three light sources. The first colour should stay stable in all the three lights, the second should change visibly in the fluorescent light (TL84) and the third should change in Tungsten (A). The first dyestuff combinations, which showed visually attractive changes, were an olive green and the decision has been taken to proceed with this, and to determine the best way to create and manipulate the effect on the basis of one colour.

2.2 Knit as material and medium

Knit has been chosen as the material to combine the purposefully metameric dyed yarns. I am a trained textile artisan and a knitwear designer, with knit as my core competence: the use of textile techniques as a medium for these artworks is a logical consequence. Jessica Hemmings' makes clear that knit contributes

> "… to a vast array of disciplines, including contemporary and traditional crafts, modern literature, fine art, feminism, activism and history" (Hemmings 2010).

[1] D65 and A are Standard Illuminates, defined by the International Commission of Illumination, (CIE), D65 is a definition of day light with a temperature of about 6504 Kelvin. A corresponds to incandescent light with a temperature of about 2856 Kelvin. TL84 instead is a definition of a fluorescent lamp with a temperature of about 4000 Kelvin. (Hunt 2011).

Like Hemmings, this project seeks to acknowledge and expand the contribution knitting can make to different disciplines[2].

With the first dyed yarn, different fabrics were produced using stripes, jacquard and more complex structures; these were then observed under defined light sources and the effects evaluated according to the subjective aesthetic visual judgement of an artist. These initial explorations were the crucial basis for developing subsequent concepts for installations and performances.

2.3 Light, Performances & Installations

It had been the intention to construct a light cabinet to test the work, but during the research the colour change triggered by common light sources shifted this: it was decided to work with everyday light sources underlining the prosaicness of the phenomenon. Several bulbs were purchased from an ordinary shop, inserted in various lamps and observed against three coloured fabrics. Fluorescent energy saver bulbs produced visually attractive colour changes, as did the incandescent bulbs (halogen and the old banned bulb).

As the research aims to make visible the phenomenon, and to change the usually negative perception, it became clear that installation and performance could be an effective method for exploration and testing. Each installation and performance requires a certain light setting dependent on the concept of each work. As it is rarely possible in gallery installation settings to show artworks in daylight, the unicolour variation gets lost; by contrast performances give an opportunity to lead the audience from rooms with daylight to those with different artificial illumination. In practice it has been difficult to control the setting of the light sources and the installation was not yet always ideal. Further research is needed to explore a broader range of illumination options and settings.

3. EXPERIMENTS, RESULTS AND REFLECTION

3.1 Installations and Performances

"green-green-green"

For the performance "green-green-green" a dress was developed, which acts as a 'canvas' during performances and gives the performer the chance to move around in a building with the audience taking advantage of the available light sources. It became clear that it was important to start the performances in daylight, as viewers experience a greater sense of wonder when something apparently unicolour becomes colourful. What was especially interesting in terms of changing perceptions, was that one observer saw a unicolour dress in the beginning in the daylight situation, but after the performance she could not revert to seeing a single colour now she knew that different colours were present. The live experience of engaging with performances reliant upon specific light generates powerful sensory affect through which a poetic physical experience can unfold (Figure 1).

[2] As well Turney (Turney 2009) stresses the important cultural contribution of knitting.

Figure 1 Image of the Performance: "green-green-green", 2014, Nottingham UK

"green-green-green_1_03:11"

Subsequent developments involved images of the performer knitted with a Jacquard technique. By reducing the colour range of the images with the software Photoshop to just three colours, images were produced with the three metameric green dyed variations of yarn. "green-green-green_1_03:11" (Figure 2) was tested in the 'Knitting Nottingham' exhibition, Bonington Gallery, Nottingham UK where it was framed as a performative installation: as Erika Fischer-Lichte argues, the key aspects of performativity are unpredictability and a transformative power (Fischer-Lichte 2012). The installation is time-based and the image performs a colour change, which is not predictable. This subtle and aesthetic wonder can change the perception of the phenomenon. Leavy (Leavy 2009: 255) formulates it like this:

> "The arts can grab hold of people's attention in powerful ways, making lasting impressions. Art is immediate. …; a piece of visual art can stop people in their tracks and jar them into seeing something differently; …".

In this exhibition, the Tungsten spotlight was working appropriately, but the fluorescent light was put just underneath the artwork and unfortunately was not strong enough to experience the second colour variation accurately.

Figure 2: "green-green-green_1_03:11", 2014, Bonington Gallery, Nottingham UK

"Trilogy of light"

In order to consider the specific types of light to be used within the research, it was necessary to explore a range of light sources, and as a by-product an archive of images of lamps and light was created (Figure 3). At a certain point, this material became interesting in itself, and this subject matter formed the source in turn for the image in three knitted squares forming "Trilogy of Light" (Figure 4).

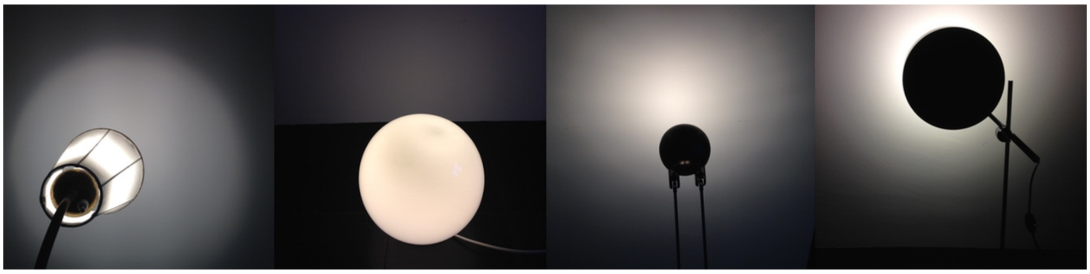

Figure 3: Various photos of lamps and light

Figure 5: "Trilogy of light" in Tungsten

Each knitted square has an image of the same lamp, made using differently dyed yarns to create three different metameric options. In daylight the human eye is not capable of perceiving the differences of colour and the image is hidden: the colour variations only occur when artificial lights are used. In this installation, the same cone of light is shown three times, but each 'canvas' reacts differently to the same light situation. It is a double game: the light itself is a form on the image, made visible by the form of the lampshade. Böhme (Böhme 1995) asserted, that we could see light only, if it appears as a medium. In fact the canvas acts as a medium; the lamp is the carrier of the light source and the light source of the standard lamp in front of the installation is the trigger. Through this combination the phenomenon comes alive. The knitted trilogy, provoked by various light sources, plays with perception and offers a visual and aesthetic experience. In this research the image is a medium to enable insight. A new point of view of this 'unwanted' physical colour phenomenon is generated. The conscious witnessing of the phenomenon enables a new experience. For Böhme (Böhme 1994) all light artists are tutors because their works are exercises of perception: as they offer the possibility to sense, observe and to feel the impact of light, to understand something of the context of light, room and perception, which is often forgotten and unobtrusive in the daily life. I see the performances and installations in this sense.

4. CONCLUSIONS

The artwork "Trilogy of light" as part of this research leads to a new consideration of the unwanted metameric phenomenon and therefore it is offering new insight. New knowledge is created through practice-based research; creating artworks, which are able to be experienced and which can be showed in different contexts to diverse audiences. The research has been tested with audiences through a series of performances and installations across the last year. It has been interesting to have responses from fellow researchers, artists, children and so on: all encountered the wonder of the subtle colour change and proved to be astonished by this banal phenomenon. Those working in colour education have already asked for demonstration material, so an educational output is possible.

This performative artwork is an embodied experience; research through practice and exploring through observing. The artworks open the phenomena to further questions. After performances or discussions about the research, it was confirmed that everybody knows the phenomenon, but nobody really knows it. The performances piqued the curiosity of audiences and changed their understanding as the hidden image shows its true colours, when it is provoked by various light situations: new insight is created and leads to a conscious appropriation of the physical colour phenomenon. The research is still on going and there is further development of installations and performance needed with the goal to communicate with images and words and to debate and test the research in the public domain. This work is a contribution in the field of colour and light and aims to reach a broad audience to spread the new observation of this phenomenon and to explore subtle instances of 'wonder' provoked by encounters with metameric phenomena. Working to consider how the poetics of this experience generate new aesthetic and artistic knowledge, it will take up John Dewey's contention that in the use of the senses a possibility of insight is embodied.

ACKNOWLEDGEMENTS

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Does colour really affect pulse rate and blood pressure?

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ABSTRACT

It is commonly believed that colour affects our heart rates and our blood pressure. However, evidence for this is limited. In this study, 42 participants took part in an experiment to explore the effect of the colour of an environment. Physiological measurements were taken of blood pressure and pulse rate after exposure to coloured-light environments for about 20 minutes. It was found that pulse rate was raised under red light compared with blue and green light. It was also found that blood pressure was raised under red light. However, no statistically significant effects were observed.

1. INTRODUCTION

There are two possibilities why a certain colour could induce a particular reaction (Kaiser, 1984). Firstly, it could be explained as physiological autonomic reactions to colour. Secondly, the responses could be evoked (possibly, for example, as colour associations) from observers' perception of the world. It is still debated *whether the reaction comes from nervous autonomic systems or a cognition process of past culturally based experiences with colour, or the two mechanisms simultaneously* (Kaiser, 1984).

For autonomic nervous systems typically, the following techniques have been employed: electroencephalogram (EEG), galvanic skin response (GSR), skin conductance response (SCR), palmar conductance, respiration movement, blood pressure, and heart rate. Although a significant effect of colour on these autonomic systems (except heart rate) was found by Gerard (1958), a later study found that only for GSR was there a significant physiological effect of colour (Jacobs and Hustmyer, 1974). A review of the literature in 1984 revealed very little evidence that colour can affect heart rate or blood pressure (Kaiser, 1984). More recently, Spath (2011) did find a decrease in blood pressure and heart rate when participants relaxed in a pink room; however, the experiment was not controlled and it is possible that participants may have shown a similar reduction if they had relaxed in a white room, for example. The question of whether colour (and coloured light in particular) can induce physiological changes is therefore still open and this study addresses it.

2. METHOD

The study was conducted in a lighting laboratory at University of Leeds (UK). The room was equipped with controllable LED lighting. A personal colour environment was constructed using a pop-up photographic studio (see Figure 1) which was illuminated externally with lighting of one of four colours (white, red, green and blue). The light inside the environment was diffuse (apart from a patch that was behind where the participants sat) and was adjusted so that a measurement of the interior of the environment had a luminance of 4.21-4.27 cd/m². Note that this level was determined primarily by the blue-light condition which has low luminance even at the brightest setting. Since it was important that each light was set to the same luminance the luminance of the blue light was a controlling factor.

A total of 42 participants took part in the study; 22 females and 20 males aged 21-35 years. No major medical or visual disabilities were detected. All subjects were run separately. The subjects were divided (randomly but balanced with approximately equal gender and nationality in each group) into three groups according to the three different coloured lights (red, green, and blue). Therefore, there were 14 participants for each colour condition.

Figure 1: The personal-colour environment in the four different conditions. Note that the computer was only present during pre-experimental measurements and was not in the environment during the actual experiments.

Each participant was first exposed to the white-light condition (control) and asked to complete an action-behaviour tendency (ACS-90) questionnaire (Kuhl, 1994) during which they became adapted to the light. The questionnaire results are not being considered in this paper. After completing the ACS-90 questionnaire each participant's blood pressure and pulse were measured. The colour of the light was changed (to either red, green or blue, depending which group they were in) and in order that the participants spent the same amount of time under each light, they were asked to complete a short logic test. On average participants spent about 20 minutes under each lighting condition and blood pressure and pulse rate were measured at the end of this period.

Different participants were exposed to red, blue and green light and therefore a direct comparison between the heart rates, for example, under the different lights cannot be carried out. Instead, in this work we consider the change in heart rate (and blood pressure) for each participant when they first adapted to white light and then adapted to a coloured light.

3. RESULTS AND DISCUSSION

Table 1 shows the pulse rate results and shows that, on average, there was an increase in pulse rate under the red light (compared with the white light) and a decrease under the green and blue lights. However, none of the differences were statistically significant ($p > 0.05$).

Table 2 shows the blood pressure results and shows that, on average, there was an increase in blood pressure (both systolic and diastolic) under the red light. However, none of the differences were statistically significant ($p > 0.1$).

PR		
red	green	blue
0	-9	0
2	-7	0
-5	-5	-3
-5	1	5
1	-6	-7
-4	-6	4
-1	-16	-4
7	0	-5
6	5	-3
7	8	2
-1	2	-4
7	2	8
-8	6	1
-1	1	0
0.3571	-1.7143	-0.4286

Table 1: The difference between the pulse rate measured under the test light and the control light is calculated for each participant. The mean differences for each of the three test lights are shown in the bottom row.

BP (Systolic)			BP (Diastolic)		
red	green	blue	red	green	blue
-6	10	1	-1	1	-5
-7	3	0	1	2	-4
7	-10	1	1	-5	-2
-7	0	4	-8	8	4
-5	-5	3	-6	-9	-1
-4	-1	2	-1	-2	-1
8	-12	-3	-1	-5	1
5	0	-5	2	0	-1
3	-16	-1	10	-1	0
-4	-4	9	6	12	8
11	-5	-5	8	3	-3
5	8	3	11	2	-26
2	-5	0	-5	0	2
23	10	-7	17	12	-10
2.2143	-1.9286	0.1429	2.4286	1.2857	-2.7143

Table 2: The difference between the blood pressure measured under the test light and the control light is calculated for each participant. The mean differences for each of the three test lights are shown in the bottom row. Data are shown for systolic and diastolic conditions.

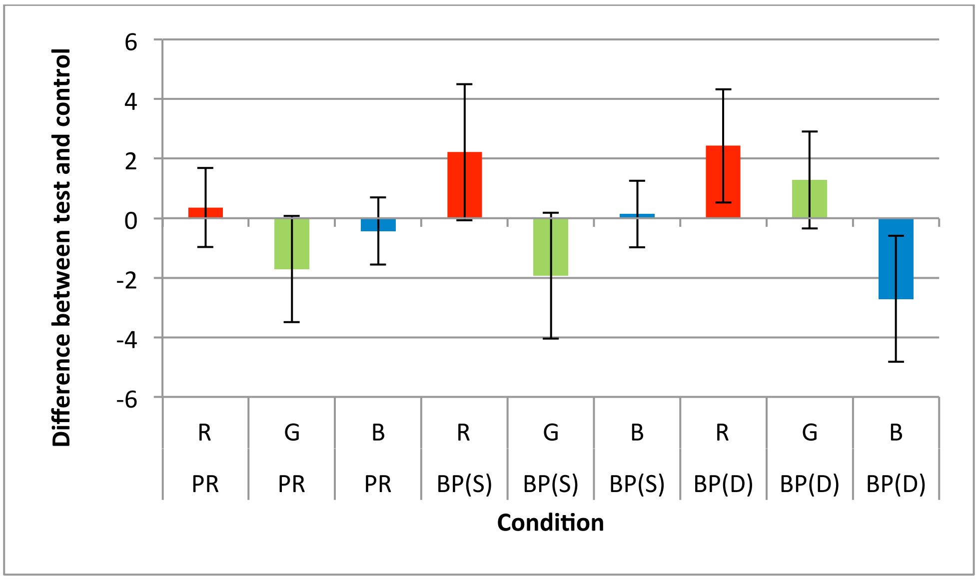

Figure 2: Summary of the physiological measurements. The mean differences in pulse rate PR, systolic blood pressure BP (S) and diastolic blood pressure BP (D) between the test and control light conditions are shown.

4. CONCLUSIONS

In this study, 42 participants took part in an experiment to explore the effect on their physiological response. Measurements were taken of blood pressure and pulse rate. When compared with the control condition (white light), the pulse rate increased under the red-light condition and decreased under the blue- and green-light conditions. The effects were not statistically significant, however; this is consistent with Jacobs and Hustmyer (1974) who found no effect of colour on heart rate.

When compared with the control condition, blood pressure (systolic and diastolic) increased under the red-light condition. However, there was no statistically significant effect of the test colour on blood-pressure change. This is consistent with Kaiser (1984) who noted that he had “unpublished data which show no differences in systolic blood pressure as a function of observers looking at grey, red, blue, green, or pink”.

Despite anecdotal evidence that colour affects blood pressure and heart rate, in this study we find no statistically significant effect despite using colour environments that were very intense and likely to be far more colourful than the environment in most practical applications. However, it cannot be ruled out that in this study there were simply too few participants to find a significant effect since although there were 42 participants there were only 14 for each colour condition. The observation that red did increase blood pressure and pulse rate (although not significantly) is intriguing however and further work is probably needed with much greater numbers of participants to be able to make a robust and general conclusion. All that can be said is that, in this study, no effects were found. It seems likely, that even if a further study with more participants finds a significant effect then the effect may not be very meaningful since the magnitudes of the differences (even under the relatively extreme conditions used in this study) were quite small.

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Effects of Font Size on Visual Comfort for Reading on a Tablet Computer

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ABSTRACT

To investigate the effect of display size on visual comfort for e-reading, two psychophysical experiments were conducted. During Experiment 1(iPad 2-size) and Experiment 2(iPod touch 4-size), 20 older and 20 young observers were presented with 190 pairs of document layouts. Each observer was asked to pick one of the two layouts, of which the observer felt more comfortable to read the text. The font size of Experiment 1 was bigger than the font size of Experiment 2. The scale values for the observer response were determined using the paired comparison method. The results of Experiment 1 and Experiment 2 show that older observers tended to prefer strong text-background lightness difference in a document layout, while young observers tended to prefer moderate lightness difference. The scale values from iPad 2-size to iPod touch 4-size for older and young observers shown that the difference of visual comfort between black background and others background is increased. However, the difference of visual comfort between white background and others background only increased for young observer. This phenomenon for young observers was different from the scale values for older observers.

1. INTRODUCTION

There have been extensive studies into the impacts of text-background contrast on visual comfort using desktop computer displays (Scharff 2002; Buchner 2007). Little was known, however, as to whether the findings also apply to e-reading devices, such as iPads or Kindle. There are more and more people using tablet computer displays for e-reading, it is important to know how users use these devices effectively and avoid any visual discomfort. The previous study(Darroch et al. 2005) shown that designers of interfaces for handheld computers provide fonts in the range of 8-12 point to maximize readability for the widest range of users. The equipment was HP iPAQ hx4700 which has a 65,000 colour TFT screen with a resolution of 640x480 pixels was used to present the text. The resolution of HP iPAQ hx4700 is smaller than the resolution of tablet computer such as iPad 2 or iPod touch 4. Our study aims to investigate the effect of display size(font size) for older and young observers reading on a tablet computer.

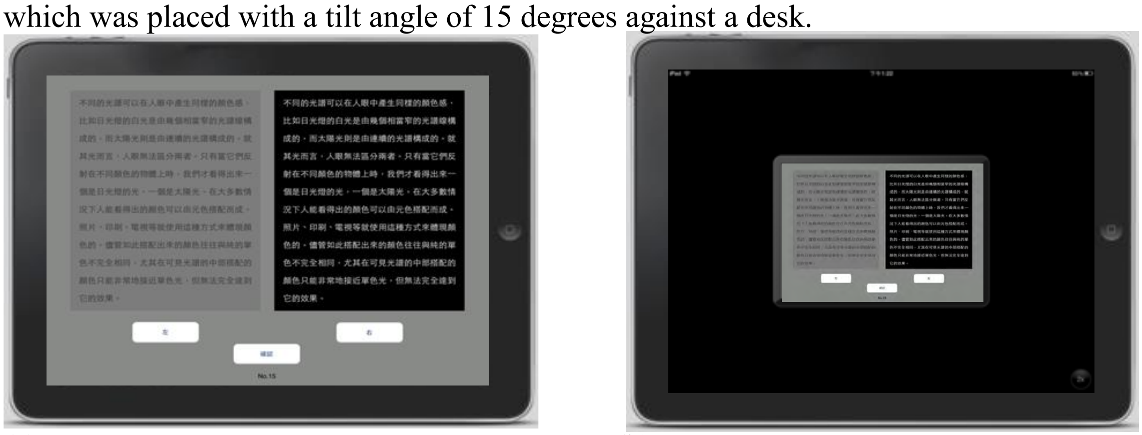
2. METHOD

To investigate the effect of display size on visual comfort for e-reading, two psychophysical experiments were conducted. During Experiment 1 and 2, each observer was asked to pick one of the two layouts, of which the observer felt more comfortable to read the text. The only difference of these two experiments is the font size of article shown on the iPad 2. Based on the 5 achromatic colours, 20 text-background combinations were generated, considering both positive and negative polarity conditions. Table 1 shows colorimetric measurement data for the 5 colours including luminance and the CIE values. The pair of document layout was composed by 2 text-background combinations from 20 text-background combinations. This resulted in 190 paired comparisons. Each document layout was presented on the same text, the only difference being the lightness values of the text and of the background for the two document layouts.

Table 1.CIE colorimetric data for colour samples used in Experiment 1 and Experiment 2

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

Twenty older(aged 60 years) and twenty young(aged 20-30 years) observers were presented with 190 pairs of document layouts on an iPad 2(as shown in Figures 1 (a)) during Experiment 1. Twenty older(aged 60 years) and twenty young(aged 20-30 years) observers were presented with 190 pairs of document layouts in a simulated iPod touch 4 size also shown on the iPad 2(as shown in Figures 1 (b)) during Experiment 2. The font size of Experiment 1 was bigger than the font size of Experiment 2. The display was situated in a darkened room, with the only light source coming from the iPad 2. The display peak white had a luminance value of 397.34 cd/m2, with CIE chromaticity (x, y) = (0.3005, 0.3115). The viewing distance was around 300mm between the observer and the iPad 2, which was placed with a tilt angle of 15 degrees against a desk.



(a) (b)

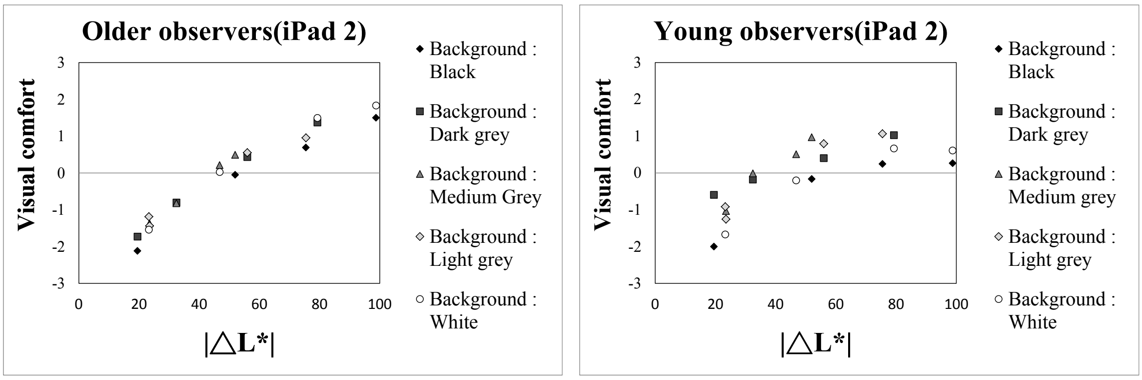
Figure 1: Examples of screen layouts for (a) Experiment 1 and (b) Experiment 2

3. RESULTS AND DISCUSSION

The scale values of visual comfort were determined using the paired comparison method (Thurstone 1927). The scale values obtained from Experiment 1 for older observers were plotted against the lightness difference value, as illustrated in Figure 3 (a). Obviously the CIE lightness difference between text and background affect the observer response. It is clear from the graph that the higher the lightness difference between text and background, the higher the visual comfort for older observers. Note this tendency does not seem to be affected by the background luminance. On the other hand, Figures 3 (b) shows that in general, for the lightness difference over 80 for young observers, the visual comfort value remains unchanged or even starts to decline. This tendency for young observers is different from that for older observers as described above.

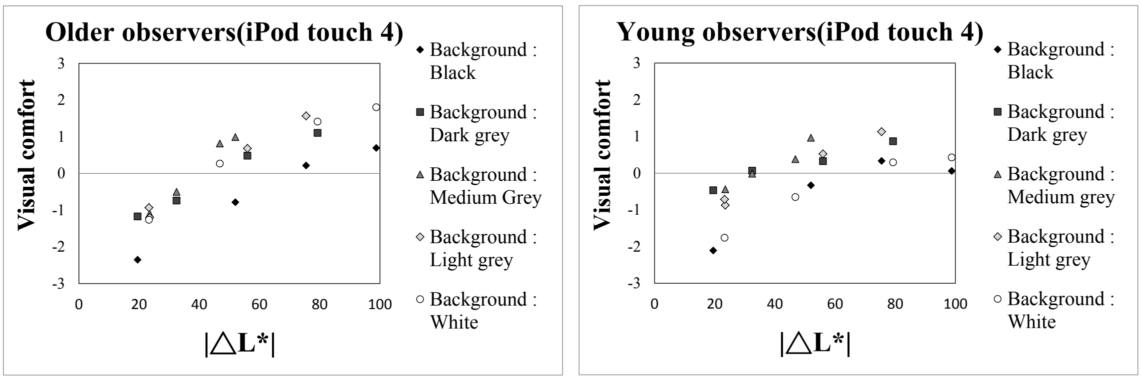
Figure 4 (a) shows the results of Experiment 2 for older observers. As illustrated in the graph, the higher lightness difference between text and background, the higher visual comfort for older observers. Such a trend does not seem to be affected by the font size of the article shown on the iPad2. This suggests that the older observers tended to prefer higher lightness difference between text and background in a document layout. For young observers, on the other hand, Figure 4 (b) shows that in general, the larger lightness difference between text and background, the higher visual comfort value, while for the lightness difference over 80 or so, the visual comfort value remains unchanged or even starts to decline.

The scale values from iPad 2-size(Experiment 1) to iPod touch 4-size(Experiment 2) for older and young observers shown that the difference of visual comfort between black background and others background is increased. However, the difference of visual comfort between white background and others background only increased for young observer.



(a) (b)

Figure 3: Visual comfort plotted against CIE lightness difference (△L) between text and background as results of Experiment 1 for (a) Older observers and (b) Young observers*



(a) (b)

Figure 4: Visual comfort plotted against CIE lightness difference (△L) between text and background as results of Experiment 2 for (a) Older observers and (b) Young observers*

4. CONCLUSIONS

Two psychophysical experiments were conducted to investigate the visual comfort for different font size, including young and older observers. According to the experimental results, older observers tended to prefer large lightness difference (Experiment 1 and 2) between text and background shown on the iPad 2. For young observers, on the other hand, a document layout with a medium lightness difference (Experiment 1 and 2) between text and background tended to be most comfortable to read. This suggests that the font size has little influence on the tendency of visual comfort for older and young observers. Note that the visual comfort of black background is the lowest scale values for older observers. In contrast, the visual comfort of black and white background is the lowest scale values only for young observers. This phenomenon for young observers is different from the scale values for older observers.

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Influence of spectral component of white light on the discomfort glare

—Contribution of image and non-image forming pathways—

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ABSTRACT

Discomfort glare is a remarkable issue on novel light sources such as solid state illuminating light sources (LEDs and OLEDs). In this research, we focused on the fact that solid state light sources differ greatly in spectral characteristics from conventional light sources. In our previous studies, we conducted subjective evaluation experiments using metameric lights with different spectral characteristics and the same photometric value to find out whether there are differences in discomfort glare. The results showed that although each luminance of test light was the same, discomfort glare has a clear dependency to spectral distribution of the test lights. In particular, excitation quantity around specific wavelengths had been correlated with discomfort glare evaluation. Therefore, we investigated the contribution of ipRGCs as non-image forming pathways and rods as image-forming pathways to the discomfort glare. We then found a correlation between the quantity of them and the psychophysical evaluation of discomfort glare.

1. INTRODUCTION

Recently, discomfort glare is a crucial issue regarding novel light sources such as LEDs or LEDs. There are many optical characteristics between traditional light sources and novel light sources. In particular, spectral distributions of those light sources are quite unique.

Our previous studies showed a clear dependency between spectral characteristics and discomfort glare perception (Toyota et al. 2014). In those studies, a series of spectral distribution of test light that had the same chromaticity as daylight [T = 6500 K, xy chromaticity (x, y) = (0.3127, 0.3290)] and the same luminance for all of those as metameric white lights was designed by combining several monochromatic lights with 20 nm spectral bandwidth. We employed several limitations to simplify the spectral designing process because it is well known that there are innumerable spectral distributions that correspond to the same chromaticity (Schmitt 1976). The central wavelength of each monochromatic light was preliminarily fixed (as shown in Table 1) and the combining ratio of each monochromatic light was optimized. Each test light was represented by a digitally-controlled spectrally programmable light engine (OneLight Spectra, OneLight Corp.). A series of subjective discomfort glare ratings by nine levels conforming to a conventional manner was conducted. Results showed that discomfort glare perceptions varied even if test light of the chromaticity and luminance had the same photometric value (as shown in Figure 1). Discomfort glare perception seems to be particularly related to the spectral intensity around the wavelength of 500 nm of white lights.

The aim of this study is to discuss whether the mechanism of the discomfort glare perception could be influenced by the spectral characteristics of light sources. We focused on the relationship between results of the discomfort glare ratings and several cellular responses. In particular, we are interested in how image or non-image forming pathways contribute to the discomfort glare perception.

Table 1. Spectral conditions of metameric white lights as test lights.

Condition	Central wavelength [nm]			Photometric value		
	λ_1	λ_2	λ_3	Lv [cd/m^2]	x	y
T1			507	18356.74	0.3117	0.3265
T2	450	610	533	18137.53	0.3132	0.3292
T3			555	18467.40	0.3125	3.3280
D1	450	568		18618.26	0.3156	0.3326
D2	491	610		18444.05	0.3156	0.3326
Broad				18275.97	0.3010	0.3297

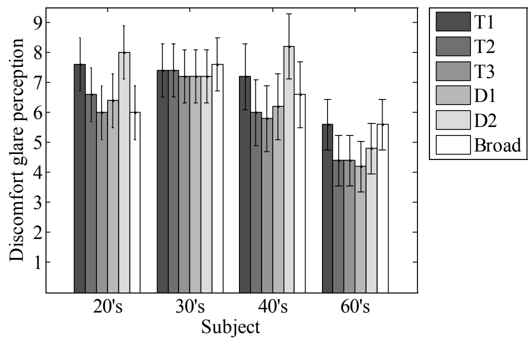


Figure 1: Discomfort glare ratings for metameric white light.

2. METHOD

We investigated the relationship between spectral characteristics and the discomfort glare perception mechanism focusing on the following perspectives.

(1) Luminance deviation caused by artifacts of reproducing the test light.

(2) Image forming pathways: rod photoreceptors.

(3) Non-image forming pathways: intrinsically photosensitive melanopsin retinal ganglion cells (ipRGCs).

2.1 Contribution of the luminance deviation

In the spectral distrubution designing process, chromaticity and luminance for all of the metameric white lights were fixed at the same value. Furthermore, fine tuning of each spectral distribution of the test light was performed to correct the representation error of the light engine. However, someone might claim that such variation of discomfort glare perception could be caused by residual errors of luminance correction. Therefore, we validated the relationship between discomfort glare ratings and luminance for each test light as combination of the quantity of L-cones and M-cones stimulation.

2.2 Contribution of image forming pathways

As another possibility of the deviations of discomfort glare perception, they might be influenced by scotopic vision or mesopic vision, because a series of experiments was performed in a darkroom in previous studies. We also tested contributions by the quantity of rods stimulation using scotopic luminous efficiency function (Judd 1951) to the discomfort glare ratings.

2.3 Contribution of non-image forming pathways

It is well known that ipRGCs are responsible for the mechanisms of circadian rhythms and the pupil responses (Tsujimura 2010). Moreover, recent studies have also shown melanopsion contributes to light perception mechanisms (Brown et al. 2012). Therefore, we also focused on the contribution of ipRGCs as non-image forming pathways to the discomfort glare perception.

To calculate the quantity of ipRGCs stimulation, an action spectrum combining spectral sensitivity of S-cones and rods (Brainard et al. 2001, Thapan et al. 2001, Rea et al. 2002) was employed as showin in Equation 1.

$$C(\lambda) = S(\lambda) + 0.67V'(\lambda) \quad (1)$$

Figure 2 shows a series of spectral distributions of metameric white light that was used in experiments, a composite action spectrum as sensitivity of ipRGCs and spectral sensitivity of rods as a solid line, a dotted line and a dashed line, respectively.

3. RESULTS

Results of the discomfort glare rating were normalized to control the individual difference because the discomfort glare rating scale refers to individual judgement. All of the rating score was converted to follow normal distribution $N(0, 1)$ in each subject.

3.1 Calculation results for quantity of stimulation

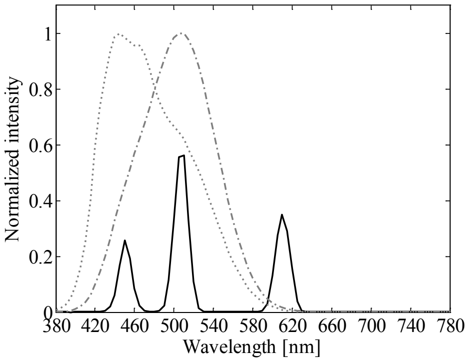
Figure 3 shows the relationship among each quantity of stimulation. Luminance as L-cones+M-cones and ipRGCs or rods were independent. However, the quantity of ipRGCs and rods were highly correrated (r = 0.9995).

3.2 Relationship between each pathway and the results of discomfort glare rating

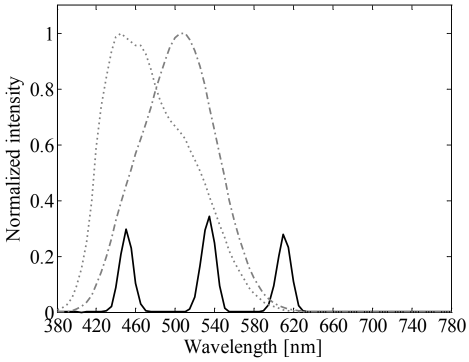
Figure 4 shows the relationship between each pathway and result of discomfort glare rating.

The luminance deviation for a series of test lights was irrelevant to the results of the discomfort glare ratings as shown in Figure 4 (a). In contrast, the quantity of rod stimulation and ipRGC stimulation are positively correlated with the discomfort glare perception ratings (r = 0.6648 and r = 0.6650, respectively) as shown in Figure 4 (c).

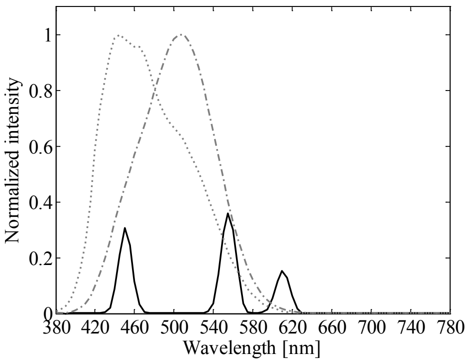
The results showed that a mechanism of the discomfort glare perception may be taking into the spectral contexts of the light sources.



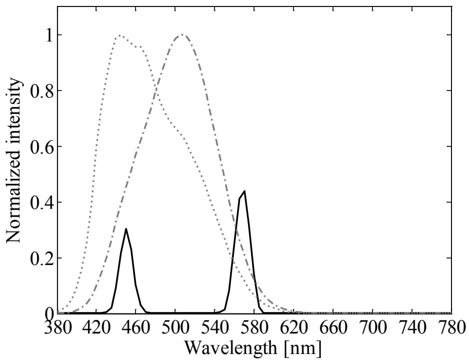
(a) T1



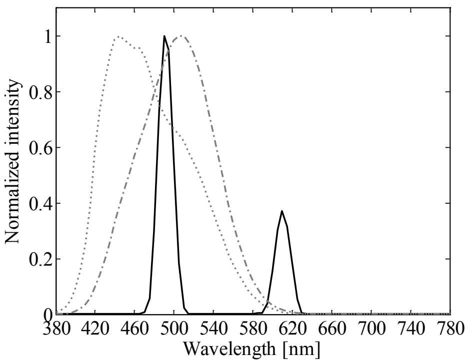
(b) T2



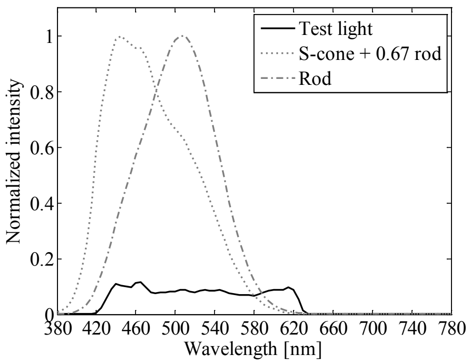
(c) T3



(d) D1

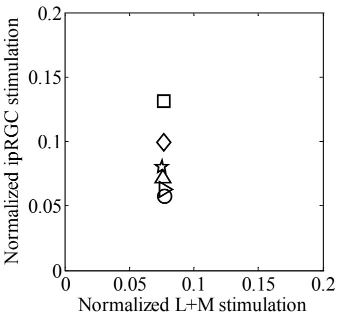


(e) D2

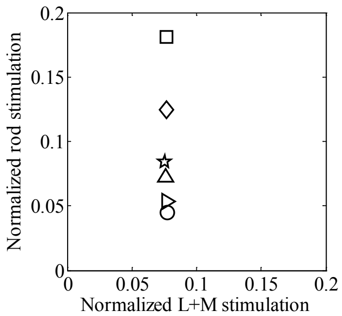


(f) Broad

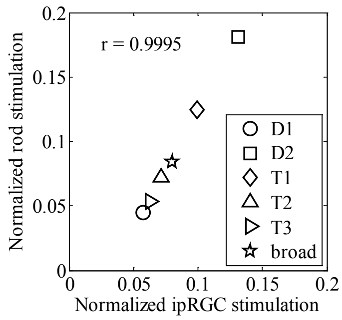
Figure 2. Spectral distributions of test lights.



(a) L+M vs. ipRGCs

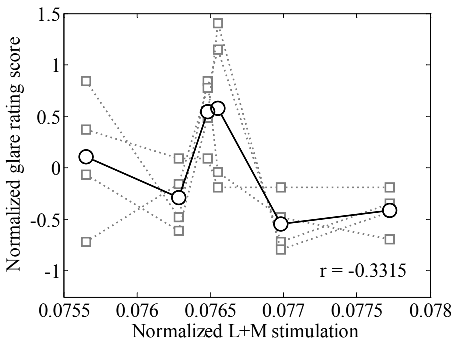


(b) L+M vs. Rods

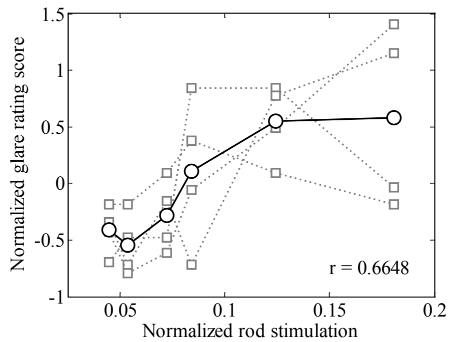


(c) ipRGCs vs. Rods

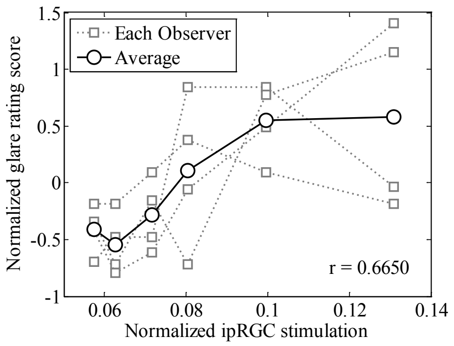
Figure 3. Quantity of stimulation



(a) L+M vs. Glare



(b) Rods vs. Glare



(c) ipRGCs vs. Glare

Figure 4. Comparison with glare evaluation and quantity of stimulation

4. CONCLUSION

In this study, we investigated the relationship between the results of the discomfort glare ratings and the quantity of cellular responses of visual or non-visual image forming pathways. Results suggest that the mechanism of the discomfort glare perception is influenced by both an image forming pathway that involves a scotopic vision and a non-image forming pathway.

Going forward, we will consider conducting simultaneous measurements of discomfort glare ratings and pupil diameters to explore the contribution of non-image forming pathways to the discomfort glare perception.

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Low-chroma colors suppress luminance-driven brain activation measured by fMRI

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ABSTRACT

The interaction between color and luminance information has been suggested by psychophysical research in human visual perception. To reveal the mechanism of the interaction, we measured brain activation while observing visual stimuli consisted of luminance and color information and varied the intensity of color information.

In the experiment, subject observed 10 color patches and achromatic background pattern. There were 4 conditions in saturation (value 0, 2, 4 and 6 in Munsell color system) of the patches in 4 levels. We measured brain activity while subject observed the stimuli. The brain activity was analysed in several visual fields.

The results showed that brain activations were the highest in the condition of chroma 0, and those of chroma 6, 4, and 2 conditions were following. It seemed that the brain activation for achromatic background pattern was suppressed by color patches and that is confirmed by additional control experiment. The amount of the suppression was more large in low chroma level condition.

1. INTRODUCTION

The interaction between color and luminance information has been suggested in human visual perception. Some reports suggested that luminance information is suppressed by the presence of color information psychophysically (Switkes et al. 1988, Kingdom 2003, Kingdom et al. 2010), though the mechanism of the suppression is not fully revealed.

To reveal the mechanism of the suppression, we measured activities of visual fields by fMRI, while seeing achromatic pattern and color patches. We manipulated saturation of the color patches as an index of color information intensity. It is also unclear in which level in visual cortex the suppression occurs. So we identified V1, V2, V3, V3A/B, hV4 and LO1 of each subject and analyzed the brain activity of those visual fields.

2. METHOD

13 subjects participated in the experiment (12 male and 1 female, mean age = 22.7 years old). All subject had normal color vision (tested by Ishihara Color Vision Test, SPP Color Vision Test and Panel D-15 Color Vision Test), and normal or corrected to normal visual acuity.

2.1 Apparatus

We used 3T MRI scanner (Verio, Siemense) for collecting fMRI images. Subject observed visual stimuli on the screen through the mirror (Figure 1). The viewing distance was 69 cm and the viewing angle was 31.5 degree × 25.2 degree, and the resolution of visual stimuli was 1280 pixel × 1024 pixel. The projector was controlled by CRS ViSaGe and calibrated by CS-200 color meter.

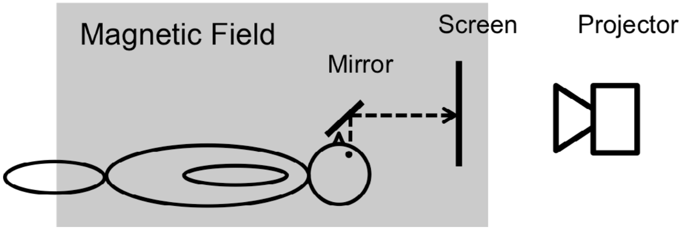

Figure 1: Experimental apparatus

2.2 Visual Stimuli

We presented 10 patches on the background pattern consisted of more than 700 achromatic oval patches (Figure 2). The patches were placed in the circle and the diameter of each circle was 3.0 degree. The patches were filled by 10 hues (5R, 5YR, 5Y, 5GY, 5G, 5BG, 5B, 5PB, 5P and 5RP on Munsell color system), and the position of each hue was randomized for each trial. The chroma of patches was set at one of 4 levels (6, 4, 2 and 0 in Munsell chroma). The Munsell value of the patches was constant (Value = 5) in all conditions (Figure 3). White fixation point was presented in the center of the stimuli.

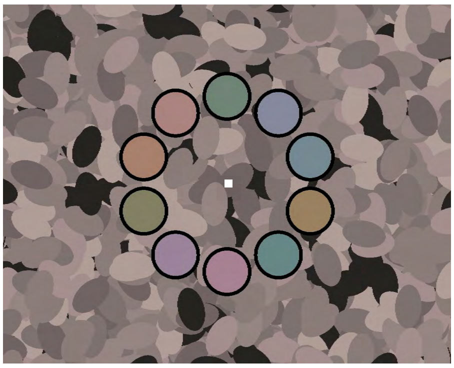

Figure 2: Overview of visual stimuli

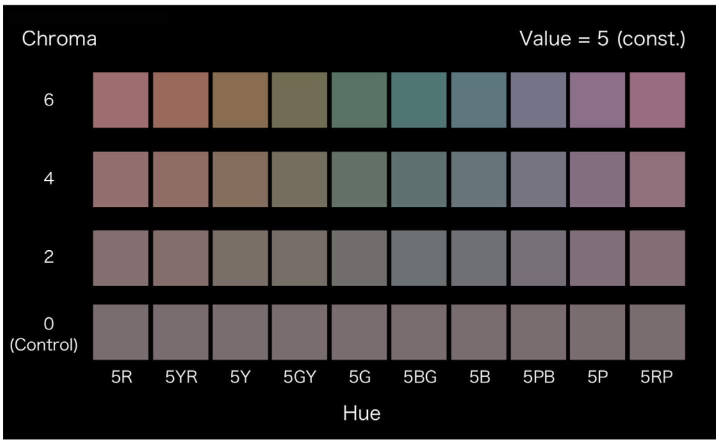

Figure 3: Hues of patches in each chroma level condition

2.2 Experimental Procedure

Each subject conducted 18 blocks of experiment. 1 block contained 12 trials (3 trials for each chroma level condition and presentation order was randomized in each block). Each trial contained stimulation phase and rest phase. The stimulation phase lasted 15 second and the visual stimuli and its scrambled pattern were presented alternatively at 1Hz. During the stimulation phase, subject watched the fixation point at the center of visual stimuli. The rest phase also lasted 15 second. In the rest phase, nothing were projected on the screen except that simple white figure is presented in first 5 second. Subject perform easy cognition task in first 5 second and rested in last 10 second. Brain activity was measured every 2.5 second during the block. (Figure 4)

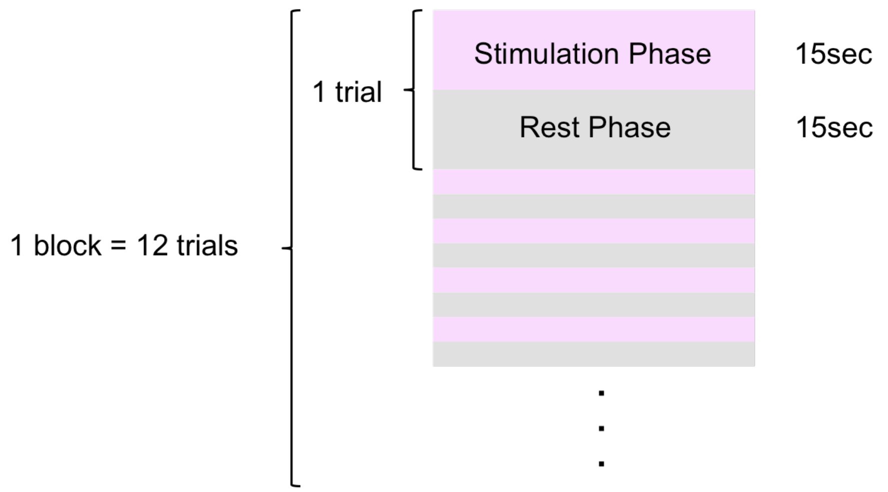

Figure 4: Experimental time course

3. RESULTS AND DISCUSSION

V1 and other visual fields were identified by travelling wave method (Wandell et al. 2007). Figure 5A shows the time course of normalized BOLD responses in V1 for each chroma level condition. Anterior half of the time course corresponds to the stimulation phase and posterior half of the time course corresponds to the rest phase. The responses of chromatic (chroma 2, 4 and 6) conditions were smaller than achromatic (chroma 0) condition. One way ANOVA indicated that there is significance main effect of chroma level condition. Post-hoc comparisons indicate significant difference between chroma 0 and 2 conditions.

To confirm that the results is not reflect brain activity driven by color information directly, we conducted control experiment in which the background pattern of visual stimuli was removed. Figure 5B shows the result of control experiment. There are no significant main effect of chroma level condition and differences in any combinations of the chroma level condition. These results suggest the presence of suppression on luminance information by color information in main experiment. In V2, V3, V3A/B, hV4 and LO1, the time courses of BOLD responses were similar to those of V1. It seems that the suppression occurs in early visual cortex, and the effect spreads to higher visual cortex.

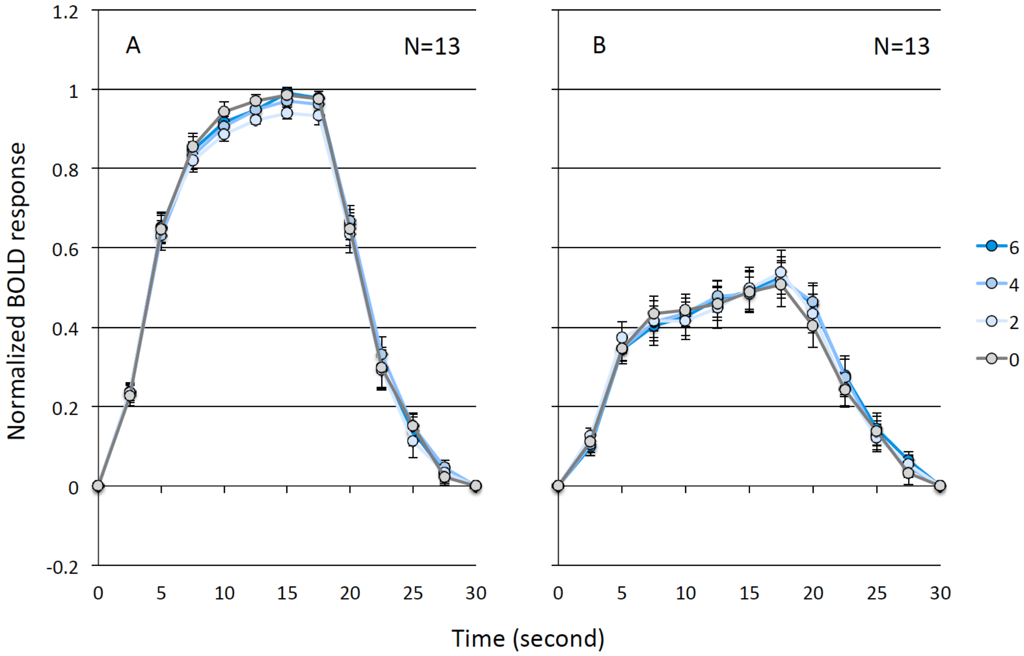

Figure 5: Normalized BOLD responses in V1

4. CONCLUSIONS

Brain activation by luminance information was suppressed when color information was attouched. The amount of suppression was larger when the color information was weak. The suppression was observed in V1, V2, V3, V3A/B, hV4 and LO1.

ACKNOWLEDGEMENTS

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A new evaluation method using the 100-hue test and age trends in color distinction ability

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ABSTRACT

It has often been noted that sight becomes yellowish with aging because of the lenses of the eyes taking on a yellow hue. As a result, the ability to distinguish color is diminished; however, the degree of decline in color distinction ability varies among individuals. Therefore, it is important to be able to determine how advanced the degree of decline is. However, there are no convenient methods for individuals to identify their status quickly.

This study proposes a new way of achieving this objective using the 100-hue test, which requires calculating the error scores of four trays and estimating color distinction ability by the size of the error score values. However, it cannot explain the extent to which color difference can be distinguished. This new index digitizes color distinction ability using probability and statistics theory and can estimate distinction ability as the color difference.

1. INTRODUCTION

It has often been noted that sight becomes yellowish with aging because of lenses of the eyes taking on a yellow hue. As a result, the ability to distinguish color is diminished. This can cause missteps and visual recognition failures, leading to accidents, collisions, or falls; the degree of the decline in color distinction ability, however, varies among individuals.

Yellow vison with aging was first regarded as a problem of vital function with the investigation by Boettner and Wolter (1962) on the optical transmittance of sample eyeballs. In Japan, Yoshida and Hashimoto (1990) aimed to clarify this problem. From measurements of the colors of the pictures taken with lenses or filters with the same wavelength transmittance characteristics as yellow vision, they estimated the sight of old people. However, their approach did not consider color adaptation as a physiological mechanism and the overestimation of effects of yellow vision. It is therefore desirable to estimate yellow vision as a psychophysical value by an experiment using old subjects.

The 100-hue test is a standard evaluation method of color distinction ability of a subject and has been studied by various researchers. Verriest (1963) conducted experiments under conditions of standard light C of illuminance level 100 lx with 480 subjects aged 10–64 years using the Farnsworth–Munsell 100-hue test and found that the error scores of senior subjects becomes high in the blue–green and red areas. In Japan, Yano et al. (1993) studied the influence of illuminance level and light color temperature on color distinction ability using the same 100-hue test as that used in this study. They made it clear that the distinction ability of senior subjects was inferior in every hue, especially the purple–red area, compared with young subjects and that the influence of light color temperature was small with a high illuminance level; however, the error scores of old subjects increased with a low illuminance of 100 lx, and the error scores of both young and old subjects increased with a low illuminance of 10 lx.

However, the error score is an ordinal scale comparing the relative magnitude relationship only. It does not provide enough information about the scale of difference of color caps distinguished by the subject. A new evaluation method is needed to measure this. In this paper, we propose a new evaluation method using the 100-hue test and report an example analysis using the new evaluation method.

2. PROPOSAL OF THE NEW INDEX OF THE COLOR DISTINCTION ABILITY USING THE 100-HUE TEST

2.1 100-hue test

The 100-hue test (Farnsworth, 1943) was developed by Dean Farnsworth in the 1940s to evaluate the color distinction ability. Figure 1 is a 100-hue test (ND-100) devised by Japan Color Enterprise Co., Ltd. This 100-hue test consists of 100 color caps that have the same value and chrome. The 100 color caps were lined up at equal intervals along the length of the test equipment, displaying 100 color difference units (NBS units) on the CIE 1964 (U*V*W*) color space. The 100 color caps were divided into four trays, each with 25 caps. The other two next-color caps were fixed at either end of each tray. Subjects were asked to replace the 25 removable caps as the hue gradually changed.

Figure 1: 100-hue test

2.2 Error score

The error score is the traditional evaluation index usually used in the 100-hue test. This score was calculated from the test order of the color caps lined by a subject by the procedure indicated in Table 1, and it indicated the degree of error. A high error score implied low color distinction ability. Table 2 shows a calculation example. However, the error score cannot provide information as to the degree of difference between color caps distinguished by the subject.

Table 1 : Calculation procedure of the error score

Step 1) Write the number of the color cap placed by a subject in space of "Test order" on table 2.
Step 2) Calculate the difference between the next 2 numbers of "Test order," and write the difference in a blank space between "・" and "・" on the "Difference" line.
Step 3) Add the next 2 numbers of "Difference," and write the calculation result in a blank space under "・" of the "Add" line.
Step 4) Subtract 2 from numerical values on the "Add" line and write the result on the "Error score" line.
Step 5) Add 25 error scores and it will be the sub-total error score. In total, 4 sub-total error scores and "total error score" will be obtained.

Table 2 : A calculation example of the error score

Position	100	1	2	3	4	5	6	7	8	9	10	11	12	13	14	·	·
Test order	(0)	1	2	3	5	4	6	9	8	7	10	11	12	13	14	·	·
Difference		1 ·	1 ·	1 ·	1 ·	2 ·	1 ·	2 ·	3 ·	1 ·	1 ·	3 ·	1 ·	1 ·			
Add		2	2	3	3	3	5	4	2	4	4	2	2	2	2	·	
Error score		0	0	1	1	1	3	2	0	2	2	0	0	0	0	·	

2.3 Development of a new color distinction index

It seemed appropriate to consider all color caps instead of the next color cap only for an accurate estimation of color distinction ability. Even when a subject has a confusion between color caps, the possibility exists that the subject has lined up the color caps in the right order by chance. Therefore, it is necessary to include a concept of the expectation value in a new evaluation index in order to take accidents into account.

The concept and procedure of this new index was as follows. Before deriving the value "n(i)," the confusion amount "C(i)" was defined. The C(i) calculation procedure was as follows. The difference between any two color cap numbers was defined as the distance between the two. The author assumed that the color cap was placed in the wrong position when the color cap that should be placed on the left side of color cap No.i was placed on its right side, or vice versa, and the confusion amount C(i) was defined by the equation

$$C(i) = \Sigma\, \gamma\, d_{ij} \qquad \cdots\cdots \text{equation (1)}$$

where "i" is the number of the target color cap, "d_{ij}" is the distance between color cap Nos.i and j, "γ" is a variable with a value of either "0" or "1" : when color cap No.j was placed in the wrong order in relation to color cap No.i, "γ" becomes "1", and when placed in the right order, "γ" becomes "0." Equation (1) provides the total distance between color cap No.i and all color caps placed in wrong orders. Table 3 is a calculation example where the confusion amount C(7) of No.7 become 7.

Each color cap usually has two color caps of the same distance. As the color caps were divided into 4 trays, however, the color cap No.27, for example, has only one cap with a distance of more than 2 (the color cap with a distance of 2 is only No.29). Therefore, when the color cap was lined up by mistake in such a case, a weighting factor (=2) was adopted. Calculation example 2 is indicated in Table 3.

Next, "n(i)" can be inferred from the confusion amount C(i). The "n(i)" value indicated the distance between the two confused color caps. Before n(i) was defined, the following two assumptions were made :

Assumption 1 : When confusion does not occur, all color caps are lined up in the correct order.

Assumption 2 : When confusion occurs, the color cap is lined up in the correct order with a probability of 1/2 and is lined up in the wrong order with a probability of 1/2.

When taking into account these assumptions, in a case where confusion does not occur at all, the expected value of C(i) is "0." When confusion occurs with the color caps with a distance of 1, two color caps with a distance of 1 will be lined up in the wrong order with a probability of 1/2 each. Therefore, when confusing color cap No.i with a color cap with a distance of 1, the expected value of the confusion amount C(i) will be 1 [= 1(distance) × 1/2 (probability) × 2 (caps)]. When confusion has occurred with a color cap with a distance of 2, two color caps with a distance of 1 and two color caps with a distance of 2 will be lined up in the wrong order with a probability of 1/2 each. Therefore, C(i) will be 3 [= 1 (distance) × 1/2 (probability) × 2 (caps) + 2 (distance) × 1/2 (probability) × 2 (caps)].

Equally, when confusion occurs with color caps with a distance of N, the expected value of the confusion amount C(i) will be expressed as

$$C(i) = \Sigma\, (i \times 1/2 \times 2) = N\,(N + 1)/2 \quad \cdots\cdots \text{equation (2)}$$

Equation (2) can be solved from N. It is possible to define the n(i) value using the confusion amount C(i) derived from an experimental result [see equation (3)].

$$N = n(i) = [-1 + \sqrt{(1 + 8 \times C)}]/2 \quad \cdots\cdots \text{equation (3)}$$

Table 3 : Calculation examples of n(i)

Calculation example 1: The confusion amount C(i) and n(i) value of color cap No.7

Order	100	1	2	3	4	5	6	7	8	9	10	11	12	13	14	······
Test order	(0)	1	2	3	5	4	10	9	8	7	6	11	12	13	14	······

When looking at color cap No.7,
the color caps placed on the right side by mistake are … No.6
the color caps placed on the left side by mistake are … No.8, No.9, No.10
Therefore, $C(7)= \Sigma\, (\gamma \times d_{7j})= 1 + 1 + 2 + 3 = 7$.
And $n(7) = \{ -1 + \sqrt{[1 + 8C (7)]}\} /2= [-1 + \sqrt{(1 + 8 \times 7)}]/2 = 3.275$.
In conclusion, it is presumed that the subject confused the color cap No.7 with the color cap of distance 3.275.

Calculation example 2 (weighting): The confusion amount C(i) and n(i) of color cap No.27

Order	25	26	27	28	29	30	31	32	33	34	35	36	37 ······
Test order	25	26	30	28	27	29	31	32	33	34	35	36	37 ······

When looking at color cap No.27,
the color caps placed on the right side by mistake are … none
the color caps placed on the left side by mistake are … No.28, No.30
The color cap No.25 is fixed. The color cap of distance 3 from No.27 is only No.30.
Therefore, the weighting factor (=2) is adopted on No.30.
There, $C(27) = \Sigma\, (\gamma \times d_{27j}) = 1 + 3 \times 2 = 7$.
And, $n(27)= \{-1+ \sqrt{[1 + 8 \times C(27)]}\}/2 = [-1+ \sqrt{(1 + 8 \times 7)}]/2 = 3.275$
In conclusion, it is presumed that the subject confused the color cap No.27 with the color cap of distance 3.275.

3. ANALYSIS OF AGE TRENDS IN COLOR DISTINCTION ABILITY USING THE NEW INDEX

3.1 The experimental outline

An experiment was conducted in the room with only artificial lighting from three wavelength fluorescent lamps. The average illuminance on a desk surface was 411 lx.

There were 34 subjects (nine people in their 50s, seven in their 60s, and seven in their 70s as the old groups, and 11 in their 20s as the young group). The subjects were checked using the Ishihara color blindness test plate, and the color vision of all subjects was normal. The subjects familiarized themselves with the 100-hue test before the experiment.

3.2 Relationship between age and color distinction ability

The average n(i) value for each subject for each tray was calculated. The results are indicated in Figure 2. As an overall tendency, old subjects had high n(i) values. In particular, the n(i) values of subjects in their 60s and 70s were high in the second tray consisting of the color caps in the green–blue area and in the fourth tray consisting of the purple–red area. And the individual variation was seemed to be large. Some subjects in their 50s, 60s, and 70s had the same n(i) values as the subjects in their 20s.

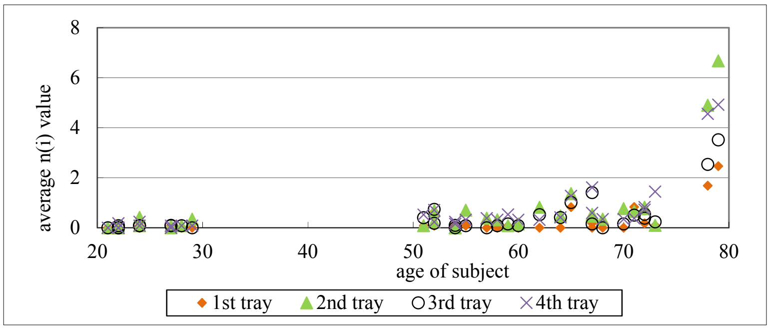

Figure 2: Average n(i) of each subject for each tray

Next, the average n(i) for each color cap for each age group was calculated. The calculation result is indicated in Figure 3. From No.10 to No.35 and from No.70 to No.80, the n(i) value was low for every age group, and the differences between the n(i) values among age groups were small. On the other hand, the differences between the n(i) values among age groups were large from No.35 to No.60 and from No.85 to No.5. The older group tends to have higher n(i) values.

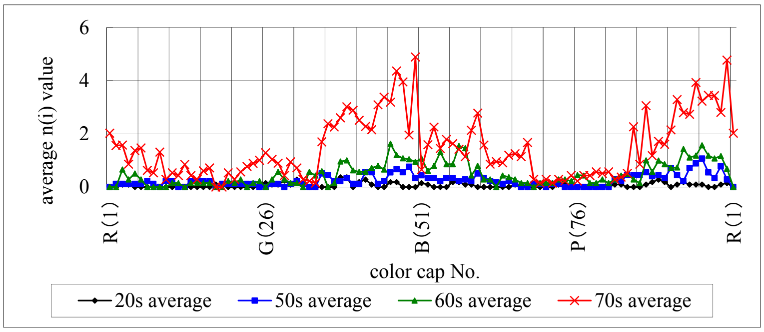

Figure 3: Average n(i) of each color cap for each age group

One hundred color caps were divided into 10 hues of the Munsell color system to make the result indicated in Figure 3 easier to understand. Figure 4 shows the n(i) value of each hue for each age group. As seen in Figure 4, the subjects in their 20s can distinguish all color caps almost perfectly. The older subject group had higher n(i) values on almost all of the hues than the young group. Particularly, the distinction ability falls suddenly for those in their 60s and 70s. This tendency was conspicuous in the hues of G, BG, B, and RP. On the other hand, the decline in the distinction ability in the hues of YR, Y, GY, and PB was inconspicuous. Although no subjects in their 30s and 40s participated in this experiment, it can be surmised that color distinction ability does not fall gradually with age but rather that the decline in color distinction ability appears as a sudden change after the 50s.

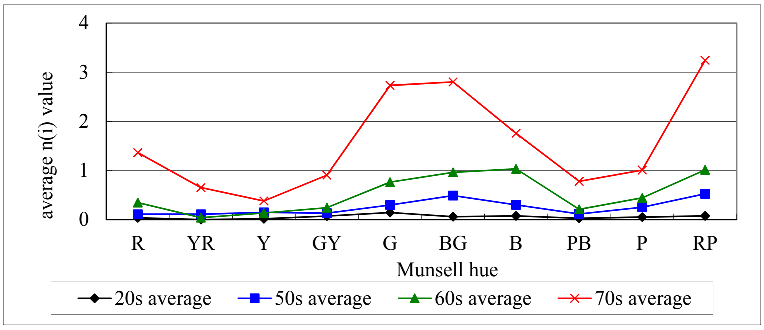

Figure 4: Average n(i) of each hue for each age group

4. CONCLUSIONS

Yellowing vison with aging is widely known, but there were no ways to assess color distinction ability correctly and easily. The error score of the 100-hue test is used as one measure of judgment, but it cannot explain the extent to which color difference can be distinguished. The new index proposed in this paper is different from the error score in two ways. First, a relationship between the target color cap and all other color caps is taken into consideration in the new index. Second, the new index is based on a concept of probability and statistics. This new index, the n(i) value, displays distinction ability as the difference between the color caps, but if the color difference between the color caps is known, the distinction ability can be estimated as the color difference.

The results of the test of 34 subjects in their 20s–70s was analyzed using this new evaluation index. The results indicated that color distinction ability in the G–BG–B area and the RP–P area falls conspicuously in subjects in their 50s and over. Individual variation was found to be large, with some subjects in their 50s to 70s having the same distinction ability as those in their 20s.

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Study on image statistics when color attracts human attention

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ABSTRACT

Computational models of human visual attention predict candidate locations in a visual scene to which human may pay attention by using bottom-up visual features such as orientation, color, and luminance (Itti et al., 1998). These features are assumed to contribute equally to constitute a single saliency or conspicuity map. A previous study applied a machine learning technique to seek the optimal weights for the features, and showed that the weight for orientation is larger than those for other features (Zhao and Koch, 2011). Although the result suggests the dominance of orientation for the deployment of attention based on low-level features, it has not been clarified whether relative efficiency among low-level features is always constant in individual images. First, we computed orientation-based and color-based saliency maps of around 500 natural images, and evaluated prediction accuracy by means of the area under the curve (AUC). The results showed that orientation-based saliency outperforms color-based saliency, on average, which is consistent with the result of the previous study. The images were sorted based on the difference of AUC scores between color and orientation so that we classify the images into two categories: color-dominant and orientation-dominant images. For around 25% of the images, color information was more effective than orientation information to predict gaze locations. We also obtained image statistics of the images in CIE $L^*a^*b^*$ color space to characterise what properties of the images yeilded the better performance in color-based saliency. We found that skewness and kurtosis of a^* were significantly larger in color-dominant images than those in orientation-dominant images. These results suggest that the simple image statistics could determine low-level visual features that attract attention in humans.

1. INTRODUCTION

Brain selects and processes important or meaningful information and ignores others. Such a selection mechanism is called visual attention, which allows us to process parts of external world relevant to ourselves among enormous information. However, fundamental mechanism of visual attention is less understood. Several psychophysical studies argued relationships between attended locations and gaze positions (e.g., overt attention; Posner 1980), and therefore, most computational studies tried to predict human gaze locations. One of the most successful concepts to predict gaze shifts is the saliency map which visualizes attractiveness of each spatial position in a given image (Koch and Ullman, 1985; Itti et al., 1998). In this saliency map approach, it is assumed that the different low-level features attract human attention independently. Low-level visual features such as orientation, color, and intensity (luminance) are extracted topographically, and they are combined into a saliency (conspicuity) map.

Most of the models hypothesize that individual features contribute equally to constitute a saliency map (e.g., Itti et al., 1998). A previous study has made an attempt to seek the optimal weights for the low-level visual features to predict gaze positions among natural images, and showed that the contribution of orientation tended to be larger than other low-level features (Zhao and Koch, 2011). Although the result suggests that orientation information is useful to predict gaze shifts, it has not been investigated whether relative efficiency among low-level features should always be constant for individual images.

First, we investigated performance of orientation and color information to predict gaze shifts in individual natural images. We obtained saliency maps from single features, and found the dominance of orientation-based saliency map in the prediction of gaze locations compared to that of color-based saliency map on average, reproducing the finding of the previous study (Zhao and Koch, 2011). We compared prediction accuracy of gaze shifts between orientation-based and color-based saliency maps of individual images, and found that color-based saliency predicted gaze shifts more accurately for approximately 25% of natural images. This result suggests that efficient visual features for predicting gaze shifts could be different among images.

We examined characteristics of the images that yielded the dominance of color information. It is reported that brain takes advantages from the statistical structures of natural images by means of efficient processing (Hoyer and Hyvärinen, 2000; Olshausen and Field, 1997), so that image statistics are candidates for explaining the better performance of color-based saliency. In the present study, we utilized four statistics (mean, variance, skewness and kurtosis) of the images in CIE $L^*a^*b^*$ color space. We found that skewness and kurtosis of a^* are significantly larger when color capture gaze shifts, suggesting that simple image statistics could be the descriptor of low-level features which capture human's attention.

2. METHOD

2.1 The model

Implementations of saliency map have been published elsewhere (e.g., Itti et al., 1998; Hiratani et al., 2013; Judd et al., 2009; Zhao and Koch, 2011). The essence of computation is given below. Low-level visual features (orientation, color, and intensity) that are represented in early visual cortices are extracted topographically from an input image, yielding feature maps.

The attractiveness of a visual feature is not determined by itself, rather depends on context. For instance, one feature (e.g., a red bar) surrounded by similar features (e.g., magenta bars) is less attractive compared to the case that the feature surrounded by dissimilar features (e.g., green bars). In the model, this mechanism is realized by a map-normalization operator which reduces attractiveness of a feature that has multiple peaks of values (Itti et al., 1998).

Range of values in each feature maps is different so that the maps are normalized. Feature maps are summed linearly to obtain final output (saliency map) that represents attractiveness of each spatial position. In the present study, we obtained saliency map from single features (orientation or color) in order to investigate predictability of each visual features.

2.2 Natural images and eye-tracking data

Natural images and eye-traking data when perticipants looked the images were taken from MIT dataset (http://people.csail.mit.edu/tjudd/WherePeopleLook/index.html). We choosed natural images whose size is 1024×768 pixels (n = 463). The choosen natural images included various objects (e.g., animals, foods, buildings, and vehicles), and various scenes (e.g., outdoor/indoor and urban/nonurban scenes). 15 subjects perticipated in experiments for eye-tracking. More details of the experiment are described in other pubulished article (Judd et al., 2009).

2.3 Evaluation of the model

Prediction accuracy of a saliency map is evaluated by Receiver Operating Characteristics (ROC) in terms of Area under the ROC Curve (AUC). AUC is popularly used to evaluate the performance of a saliency map (Judd et al., 2009; Zhao and Koch, 2011). Obtained saliency map was binarized at p % threshold of the map. Then, we obtained the rate of human fixations within the map. A hit rate curve is plotted as the function of threshold by changing threshold p. The area under the hit rate curve indicates the prediction accuracy of the model.

3. RESULTS AND DISCUSSION

The purpose of this study is to investigate whether efficiency of individual features to predict gaze locations is kept constant on individual images, and to identify chracteristics of natural images that lead the better performance of color information. We obtained saliency map from either orientation or color, and showed that orientation-based saliency outperforms color-based saliency on average (AUC scores are 0.69±0.12 for orientation, 0.60±0.15 for color; mean ± SD. This is consistent with the result of the previous study (Zhao and Koch, 2011). We analysed performance of each feature by taking the difference of AUC scores between color-based and orientation-based saliency map of individual images. Natural images were classified as color-dominant and orientation-dominant images. The number of color-dominant images was 120 out of 463. Figure1 shows the examples of color-dominant and orientation-based dominant image. The color-dominant images tended to contain one or two large objects of which color and luminance are different from a background, and the orientation-dominant images tended to have monochromatic objects as salient image features.

We examined the characteristics of images that lead the better performance of color-based saliency map. It has been reported that brain takes advantages from statistical structures of natural images (Hoyer and Hyvärinen, 2000; Olshausen and Field, 1997), so that we obtained four image statistics (mean, variance, skewness, and kurtosis) of the images in CIE $L^*a^*b^*$ color space. Figure2 shows skewness and kurtosis of the top 15 color-dominant and the top 15 orientation-dominant images. There are significant difference of skewness and kurtosis of a^* between color-dominant and orientation-dominant images (skewness of a^* is 1.43±3.94 for color dominant images and 0.13±1.12 for orientation dominant images, t-test, $p < 0.05$; kurtosis of a^* is 13.32±89.65 for color dominant images and 6.78±35.06 for orientation dominant images, t-test, $p < 0.05$; mean ± SD). The finding agrees with the concept of saliency. For instance, one colored object becomes highly salient when surrounded by achromatic objects (in this case, skewness and kurtosis of *a** or *b** are expected to become larger). In contrast, human seeks other cues such as orientation if color does not provide useful information (e.g., a uniform colored image yields low skewness). The result demonstrated that the image statistics determine low-level visual features which capture human attention.

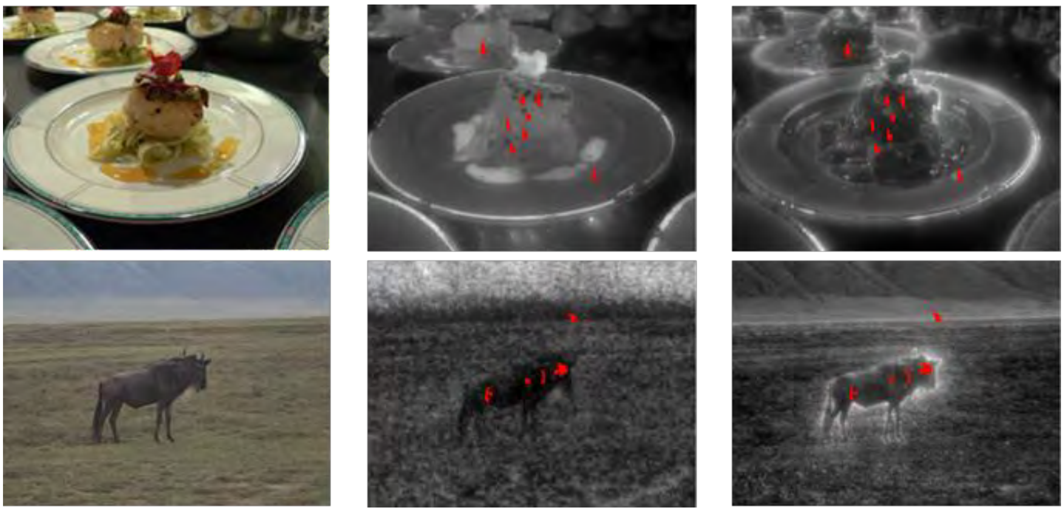

Figure 1: Example outputs of the model. The image which is accurately predicted by color-based (top row) and orientation-based saliency maps (bottom row). Input images (left column). Color-based saliency map (center column) and orientation-based saliency map (right column). Intensity of the maps represents estimated attractiveness at each spatial position. Gaze shifts in one subject are superimposed to the saliency maps. Red symbols represent fixation points.

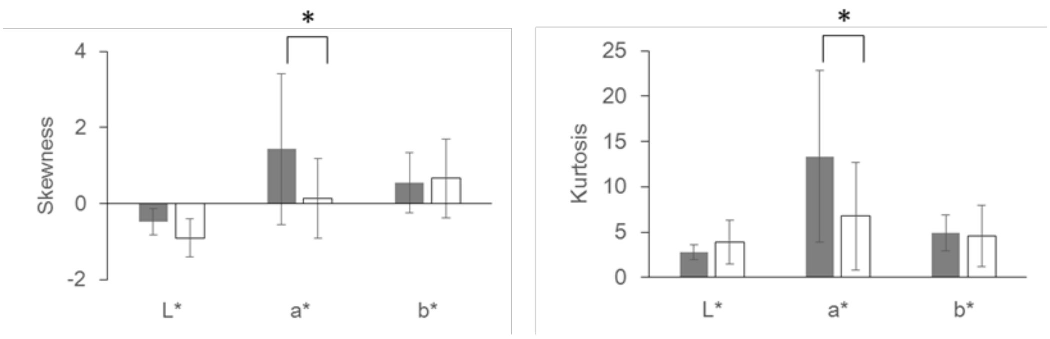

*Figure 2: Skewness (left) and Kurtosis (right) of natural images in CIE L*a*b* coordinates. Gray and white bars indicate averaged statistics of 15 color-dominant and orientation-dominant images, respectively. Error bars indicate standard deviations.*

4. CONCLUSIONS

This article demonstrated that effectiveness of the low-level visual features that capture attention is different among natural images. Although the number of analysed images is limited, color-dominant images had larger skewness and kurtosis in a^* than those of orientation-dominant images. The result provides the idea that the simple image statistics could determine low-level visual features that attract attention in humans.

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Prior knowledge modulates peripheral color appearance

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ABSTRACT

Color perception deteriorates with increasing eccentricity in the visual field. Here, we investigated peripheral color perception using a painting method, asking how prior knowledge affects color appearance. A professional artist was presented with complex, cluttered images in the visual periphery. The task was to paint as accurately as possible how each image appeared. Eye tracking assured that the image was only viewed in the periphery. The resulting paintings were strongly compromised. After finishing a painting, the target image was freely viewed to acquire knowledge about it. Next, the same image was presented at the same peripheral location and painted again. There were two conditions for the second painting. In the first condition, the image was again masked when not fixating the fixation dot (as during the first presentation). In the second condition, the image was not masked, allowing saccades to the image. In both conditions, the paintings resulting from the first presentation showed clear differences compared to the second presentation. Salient color regions in the images that were not painted during the first presentation, were painted during the second presentation. Color changes were less pronounced in the first than in the second condition. Importantly, several image features were remembered but not painted during the second presentation, showing - in addition to subjective reports – the perceptual nature of the effect. Our results indicate that prior knowledge of peripheral targets strongly shapes perception.

1. INTRODUCTION

Color sensitivity deteriorates with increasing eccentricity (Moreland, 1972). The extent of this deterioration is still unclear. For example, it has been proposed that color vision is absent at eccentricities larger than 40 degrees of visual angle (Moreland & Cruz, 1959). However, it has also been shown that, depending on the stimulus properties, color can still be discerned at larger eccentricities, even up to 90 degrees (Noorlander, Koenderink, den Ouden, & Edens, 1983). Peripheral vision is not only characterized by diminished color sensitivity. One of the major limiting factors of peripheral vision is crowding - the deleterious influence of neighboring items on the perceptibility of a target (e.g., Levi, 2008). For example, an isolated letter that is easily recognized in the periphery is indiscernible when other letters are presented in close proximity. Crowding depends on several factors, e.g., eccentricity (Bouma, 1970), target-flanker similarity (Kooi et al., 1994), grouping (Sayim, Westheimer, & Herzog, 2010), and prior knowledge (Zhang et al., 2009). The influence of crowding on color perception is rarely investigated. However, it has recently been shown that the perception of hue and saturation deteriorates when the target is crowded (van den Berg, Roerdink, & Cornelissen, 2007). Using visual noise

(Greenwood, Bex, & Dakin, 2010), and letters and letter-like symbols (Sayim & Wagemans, 2013), it has been shown that crowding does not only impede performance but also changes appearance.

Here, we used a painting method to investigate appearance changes in complex, cluttered images, asking first, how color appearance is influenced by crowding, and second, whether knowledge about target images modulates appearance. This explorative painting method in conjunction with complex images allowed us to explore these questions simultaneously, using the entire image as a target. We found strong modulation of color appearance, and a clear influence of knowledge on target perception.

2. METHOD

We investigated peripheral color appearance with a painting method. A professional artist (the last author of this manuscript, TvU) was presented with complex, cluttered images in the right visual field. The task was to capture as accurate as possible how the image appeared.

2.1 Apparatus

Stimuli were presented on a Sony Trinitron GDM-F520 CRT monitor driven by a standard accelerated graphics card. The screen resolution was set to 1152 by 864 pixels; the refresh rate was 120 Hz. A chin and head rest was used to restrict head movements. The screen was viewed from a distance of 58 cm. Eye positions were monitored by an SR Research EyeLink 1000 running at a sampling rate of 1000 Hz. An elevated, inclined drawing board was placed in front of the head and chin rest to allow for painting without leaving the head rest. Colored crayons were used to paint. MATLAB (Mathworks, Natick Massachusetts, USA) in combination with the Psychophysics toolbox (Brainard, 1997) was used for stimulus presentation.

2.2 Stimuli

Stimuli consisted of two complex, cluttered images (Figure 1). Images were 15.0 degrees wide, 10.2 degrees high, and were presented on the horizontal midline of the screen, centered at 12 degrees eccentricity in the right visual field. The first image consisted of various shapes, such as ellipses, rectangles, and lines (the “Miro”-Image, Figure 1A, left). The second image consisted of an arrangement of rectangles with different sizes and colors (the “Mondrian”-Image, Figure 1B, left). Both images varied strongly in color and luminance. Images were presented on a gray background (50.5 cd/m^2). A fixation dot was presented at the center of the screen. To prevent central viewing of the stimulus, the target images were masked by a pattern mask of the same size as the target whenever the participant did not fixate the center of the screen (except during the second “Mondrian” painting; see Procedure).

2.3 Procedure

Each target image was painted twice. The participating artist (TvU) fixated on the fixation dot in the center of the screen. For the first painting of each image, the target image was only presented when fixating the fixation dot, otherwise it was masked. The task was to reproduce the appearance of the stimulus in as much detail as possible. After completion of the painting, the image was shown foveally for visual inspection. Next, the target image was again presented in the periphery and painted once more. In the "Miro"-condition, the target image was again only shown when fixating the fixation dot, and masked otherwise. In the "Mondrian"-condition, the target image was not masked. There was no time restriction for (peripheral) viewing of the target image, and finishing a painting, allowing the participant to focus attention on all areas of the presented target. The painting of one image took about 40 minutes.

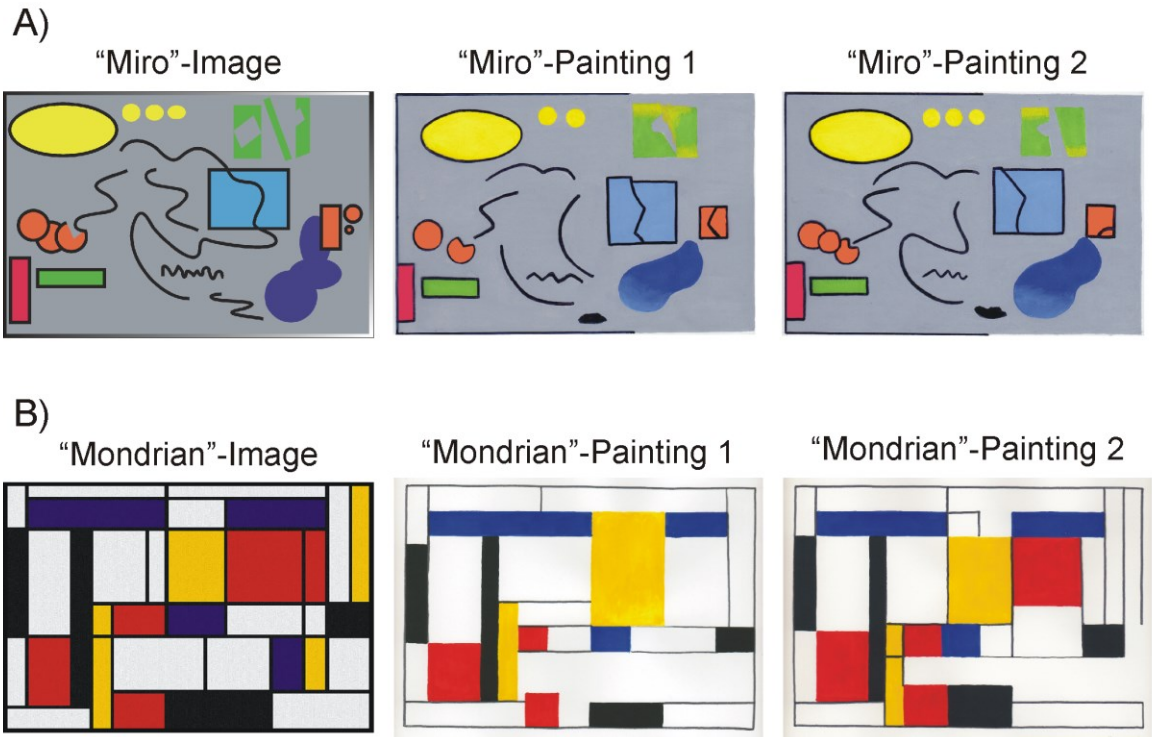

Figure 1: Original images and painting results. Target images (left column) were presented at 12 degrees in the right visual field. (A) In the "Miro"-condition, the target image was masked during the first ("Miro"-Painting 1) and second ("Miro"-Painting 2) presentation when the fixation dot was not fixated. B) In the "Mondrian"-condition, the target image was masked during the first presentation when the fixation dot was not fixated ("Mondrian"-Painting 1); during the second presentation, it was not masked ("Mondrian"-Painting 2).

3. RESULTS AND DISCUSSION

The results show a strong decrease in accuracy with increasing eccentricity (Figure 1). Sections of the target images closer to the fovea were reproduced more accurately, i.e., more similar to the target image, than sections farther in the periphery (note that due to the imprecision of the painting method, only large, categorical differences are of interest here). In the first painting of the "Miro"-Image (Figure 1A, center, "Miro"-Painting 1), several shapes and parts of shapes are depicted distorted or left out entirely. For example, instead of an orange rectangle and two orange discs (right outer edge of the painting), a single square structure was painted. However, clear differences between the target image and the painting occurred also closer to the fovea. Instead of depicting three circular/ oval items in the upper left quadrant, only two items were painted. Similarly, close to the left edge (below the horizontal midline) an empty/ gray gap was introduced between the two painted orange discs. Noticeable deviations of color appearance occurred in sections far in the periphery. In particular, uniformly colored items were depicted to contain additional hues (the green pattern in the upper right quadrant was depicted in green and yellow), or varied in regard to saturation (the bluish structure in the lower right quadrant). After free visual inspection, i.e., acquisition of detailed knowledge of the target image, the image was again presented in the visual periphery when fixating the center of the screen, and painted a second time (Figure 1A, right, “Miro”-Painting 2). The second painting was clearly different compared to the first painting. In particular, the previously missing circular/oval items were depicted in the second painting. Reports by TvU pointed at strong changes of perception compared to the first painting, e.g., “I now see clearly that there are three yellow discs”. Subjective reports also indicated a general reduction of vagueness of color appearance (“the green is clearer now”).

The first painting of the “Mondrian”-Image shows similar effects as the first “Miro”-Painting. Several (missing or added) white gaps, and missing regions with different hues show that peripheral color perception was compromised, again increasing with eccentricity. The two red rectangles and the yellow rectangle in the upper right quadrant, as well as the blue and yellow rectangles in the lower right quadrant are entirely missing. Subjective reports indicated that the large yellow rectangle sometimes appeared in parts orange – similar color mixtures and perceptual switching between different color categories at the same location were reported with other paintings (results not shown here). The second painting of the “Mondrian”-Image showed clear differences compared to the first. A large difference occurred in the upper right quadrant where a red square/rectangle present in the image was painted instead of a white region depicted in the first painting. Also, the number of deviating white gaps was reduced in the second painting.

Our results reveal a strong loss of accurate perception of detail which increased with eccentricity, reflecting the combined effect of crowding and reduced sensitivity in the peripheral visual field. In particular, the loss of large regions with strong color contrast are noticeable, raising questions regarding their visibility, for example, in standard detection experiments (note that crowding usually does not influence detection). Differences between the first and second paintings indicate appearance changes by knowledge, both when knowledge was only acquired between trials (“Miro”-condition), as well as between trials and during the second trial (“Mondrian”-condition). The large difference between the first and second trial in the “Mondrian”-condition (the red rectangle in the upper right quadrant), suggests that intermittent acquisition of knowledge strongly changed appearance. Importantly, several details of the images were remembered during the second paintings but not perceived and therefore not painted, indicating that perceptual changes, and not abstract memory, underlie these results. For example, the blue and the two yellow rectangles in the right half of the “Mondrian”-Image were remembered but not depicted (Figure 1B, right). The still clearly visible decrease of accuracy with eccentricity supports this interpretation, as do subjective reports regarding the perceptual nature of the appearance changes. Note that to paint the image, all regions of the image were (covertly) attended several times allowing maximum reduction of uncertainty about appearance. Similar, even though less pronounced, differences between the first and second painting in the "Miro"-condition show that the effect is not due to the continuous presentation of the image in the Mondrian-condition.

4. CONCLUSIONS

Our results show that peripheral vision can be strongly modulated by knowledge. In particular, images that were unknown to the participant and only viewed peripherally (first painting) resulted in different perceptions when additional knowledge was acquired about the images (second painting). The large color effects in the unknown images cannot be explained by diminished color perception in the periphery as images were sufficiently close to the fovea where color vision is good. Abstract memory does not explain the appearance differences between the first and second paintings because several details were remembered but not perceived. Rather, we suggest that our results are due to vague percepts caused by crowding which are strongly susceptible to prior knowledge (see also, Sayim & Wagemans, 2013). Future experiments will show in how far the presentation of highly complex images modulates effects of crowding. We propose that the painting method is useful to explore the perception of complex stimuli, in particular to capture perceptually vague phenomena, as painting is more precise and efficient than, e.g., verbal descriptions when stimuli are complex. Finally, we suggest that artists who depict peripherally viewed scenes (e.g., Pepperell, 2012) for scientific or artistic purposes may benefit from the use of unknown images and gaze contingent presentation.

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Decision of Validness in Custom Color Name of JIS Z 8102

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ABSTRACT

This paper is about a trial to decide valid color names from 122 foreign custom color names in JIS Z 8102 (Japan Industrial Standard). In Japan, “Systematic” and “Custom color name” are often used. Especially, custom color name have a lot of origin – ex. plant, material ,region name etc. But it was not revealed whether each custom color name is valid or not. To decide valid color names, 56 subjects had Color Matching Task and color cluster was constructed from the result of color choice task in each name. Based on the cluster and Berlin & Kay’s 11 basic colors, 26 colors were decided as validness.

1. INTRODUCTION

Generally, color names tend to be used for daily communication in color. Especially in Japan, “Systematic” and “Custom color name” are used based on JIS Z 8102 (Japan Industrial Standard). Custom color names have origin in plant, material, food and so on. But it was not revealed whether each custom color name is used accurately or not.

To clarify this question, 3 indices “Color distance between a given standard color of JIS Z 8102 and subject’s choice for it in CIE L*a*b*”, ”Familiarity of color name” and “Imaginableness of color name” were acquired from color choice experiment and questionnaires to subjects (2009, Yoshizawa et al). These indices lead new 2 parameters “Degree of recognition” and ”Distance in color space” in each color name for decision of how much recognition in each custom color name.

In another aspect, distinguishes between in custom color names included basic color – ex. Chinese red, Chartreuse Green, cobalt blue and so on - were clarified, and valid color names were decided in each group with included basic color based on Berlin & Kay’s 11 color words (2009, Yoshizawa et al).

Against this aspect, the aim of this research is to reveal validness of Custom Color Name in 122 foreign custom color name of JIS Z 8102（except of color names “Gold” and ”Silver”）.

First, cluster analysis makes some color name clusters from data of color choice experiment in each 122 name. Finally, representational color is decided based on Berlin & Kay’s 11 basic color names and color difference between a given standard color of JIS Z 8102 and subject’s choice for it in CIE L*a*b*” in each cluster and validness of each custom color can appear.

2. METHOD

2.1 Color Matching Task

Each subject was given the task of matching color names with the respective colors. Figure 2 shows a related tool. Subjects read a custom color name written on a card and chose a color from 468 color chips. In case they could not match a color with its name, they had to choose a color chip. Custom Color Chart and PCCS 201-L (both are Color Chart: Japan Color Enterprise Co. Ltd.) were used as color chips. 468 colors were attached on the board. White fluorescent lights (FLR 40-S-W/M-x36, by Panasonic, Japan) were used as the source of light and were adjusted at 500lx on the color chips.

2.2 Subjects

56 Japanese college students participated in this test (30 men and 26 women in the age range of 19–28 years). Of all the subjects, 72.2% belonged to the design section; however, they had little opportunity to study color names in detail.

Figure 1: Image of color matching task.

3. RESULT & DISCUSSION

3.1 Cluster Analysis

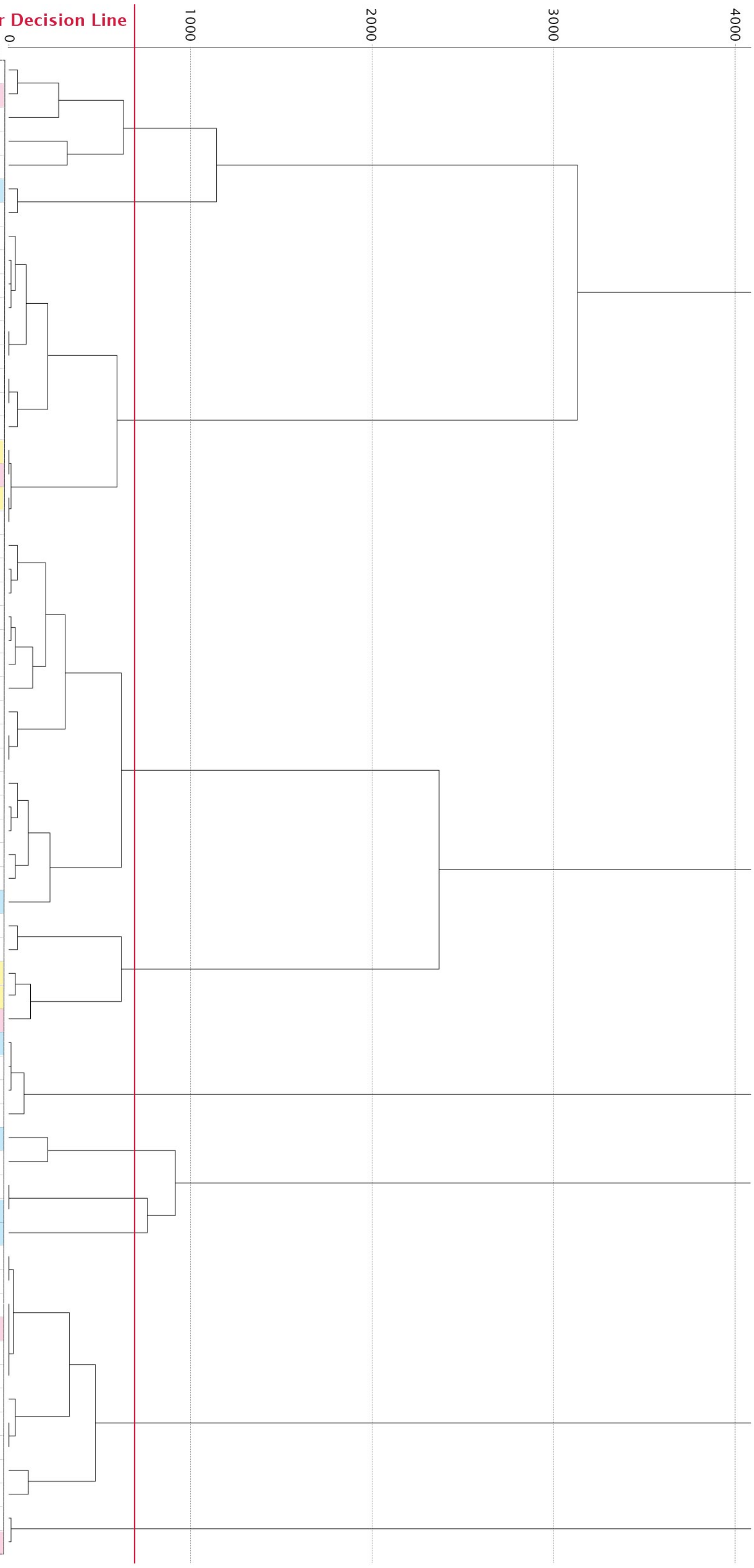
In each color chart, parameters L*,a* and b* of CIE L*a*b* acqired with i1 (color measurement instrument by x-rite Co. Ltd.). Average of L*, a* and b* in each color were used for constructing cluster with Ward method（Figure 2 & 3 : Average value of Color distance [ΔE] between a given standard color of JIS Z 8102 and subject’s choice for it in CIE L*a*b*” in each color name are shown in Figure 2 & 3）

3.2 Cluster Analysis

To decide valid color names from the cluster, three regulation were considered : a) To follow Berlin & Kay’s 11 basic color (pink marker in Fig 2 & 3), b) To follow color name qualified ΔE: Color distance based on ASTM Method E93-53 (as possble as), and c) To decide the lowest color name as a represental color in each cluster except a) & b).

Based on these regulation, 26 valid color were decided (Cluster Decision Line [red line] in Figure 2 & 3)

Color Name	Munsell	ΔE(*)
Rose Pink	10RP 7/8	23.7
Pink	2.5R 7/7	23.0
Magenta	5RP 5/14	31.0
Carmine	4R 4/14	39.0
Salmon Pink	8R 7.5/7.5	22.4
Wine Red	10RP 3/9	13.0
Old Rose	1R 6/6.5	32.4
Cochineal Red	10RP 4/12	19.9
Coral Red	2.5R 7/11	32.2
Scarlet	7R 5/14	25.7
Poppy Red	4R 5/14	12.7
Ruby Red	10RP 4/14	13.6
Rose Red	7.5RP 5/12	21.6
Rose	1R 5/14	17.3
Strawberry	1R 4/14	16.8
Cherry Pink	6RP 5.5/11.5	21.6
Signal Red	4R 4.5/14	8.7
Red	5R 5/14	11.9
Tomato Red	5R 5/14	10.4
Chinese Red	10R 6/15	33.6
Burgundy	10RP 2/2.5	48.3
Burnt Sienna	10R 4.5/7.5	46.3
Burnt Umber	10YR 3/3	36.0
Umber	8YR 5.5/6.5	40.3
Raw Umber	2.5Y 4/6	40.9
Orchid	7.5P 7/6	52.0
Bronze	8.5YR 4/5	26.1
Terracotta	7.5R 4.5/8	41.5
Tan	6YR 5/6	34.4
Pansy	1P 2.5/10	69.7
Raw Sienna	4YR 5/9	53.1
Buff	8YR 6.5/5	38.4
Sepia	10YR 2.5/2	31.6
Leghorn	2.5Y 8/4	40.7
Lilac	6P 7/6	50.4
Rose Gray	2.5R 5.5/1	23.7
Bordeaux	2.5R 2.5/3	38.8
Vermilion	6R 5.5/14	59.2
Chocolate	10R 2.5/2.5	12.9
Cocoa Brown	2YR 3.5/4	12.5
Brown	5YR 3.5/4	15.7
Baby Pink	4R 8.5/4	20.7
Shell Pink	10R 8.5/3.5	26.3
Peach	3YR 8/3.5	26.1
Nail Pink	10R 8/4	27.9
Cork	7YR 5.5/4	19.1
Blond(e)	2Y 7.5/7	30.4
Ecru Beige	7.5YR 8.5/4	26.3
Beige	10YR 7/2.5	20.0
Cream Yellow	5Y 8.5/3.5	15.8
Maroon	5R 2.5/6	57.6
Heliotrope	2P 5/10.5	55.9
Ash Gray	N 6	13.6
Gray	N 5	9.4
Slate Gray	2.5PB 3.5/0.5	21.4
Steel Gray	5P 4.5/1	13.5
Jaune Brilliant	5Y 8.5/14	105.2
Mauve	5P 4.5/9	44.7
Charcoal Gray	5PP 3/1	19.2
Hyacinth	5.5PB 5.5/6	39.2
Wistaria	10PB 5/12	48.8
Lamp Black	N 1	7.8
Black	N 1.5	2.4



: Berlin & Kay's 11 basic color names

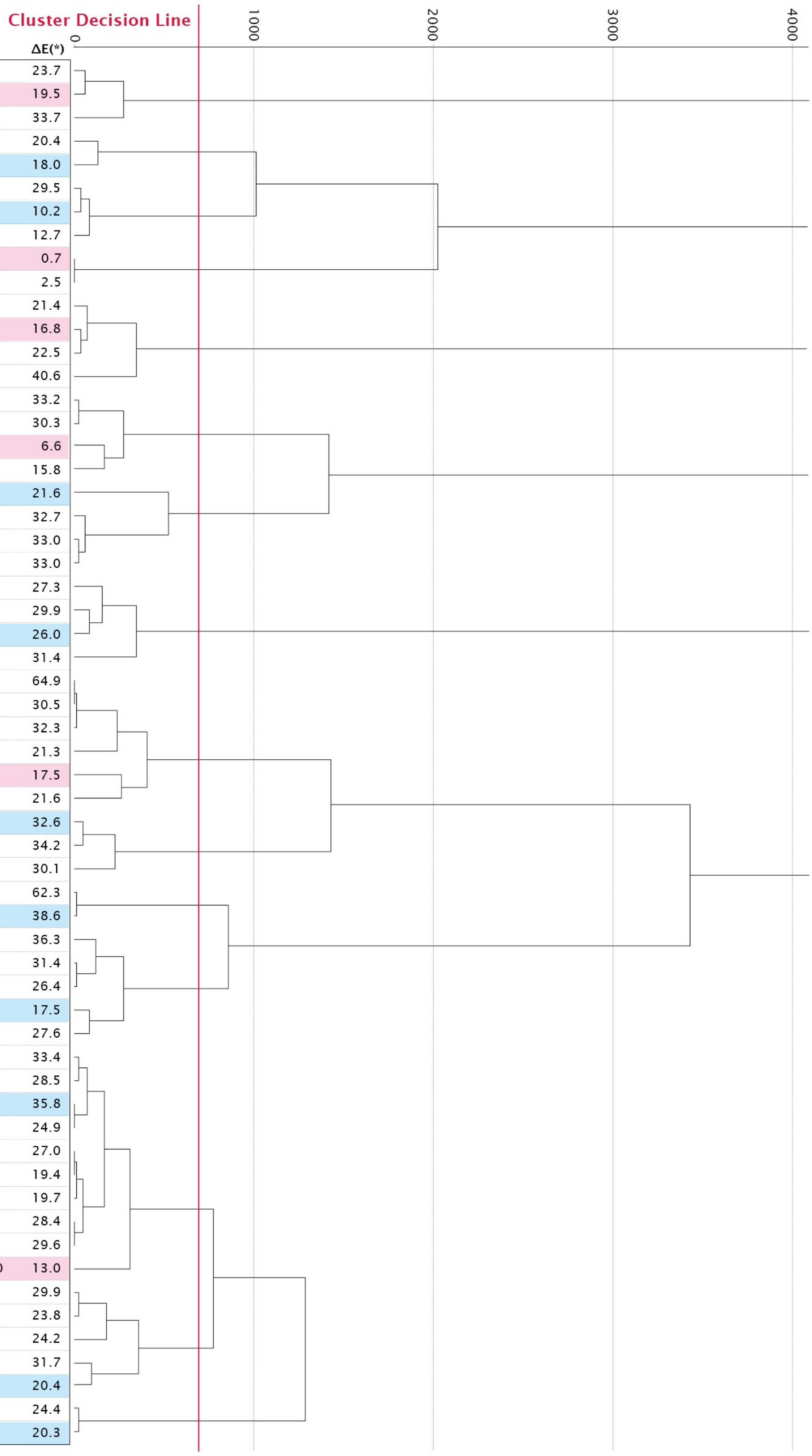
: ΔE of Color Name ≦ Berlin & Kay's basic color name in same cluster

: Color Name of the most lowest ΔE except &

*ΔE : Average Color Distance acqired from color choice task

Figure 2: Color Name Cluster from color matching task (#1)

Color Name	Munsell	ΔE(*)
Violet	2.5P 4/11	23.7
Purple	7.5P 5/12	19.5
Lavender	5P 6/3	33.7
Baby Blue	10B 7.5/3	20.4
Sky Gray	7.5B 7.5/0.5	18.0
Ivory	2.5Y 8.5/1.5	29.5
Silver Gray	N 6.5	10.2
Pearl Gray	N 7	12.7
White	N 9.5	0.7
Snow White	N 9.5	2.5
Carott Orange	10R 5/11	21.4
Orange	5YR 6.5/13	16.8
Mandarin Orange	7YR 7/11.5	22.5
Aprocpt	6YR 7/6	40.6
Golden Yellow	7.5YR 7/10	33.2
Naples Yellow	2.5Y 8/7.5	30.3
Yellow	5Y 8.5/14	6.6
Lemon Yellow	8Y 8/12	15.8
Marigold	8YR 7.5/13	21.6
Yellow Ocher	10YR 6/7.5	32.7
Chrome Yellow	3Y 8/12	33.0
Canary	7Y 8.5/10	33.0
Khaki	1Y 5/5.5	27.3
Olivedrob	7.5Y 4/2	29.9
Olive	7.5Y 3.5/4	26.0
Olive Green	2.5GY 3.5/3	31.4
Chartreuse Green	4GY 8/10	64.9
Malachite Green	4G 4.5/9	30.5
Peacock Green	7.5BG 4.5/9	32.3
Mint Green	2.5G 7.5/8	21.3
Green	2.5G 5.5/10	17.5
Emerald Green	4G 6/8	21.6
Leaf Green	5GY 6/7	32.6
Grass Green	5GY 5/5	34.2
Apple Green	10GY 8.5	30.1
Sea Green	6GY 7/8	62.3
Cobalt Green	4G 7/9	38.6
Ivy Green	7.5GY 4/5	36.3
Bottle Green	5G 2.5/3	31.4
Billiard Green	10G 2.5/5	26.4
Forest Green	7.5G 4.5/5	17.5
Viridian	8G 4/6	27.6
Nile Blue	10BG 5.5/5	33.4
Prussian Blue	5PB 3/4	28.5
Horizon Blue	7.5B 7/4	35.8
Saxe Blue	1PB 5/4.5	24.9
Marine Blue	5B 3/7	27.0
Cerulean Blue	9B 4.5/9	19.4
Cobalt Blue	3PB 4/10	19.7
Ultramarine Blue	7.5PB 3.5/11	28.4
Oriental Blue	7.5PB 3/10	29.6
Blue	2.5PB 4.5/10	13.0
Peacock Blue	10BG 4/8.5	29.9
Turquoise Blue	5B 6/8	23.8
Sky Blue	9B 7.5/5.5	24.2
Cyan	7.5B 6/10	31.7
Iron Blue	5PB 3/4	20.4
Midnight Blue	5PB 1.5/2	24.4
Navy Blue	6PB 2.5/4	20.3



: Berlin & Kay's 11 basic color names

: ΔE of Color Name ≦ Berlin & Kay's basic color name in same cluster

: Color Name of the most lowest ΔE except &

*ΔE : Average Color Distance acqired from color choice task

Figure 3: Color Name Cluster from color matching task (#2)

4. CONCLUSIONS

In this paper, to decide vail custom color name in the JIS, the cluster was formed by indices - L*, a*and b* from color choice task in each 122 foreign custom color name.

Berlin & Kay's 11 color names and ΔE: Color distance were applied for the decision. In the future, it will be necessary to clarify the significance with ANOVA in each cluster.

In another case, even if a color name's ΔE: Color distance is low, it is difficult to decide to recognize and use accurately.

Based on them, clarification in use of custom color names will focus on increasing custom color names used correctly and usably.

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Evaluation of color appearance under LED and OLED lighting based on the data obtained by a new color category rating method

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ABSTRACT

We conducted the experiments to evaluate the appearance of colors under white LED, OLED and fluorescent lamps using color chips systematically selected from the Munsell color space. We introduced a new color category rating method that was extension of the method reported by Uchikawa et al. (1994) to obtain more detailed description of color appearance. The results of the experiment 1 showed that the color category rating under each of three illuminants were similar in general, however, there were noticeable differences in some color regions. We carried out the additional experiment (Exp.2) in which color appearance was evaluated by the conventional elemental color naming method. The analysis of the results showed that multiple regression models based on the color category rating well explained the elemental naming responses, indicating the possibility that color category rating data can be transformed into the elemental color description.

1. INTRODUCTION

Technologies of solid-state lighting, such as light-emitting diode (LED) and organic electroluminescent lighting (OLED), are progressing rapidly in recent years. LED lighting is now widely used in our living environments. However there are still arguments about color appearance under these lighting environments. In this study we examined color appearances under a white LED, OLED and FL (fluorescent lamp) using a new method to describe the appearance of colors.

2. EXPERIMENT 1:

The experiment 1 was conducted to evaluate the appearance of colors under a white LED, OLED and FL using color chips systematically selected from the Munsell color space (shoji et al., 2013). We introduced a new color category rating method that was extension of the method proposed by Uchikawa et al. (1994) in a way to obtain more detailed description of color appearance.

2.1 methods

Subjects answered color appearance of a chip by selecting up to three colors out of 11 basic color terms; red(R), orange(Or), yellow(Y), green(G), blue(B), purple(P), pink(Pk), brown(Bn), black(Bk), gray(N) and white(W). Also tye assined a weighting score to each of the selected colors to make a total of 10. After adapting to a given illuminant (FL, LED or OLED) for 5 minutes, a subject responded with the color category rating method for each of 146 color chips presented on the gray background. The size of color chips from the subject was about 2 deg. The illuminance was set 500 lx at the location of the color chip. Each of the subjects repeated twice for each light source condition. 10 subjects (University students) participated in the experiments. The specifications of the light sources are given in Table 1. Figure 1 shows the relative spectral power distribution of the FL, LED and OLED used in the experiment.

Table 1: Specification of the light sources

	FL	LED	OLED
product	FL20SS-ENW/18HF	LEL-AW6N/2	P03B0909-NA12A
x	0.343	0.349	0.351
y	0.356	0.358	0.369
Tc	5200 K	5000 K	4900 K
Ra	84	81	81

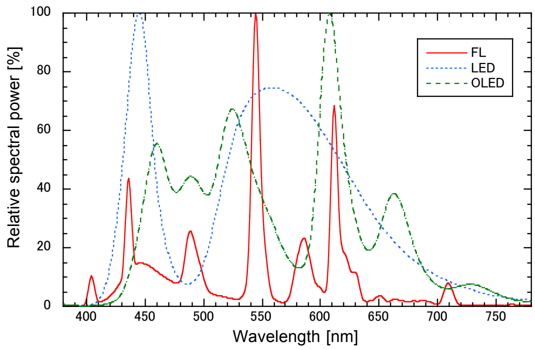


Figure 1: Relative spectral power distribution of the light sources

2.2 Results

Figure 2 shows the results of the experiment 1 (V=5, C=6) under light sources FL, LED and OLED. The color category ratings were averaged over the subjects. While the color

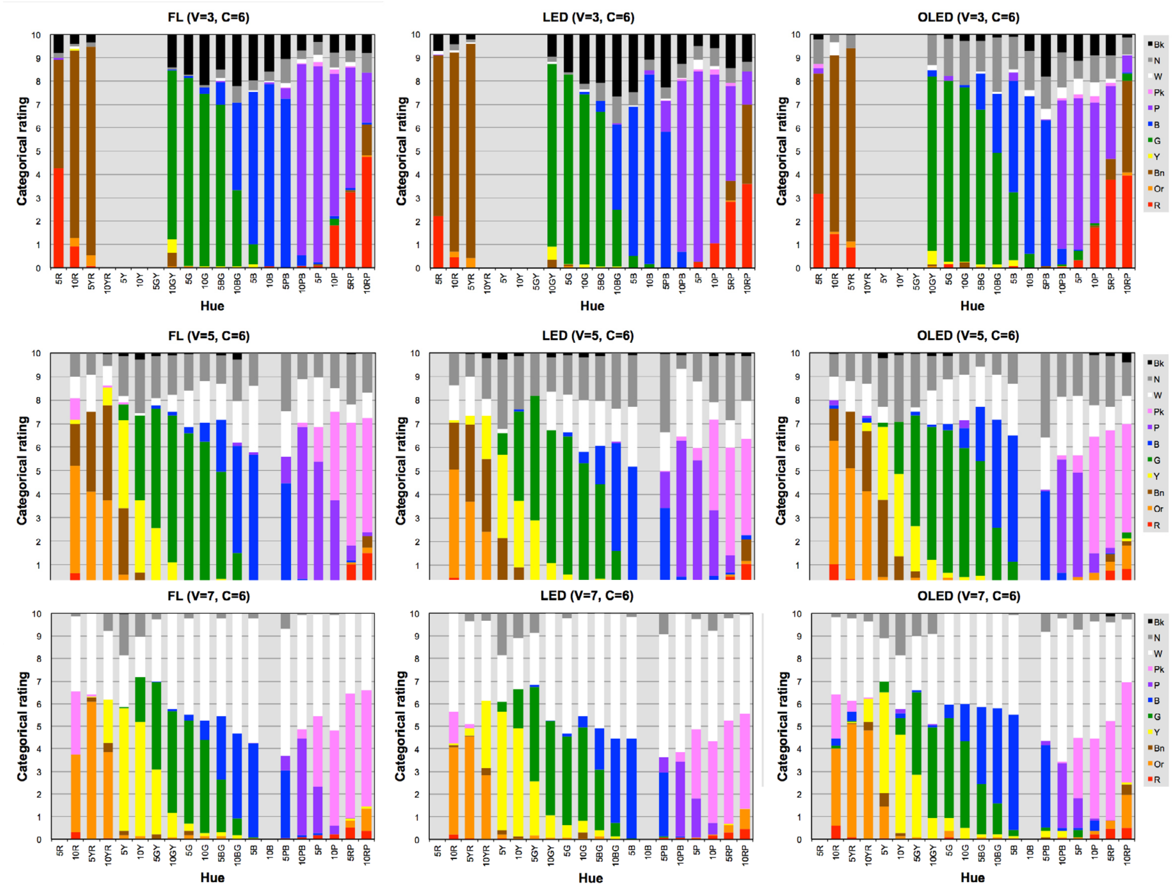


Figure 2: The results of color categorical rating for the color chips (V=3, 5,7, C=6).

category ratings under each of three illuminants look similar in general, noticeable differences in categorical rating were found in some parts of the colors. For example, the color chips between 10R to 10YR were given higher "orange" rating under the OLED than other light sources.

3. EXPERIMENT 2:

To know quantitative changes of the color appearances, we considered possibility to transform color category rating data to elemental color rating data. Then we carried out the additional experiment (Exp.2) in which color appearance was measured by the ordinary elemental color naming method.

3.1 Methods

In the experiment 2, the subjects described color appearance by giving achromatic rates (black/white), followed by chromatic rates (red/green, yellow/blue) to bring the total to 10. The number of the Munsell color chips tested in the experiment 2 was reduced to 76 from 146 in the experiment 1. Other procedures and conditions were the same as in the experiment 1.

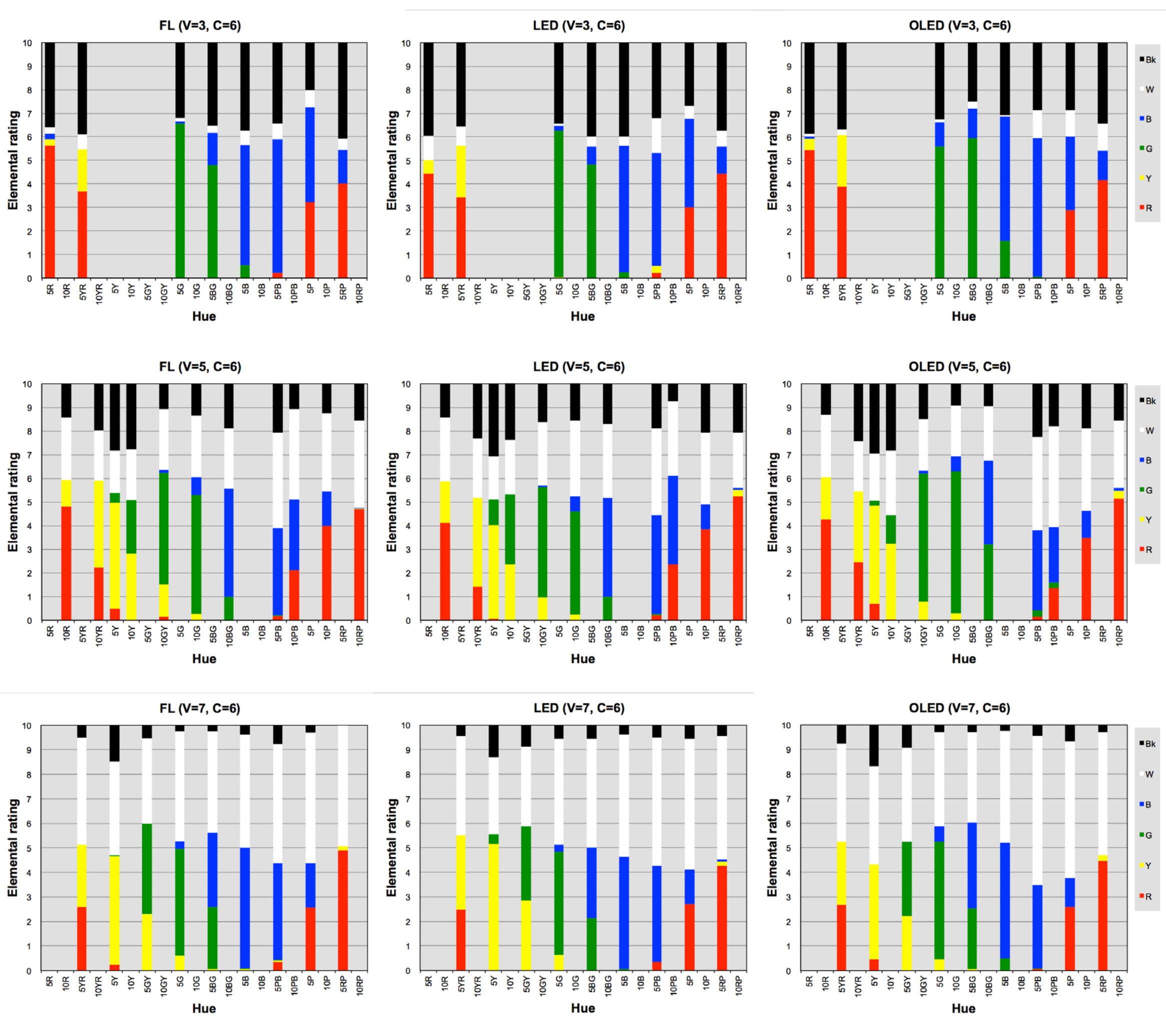


Figure 3: The results of elemental color naming for the color chips (V=3, 5, 7, C=6).

3.2 Results

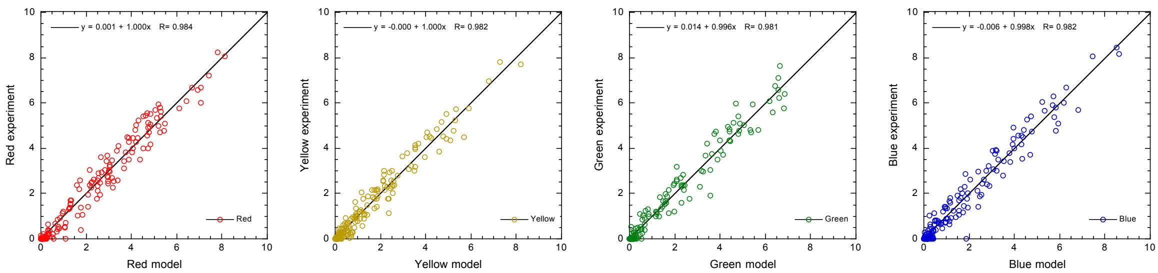
Figure 3 presents the results of the experiment 2 (V=5, C=6) under the light sources FL, LED and OLED. The elemental color naming scores were averaged over the subjects. The results of the experiment 2 show typical changes of color appearance along the hue circle. Although the color appearance show a similar change in three light source conditions, there are also some differences such as higher redness and greenness of V=5 under OLED and lower chromaticness under LED.

DISCUSSION

Each color category must be described as combination of elementary colors. For example, "purple" may be described as combination of "red", "blue" with some weighting factors. Then we considered that it might be possible to transform color category rating data to elemental color naming description. Relationship between the color category rating (Exp.1) and elementary naming (Exp.2) was analyzed with the multiple regression analysis; explanatory variables were 11 category ratings and objective variables were 6 elementary naming responses. The results of the regression were summarized in Table 2. Figure 4 shows correlation of elemental color ratings predicted by the multiple regression model and those evaluated by the subjects in the experiment 2. It is clearly shown that regression models based on the color category rating data well explain the elementary naming responses, indicating the color category rating can be transformed into the elementary color description.

Table 2: Regression coefficients to predict elemental colors from color category ratings

Elemental color	Color category (explanatory variables) R	Or	Y	G	B	P	Pk	Bn	W	N	Bk	cor-ration R
Red	0.924	0.528	-0.037	-0.006	-0.007	0.334	0.732	0.292	0.016	-0.007	-0.033	0.984
Green	0.010	-0.013	0.007	0.847	0.004	-0.007	-0.017	0.019	0.022	0.022	-0.145	0.981
Yellow	-0.022	0.407	0.872	-0.012	-0.009	-0.001	-0.003	0.188	0.007	0.016	-0.034	0.982
Blue	-0.027	-0.013	-0.030	0.030	0.920	0.468	0.009	0.012	0.022	0.006	-0.060	0.982
White	0.033	0.047	0.139	0.045	0.015	0.055	0.226	0.070	0.939	0.512	-0.134	0.979
Black	0.083	0.044	0.050	0.099	0.083	0.150	0.053	0.421	-0.008	0.449	1.395	0.971



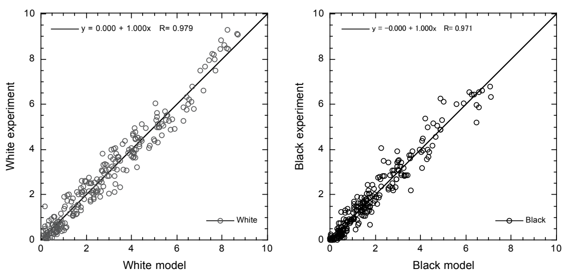


Figure 4: Correlation of elemental color ratings predicted by the model and those evaluated by the subjects in the experiment 2.

Comparison of the predicted elemental naming data derived from the regression model with the experimental data is shown in Figure 5 for the color chips (V=3, 5, 7, C=6) under the FL condition. As shown in the figure, the model based on the color category rating data well predicts changes of color appearance.

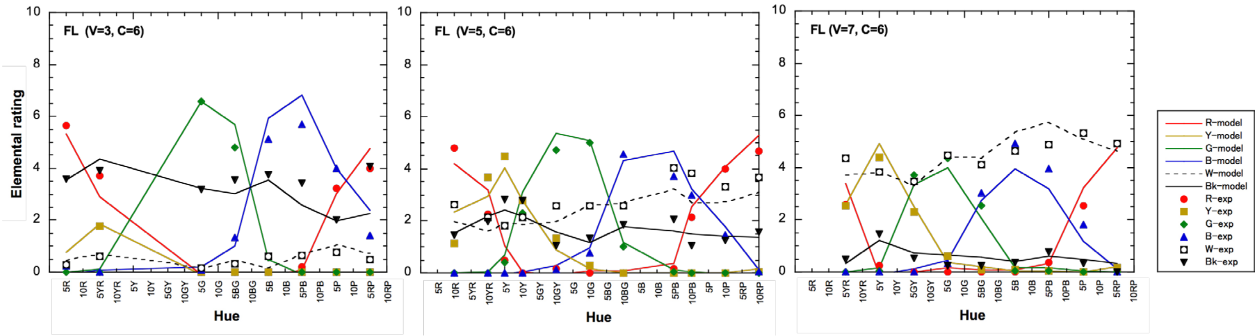


Figure 5: Comparison of the elemental rating predicted by the regression model (lines) with the experimental data (symbols) plotted for the color chips (V=3, 5,7, C=6) under the FL condition.

This study was primarily motived by to examine color appearance under LED and OLED lightings. To see the changes in color appearance, predicted elemental color naming values assigned to the color chips used in the experiment 1 were derived from the regression model based on the color category rating data. Arrows in figure 6 indicate the predicted changes of color appearance from FL to LED or OLED conditions plotted on red-green and yellow-blue axes.

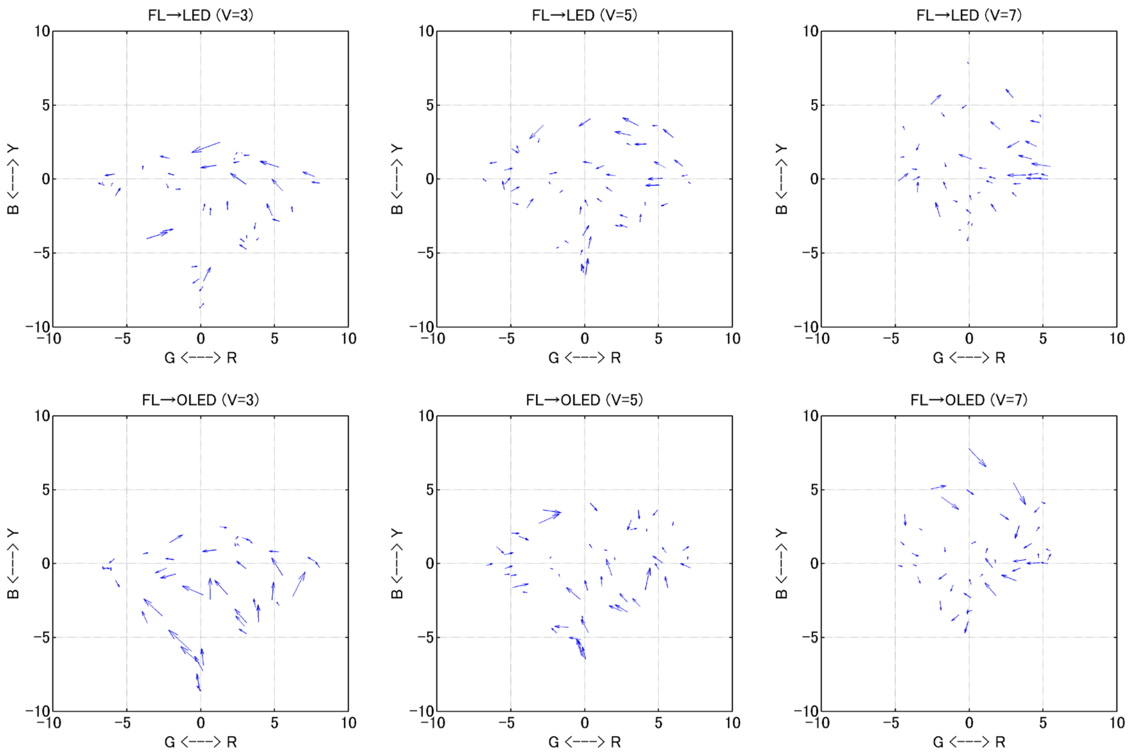


Figure 6: Predicted changes of color appearance from FL to LED or OLED lighting plotted on red-green and yellow-blue axes.

General changes of arrows in figure 6 indicate that the color chips under the LED used in the experiment may appear slightly desaturated compared with the FL. We can also see some enhancement of color appearance toward "orange" under the OLED.

Further discussion is needed to connect our data to evaluation of color appearance under solid-state light sources in a more general way. In addition, it is worth to examine usefulness of the color category rating method.

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Influence of position of colored panels to entire pattern's visibility.

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ABSTRACT

Visibility is related to the decision of area to pay attention in field of view, and must be considered in interface or advertisement. However, it has not been revealed how the visibility is determined in daily and complex scene, which contains various factors. In this study, we focused the color and its position from various factors, and measured the visibility of each color panel in a different arrangement by the paired comparison test. We evaluated the effect of arrangement of color stimuli for visibility by the selection rate of each figure pattern. Analysis of variance on the selection rate of each figure pattern by the pair comparison method revealed that one figure pattern category defined by certain features of the arrangement showed significantly lower selection rate than other categories. Additionally to such pattern categories, there were additional common features in patterns that showed exceptionally higher or lower selection rates, over all arrangement patterns. These results suggest that the arrangement of color patch affects the visibility of entire figure.

1. INTRODUCTION

In daily life, visibility of objects is heavily involved in decision of area to pay attention in field of view. The visibility is a kind of degree to attract the attention of the people with the target, and must be considered in the interface or advertisements from its feature. Such the feature in natural scenes has commonly been called as "attractiveness" especially in attention research. In this study, however, we call this kind of feature as "visibility", mostly because we would employ the paired comparison method in which a simple detection of the object in short time can be considered as a dominant key factor. Contrary, if the method of the measurement would be replaced to trace of eye movement or target detection method, the data would be more influenced by attention capture referred as the attractiveness.

Such the visibility should strongly be influenced by color, meaning that influenced by lightness and saturation. The correlation between color and visibility has been demonstrated (Shinomori et.al. 2013; Suzuki et al. 2013; Toyota et al. 2014) that the visibility by the paired comparison method can reasonably be predicted by the features of the colors. However, shape and size of a target and positional relationship of the colored parts also can affect the visibility, meaning that the degree of visibility also involves multiple factors. Unlike the experiment environment for limiting factors, multiple factors should alter the visibility in daily environments. Therefore, it is difficult to determine the degree of visibility, which is strongly concerning to concept of conspicuity in many cases, only by the effect of color, separately. In this sense, integrated previous research, such as to clarify this complex mechanism, does not exist. However, it is still too difficult to determine the mechanism of visibility using the stimulus involving many factors, limited number of factors should be selected for measurements of the visibility. Therefore, in this study, we focused the color and its position and measured the visibility with different arrangements of color panels in equal lumiannce by the paired comparison test. From the results, we considered the effect of arrangement of partly colored stimuli for visibility from the selection rate.

2. METHOD

Measurement in this experiment was carried out using the equipment installed in a dark room (Figure 1). We used a LCD display for stimulus presentation and a general numeric keypad for response. Observers were nine students (5 male and 4 female) in the mean age of 21.0 year old. They were naïve observers and authors were not included. Observers were screened by color vision tests of Ishihara-plate (38 plates edition), Standard Pseudo-isochromatic Plates (SPP) and D-15 and were confirmed to have normal color vision.

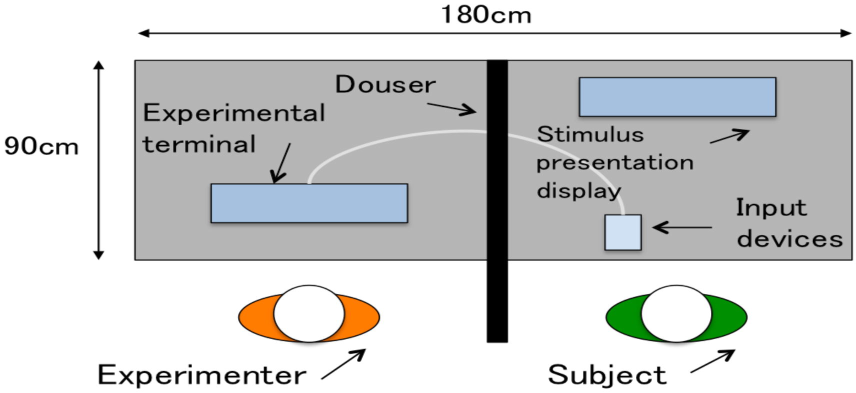

Figure 1: Apparatus

2.1 Stimulus

In this experiment, we use a set of figure patterns as the stimulus, those were consisted of 7 gray panels and two colored panels arranged to make a square shape of 3 × 3 panels. The size of the gray and colored panels were 1.8 cmx1.8 cm (1.5 ° x 1.5 ° in visual angle), making the entire figure of 4.4 ° x 4.4 °. The color for the colored panel was red, which had shown to have the highest visibility in previous studies (Shinomori et.al. 2013; Suzuki et al. 2013; Toyota et al. 2014). Panel's colors, red and gray were equated in luminance (24.68 and 24.64 cd/m^2, respectively) and their CIE 1931 xy chromaticity coordinates were (0.495, 0.323) and (0.289, 0.294), respectively, measured by a luminance and color meter (CS-200, Konica Minolta Co. Ltd.).

The set of stimulus figure pattern was composed of 36 kinds of patterns depending on the position of red (colored) panels. The patterns were classified to four categories for analysis by characteristics of the arrangement of the colored panels as shown in Figure 2; Category 1 was the classification having a rectangular arrangement of colored panels contacting with one side, meaning the adjacency in a vertical or horizontal direction. Category 2 was the classification with an arrangement characteristic of the color panels in contact with one vertex, meaning the adjacency in the oblique direction. Category 3 was the classification with a configurationally features in the column direction or the same row direction, but without adjacency. Category 4 was the classification without the configurationally feature nor the adjacency, meaning that colored panels were not in the same row or column. Show below an example of each category.

Figure 2: Examples of stimulus figure patterns belonging to four categories.

2.2 Experiment Technique

Before the experiment, the observer adapted to a dark background of the monitor screen for five minutes. In the experiment, two stimulus figure patterns were pseudo-randomly selected from 36 patterns and presented to the observer as shown in Figure 3. The observer made a response of choosing stimulus figure pattern in higher visibility from two as one trial. Trials were continued until all the combinations would be completed in the pair comparison in one session, although we did not make the comparison between the same pattern. The pair of patterns were pseudo-randomly changed after observer's response, thus, the order of pattern presentation were also change in every time of the experiment. Additionally, we tried to avoid a possible influence on determination by the presentation of preceding patterns and by retinal adaptation, which could be different between gray and colored panels. Location of the stimulus patterns presented on the screen was changed slightly between trials (shifted in any (random) direction with a random amount of distance up to 3.3 °). The paired comparison for all combinations were performed in one session and one observer performed 3 sessions. The observers took at least 5 minutes break between sessions and any time when the observer required.

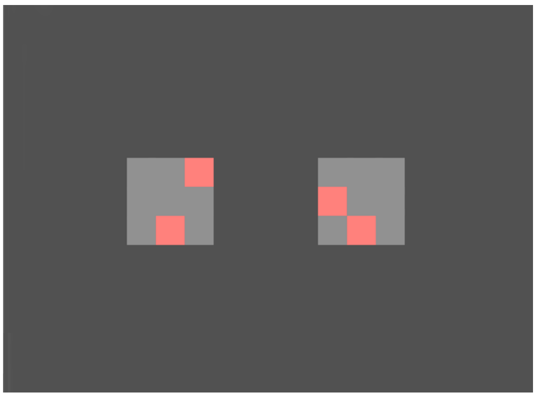

Figure 3: Example of presentation stimulus

3. RESULTS AND DISCUSSION

In this experiment, we defined a selectivity (0 to 1) as the probability of selecting one stimulus figure pattern against all other patterns (thus, not including against the same pattern) in the pair comparison method, as a reference for determining the degree of visibility. Based on the mean selectivity of all observers, ranking of the visibility in the entire patterns was determined and presented in Figure 4. The average of the selectivity for all patterns belonging to one category were also calculated and presented in Figure 5.

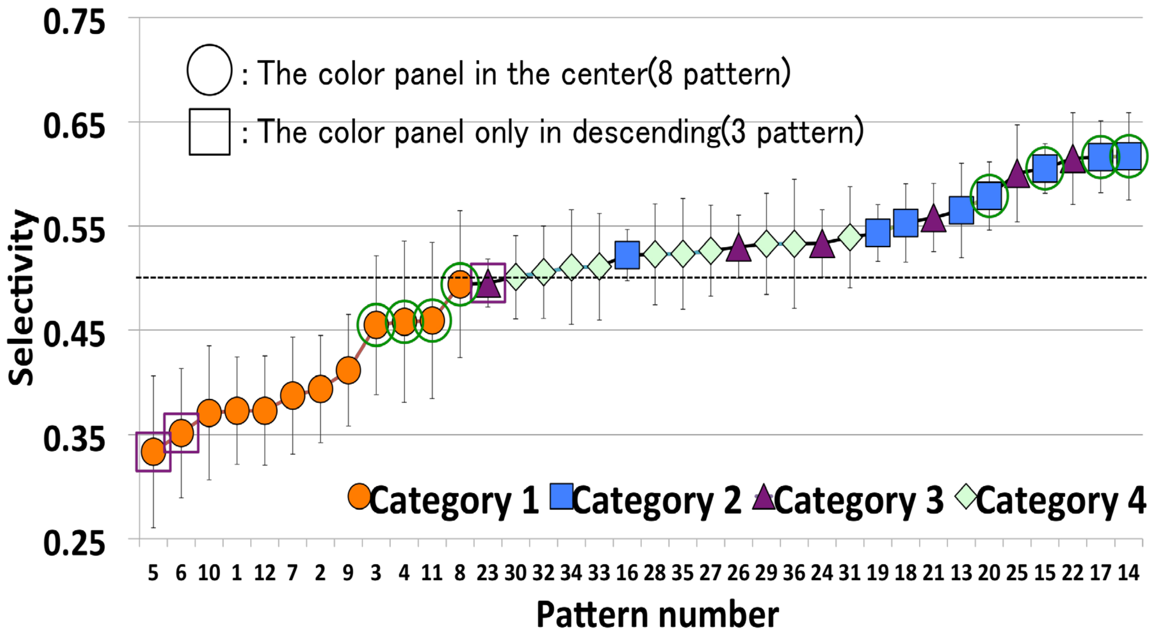

Figure 4: Ranking of the selectivity for each pattern.

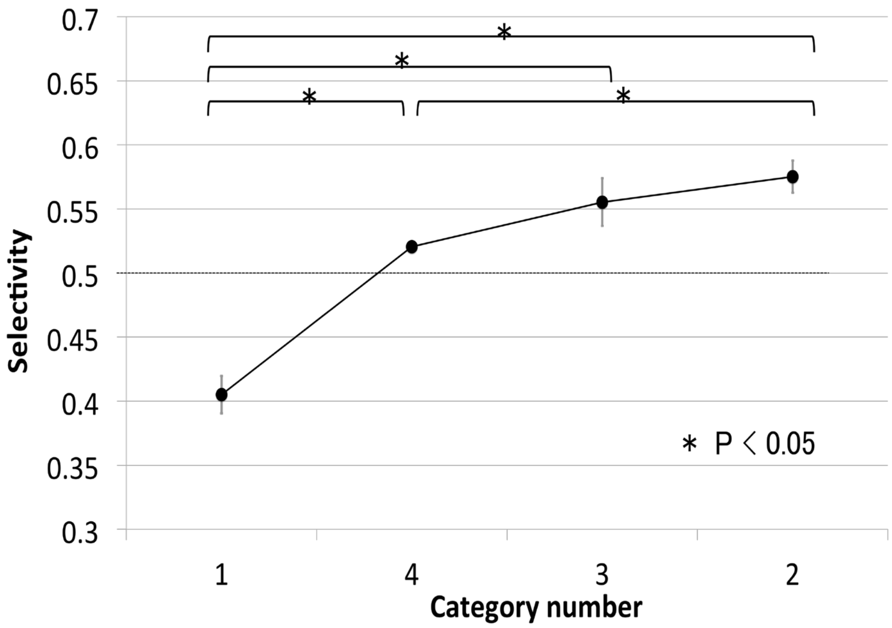

Figure 5: Ranking of the averaged selectivity for each category

The selectivity between categories, category 2 showed the highest selectivity as shown in Figure 5. Category 1 had the lowest selectivity, showing large difference in selectivity for other categories. Result of analysis of variance for selectivity between categories, category 1 showed a significantly lower selectivity ($p < 0.05$) compared to other categories, category 4 showed a significantly lower selectivity ($p < 0.05$) compared to category 2. The overall pattern selectivity in Figure 4 indicated that the patterns belonging to the same category, other than the category 3, were close in the ranking. This tendency caused the significant ranking order between categories as shown in Figure 5. Category 3 had divergence in the ranking order, although it tended to have higher rankings. However, in category 3, the ranking of pattern 23 exceptionally located in a lower order of the selectivity compared to other patterns in the same category. That is the pattern classified as colored panels are only in the most descending (bottom) column, explained more details in the later paragraph.

The main difference in the selectivity between category 1 and other categories was a way of the contact between colored panels. From this feature, patterns belonging to the category 1 were recognized as one colored rectangular in the pattern. On the other hand, other categories were recognized as the pattern having two colored panels independently. Therefore, a plurality of colored stimuli can be considered to give a stronger influence on the visibility of the subject than the single colored stimulus.

The main difference between categories 4 and 2 was an existence of the contact point and category 4 did not have the contact point between colored panels. Therefore, it is conceivable that the contact point has some influence on the visibility of the pattern. Combined with the analysis for category 1, for higher visibility, it is necessary to be recognized as separated colored stimuli while having the contact point.

We would like to mention about two special features of the pattern found in different categories; the first one is the arrangement in which one colored panel was placed in the center at the entire stimulus figure pattern. Such patterns, denoted by circles in Figure 4, commonly had the highest selectivity in the belonging category. It suggests that the color stimulus at the central portion is positively affecting the visibility. However, this feature did not go over the category border in the selectivity ranking, suggesting that this special feature can infuence to the visibility in the lower level compared to influences of contact points and arrangement that we used for classifying categories.

The other special feature of the pattern was for exceptionally lower selectivity compared to others in the same category. That is the pattern classified as colored panels are only in the most descending (bottom) column as mentioned above. Other two patterns with this special feature were both located in the rank of the lowest selectivity. The colored stimulus lopsided in the bottom column can be considered to have negative impact on visibility compared to other features. However, again, this feature did not go over the category border in the selectivity ranking, suggesting the same consideration to the pattern with the center stimulus.

We, however, did not know whether the same results would be obtained under the different conditions such as increasing the number of panels. If the number of panels will be increased, however, it may not be possible to perform the experiment practically because of the experimental time should become enormous in the paired comparison method. Thus, in the future, it is necessary to verify the effectiveness of these arrangement and positional features using a new method.

4. CONCLUSIONS

In this study, we found that the arrangement relationship between the two colored panels used for the classification of categories in this study is one of the stronger factors that influence the visibility of the overall stimulus figure. Additionally, we found several positional features, which affect the visibility of the stimulus in terms of the position relationship of the colored panel, such as the central positions and the bottom positions. The visibility of the color stimulus can be changed by such positional features, however, they are weaker and simly adding the effect to the arrangement features from the lower (weaker) level.

ACKNOWLEDGEMENTS

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A color coordination support system based on impression from color and readability of text

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ABSTRACT

Readability of color scheme is one of important factor at general text design including graphic design, or web design. Each color and color schemes owe unique psychological effects. In general text design, color choice should consider these unique psychological effects. However, this considerable color choice must need high degree of skills. In present study, authors constructed a semi-automatic color coordination support system based on psychological color theory. The color coordination support system was able to nominate font colors that specified by background color. Nominees were based on psychological color theory and readability. Readability of color schemes were measured and formulated from subjective evaluation experiments for various combinations of font and background colors.

1. INTRODUCTION

General text design including graphic design, or web design must maintain readability. Text readability is constructed from color scheme of font and background. Designers are always considering balance of interested graphical design and readability. Thus, general text design needs knowledge and skills of color including psychological effects. Knowledge and skills of color is not easy to acquire. It suggest, knowledge and skills of color is hard to suit for general text design with readability maintained. In present study, authors were tried to developing a color coordinate system for readability secured. This system is able to nominate font colors considering with psychological effects for background color of user selected. Color coordinate system nominees were evaluated readability and psychological effect factors.

2. SYSTEM CONSTRUCTION

Color coordinate system was postulated that does not depend on knowledge and skills of color. Unique and key factor of functions are,

1) selectable background color for high degree of freedom in design.

2) color schemes of system nominees were ranked order of readability.

Those two functions are implemented for considering with balance of interested graphical design and readability.

2.1 Impression from color

Images of something else were impressed from colors. It is look like some color perception generated some psychological description. Impression from color is an important factor in graphic design. Color coordinate system nominated colors from keywords. Keywords and impression are shown in Table.1. Twenty-seven words were selected with reference of preceding study[1]. Relations of keywords and colors were defined on the basis of PCCS

(Practical Color Co-ordinate System[2] by Japan Color Research Institute) as shown in Figure 1.In Table.1, digits of “1” mean that PCCS colors give impressions in corresponding columns, and digits of “0” mean that they give no impressions. The reasons why PCCS was adopted are,

1) Results by preceding studies are available that investigated the relation between color and impression from color based on PCCS.
2) PCCS is able to handle colors by their only two attributes, hue and tone.
3) The number of PCCS colors are limited to about two hundreds, so easy to process by program.

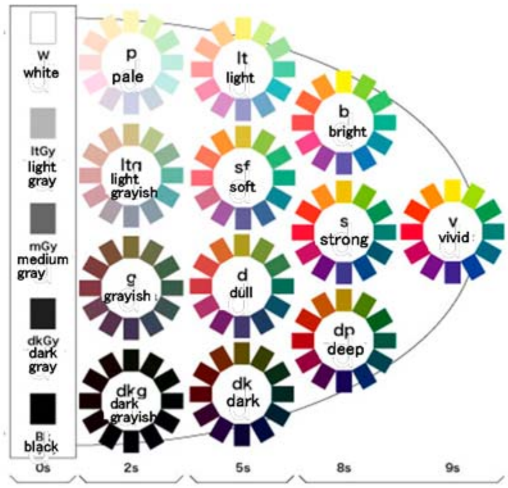

Figure 1: PCCS tone chart[2].

In present study, 201 colors (including 192 chromatic cards in twelve tone and 9 achromatic cards.) were used from PCCS harmonic cards. CIE XYZ values of 201 colors were measured by spectrophotometer (Spectrolino). D65 illuminant was used in colorimetric calculation. The XYZ values were converted to RGB values to display colors on LCD monitor with sRGB color gamut.

Table 1. Rlation between PCCS color and impression.

color notation \ impression	warm	cool	light	heavy	loud	quiet	bright	dark	dynamic	static	weak	happy	sad	merry	mirthless	sweet	spicy	·sour	bitter	masculine	feminine	healthy	unhealthy	classic	romantic	sporty	·ethnic.
v1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
v2	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
v3	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
v4	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1
v5	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
v6	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
v7	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v8	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
v9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
v10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
v11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

2.2 Readability of color scheme

Readability of font color for background color was obtained from subjective evaluation experiments for multiple combinations of font and background colors, that was conducted in our previous study. Readability was formulated from the results, as given in the following equation.

$$y = 0.0927 \mid L_1^* - L_2^* \mid + 0.00635 \mid C_1^* - C_2^* \mid + 0.843 , \quad (1)$$

where, y reperesents readability, and L_1^* and C_1^* are metric lightness and chroma in CIELAB color space for background color, respectively. Similarly L_2^* and C_2^* are metric lightness and chroma for font color, respectively.

3. PTOCESS FLOW

Control software of color cooordinate system was built with C++ programing language for Wndows PC. Process flow chart of software is shown in Figure 2. Operation and display screen of the system is shown in Figure 3.

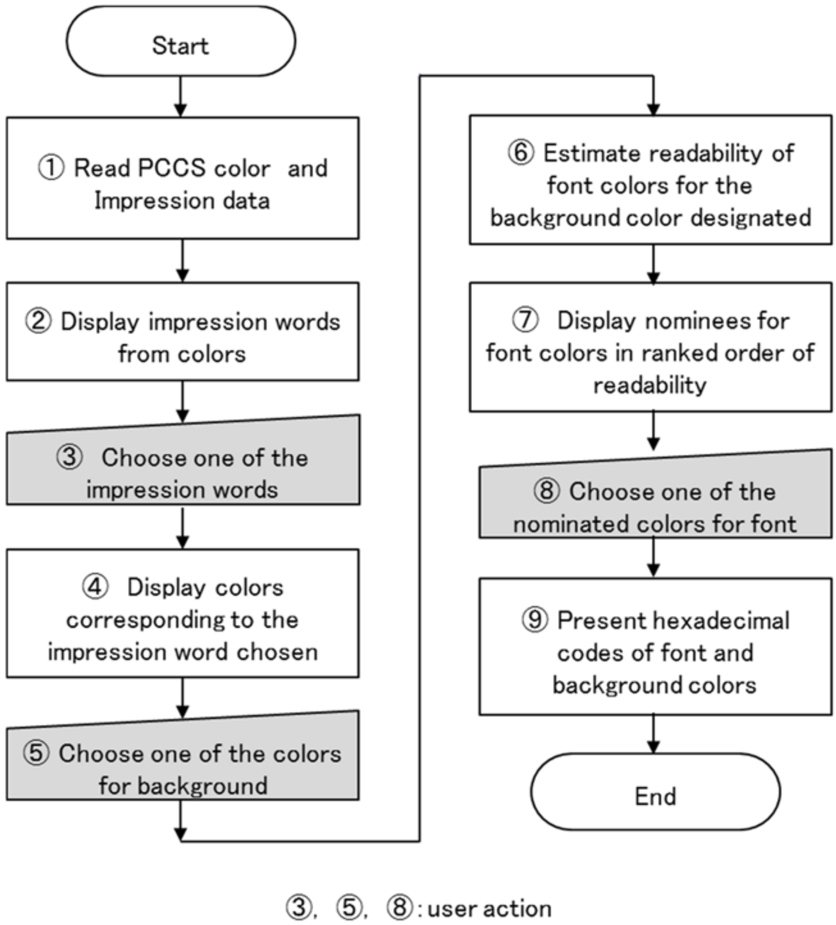

Figure 2: Process flow chart.

Impression words are displayed in window ①, and the corresponding colors for background are displayed in window ② when a user chooses one of the impression words and clicks on the execution button. Then, font colors on background color designated are ranked in order of readability and presented in window ③ when a user chooses one of the colors for bckground. The readability of font color for bckground color is calculated with Equation 1.When clicking one of the color schemes in window ③, RGB values of font and background colors are displayed in window ④.

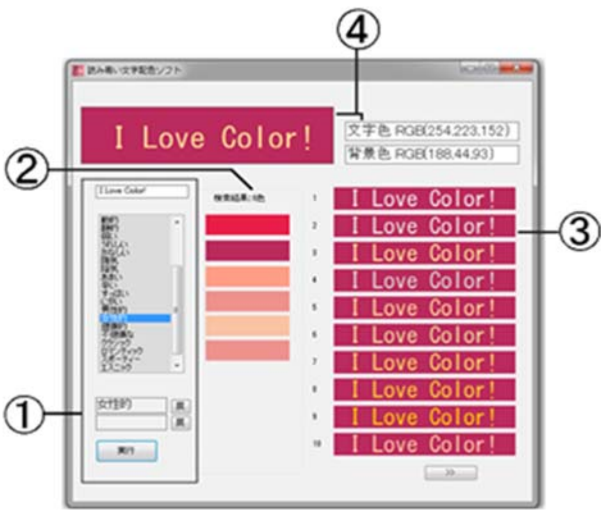

Figure 3: Operation and display screen.

4. RESULTS AND DISCUSSION

Table 2 shows examples of color scheme results obtained using the color coordinate system. It was confirmed that a fairly reasonable result was obtained for given impression words. Figure 4 shows examples of nominated font colors in ranked order of readability for background color having impression of cool. The order of readability seems to be almost valid. High ranked font colors were white or yellow with high lightness, while low ranked font colors have various hues. In present study, impression from font color is not taken account. If text area is large, impression from font color should be considered.

Actually this system was applied for graphic design of can package and confirmed to be effective in creating images as intended[3].

Table 2. Examples of color scheme results

Impression	Font color	background color	Color sch eme result
happy	55, 55, 55	254,125,116	I Love Color!
sad	238,235,237	79,98,104	I Love Color!
dynamic	233,229,224	252,45,62	I Love Color!
static	76,58,58	122,184,169	I Love Color!

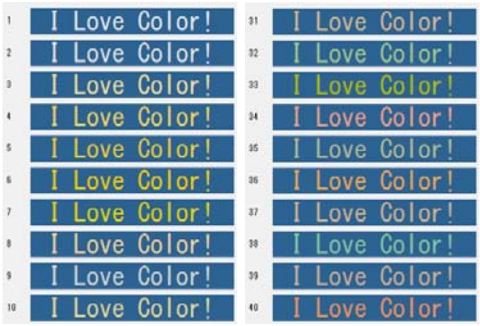

Figure 4: Nominated font colors in ranked order of readability for cool background color.

5. SUMMARY

A semi-automatic color coordination support system was constructed and evaluated. This system was able to nominate font colors in ranked order of readability for background color designated by impression from color. The system is expected to be an effective tool for color scheme for users not having enough knowledge and skills of color.

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Study on Visual Recognition of Specula Reflection about Silk and Cotton Textile

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ABSTRACT

In this study, optical property of textile was measured, and applied for human visual assessment by computer graphics to clarify the mechanism about visual recognition of silk and cotton textile. The measuring textile samples were 19 white or non-dyed textiles including silk, cotton, polyester materials, and these were plain and twill weavings. Sample was stretched on 20cm diameter cylinder surface with tensile force to sense reflectance profile with various illuminant and detect optical dimension, and measured by gonio-photometric spectral imaging system. After measuring, spectral image at 550nm wavelength of each samples was respectively analyzed and calculated to get skewness and deviation profiles of optical dimension. To analyze visual recoginition, the human visualizing assessment test was applied as magnitude estimation method combined by polar coordinates to apply two different parametric objects, angle was meaning of material type that is silk or cotton feel, and distance from origin was meaning of textile feel. The display device presented monochrome visual stimulus with this coordinates. The images of this experiment were created from metric profile and combined with typical short fiber texture like a cotton broad cloth and typical long fiber texture like a silk taffeta cloth, and variables were intensity of specula profile and texture images. As the result of this study, the boundary area of textile feel, and also silk/cotton material feel were calculated. The silk feel was approximately related with intensity of specula profile, and textile feel was approximately related with intensity of texture.

1. INTRODUCTION

The various texture and design of fabric are created by combined fiber material, spinning, weaving and finishing effects. Especially, silk and cotton fabrics are the most popular and typical cloths in human life, and also there were a lot of them represented by drawing or painting on the arts. Basically, visual recognition of silk and cotton textile is the very interesting subject.

2. METHOD

2.1 Textile measuring by Spectral Imaging (Metric Data Acquisition)

For instrumentation, liquid crystal tunable filter (Perkin Elmer, LCTF) is used as the spectrum method. And Pertie Cooling, monochromatic-CCD camera equipped with anti-blooming and white LED were used in the process. As LCTF is 10nm in half-band width, and the CCD camera with 772 X 580 pixel and closing-up distance shot in the 40 cm distance far from the apex of the sample cylinder. In this case, the resolution is 180 dpi. LED lamps were aligned through a like shape with vertical 15° through 45° angle to the sample planes from 30 cm distance. These measured samples were all attached to the planes of a cylinder with 20cm in diameter. From the lamp with the vertical 15° angle to the sample plane, it was able to get the optical geometric conditional information as a specular angle to the X axis of the result image ranges from -60° to 90°, or the one with 45° ranges from -30° to 120°. Figure 1 shows which instrument and optical geometric condition was used and based.

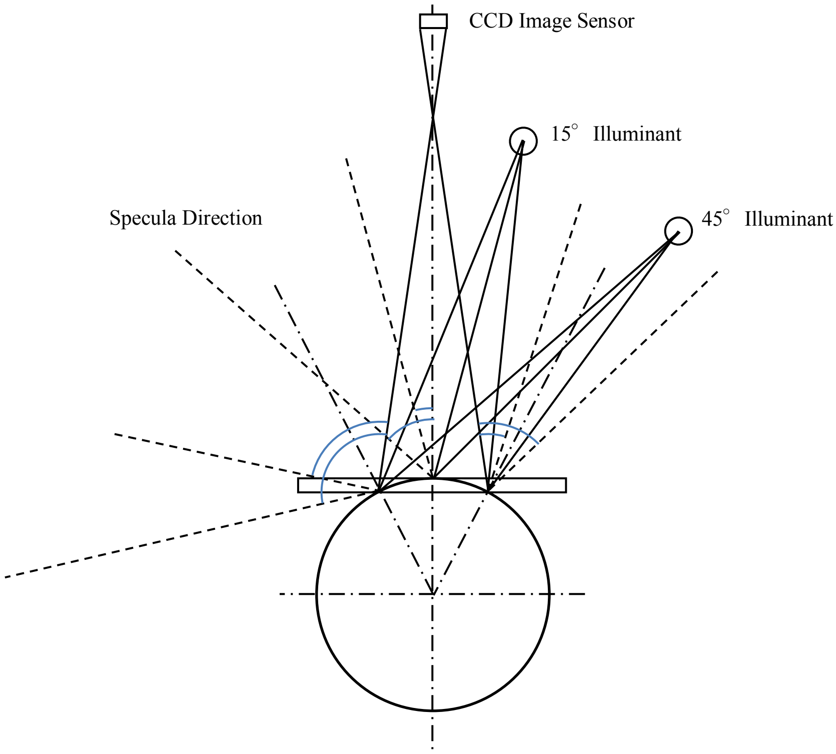


Figure 1: Optical geometry of spectral imaging system.

Measured samples were 19, including cotton, silk, synthetic fiber textile, and mat surface paper. Among these, the most representative profiles were 4; cotton broad, silk taffeta, polyester taffeta and mat surface paper. These were interpreted while using mathematical method to figure out reflectance profile to optical geometric conditions using images with 550nm. These image and L* profile of each measuring are shown in Fig.2.

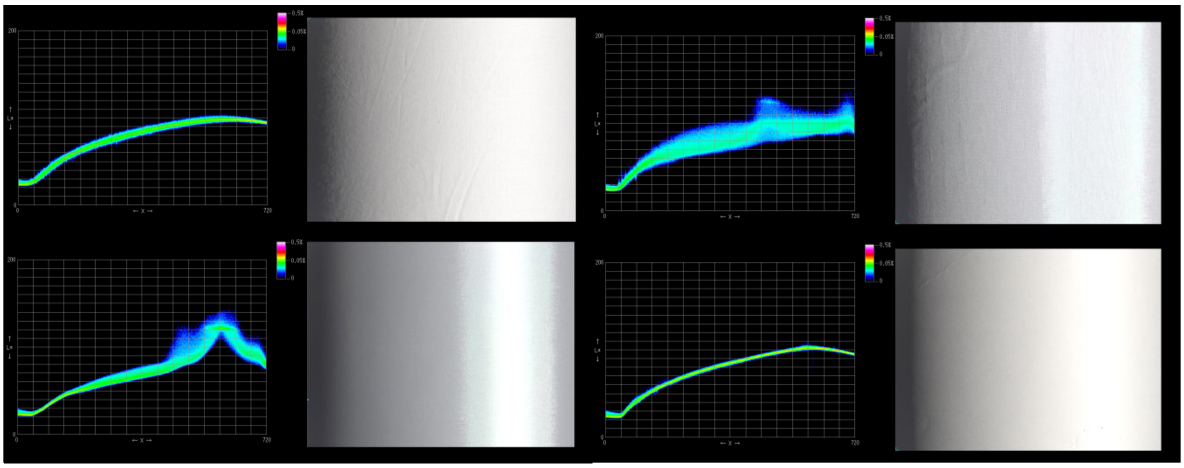


Figure 2: Measuring result of 4 chosen textile and paper.

2.2 Human visualize assessment (Visual Data Acquisition)

With basics of profile from measurement data, presentation stimulation recording based on magnitude estimate was carried out to measure perception levels. Experimental stimulations used gloss constituents from each basic reflectance profile of cotton, silk, synthetic fabric. And finally, texture such as short and long fiber, their carried combination as stimulating parameter and 32 images are created with skewness range between -0.6 to 0.8 and kurtosis range between 1.8 to 2.5 of luminance distribution. The texture intensity calculated by Laplancian filter, and created image has 1.4 to 24. The list of the used parameters in every experiment was shown in Table 1.

Table 1. The list of parameter.

Sample	Skewness	Kurtosis	Texture Intensity	Sample	Skewness	Kurtosis	Texture intensity
1	-0.46	1.86	1.41	17	0.80	2.48	6.85
2	-0.59	1.99	16.93	18	0.79	2.48	10.06
3	0.79	2.48	13.30	19	0.79	2.48	13.30
4	-0.41	1.86	15.43	20	0.79	2.47	16.55
5	-0.59	1.99	11.44	21	0.17	2.01	4.07
6	-0.59	1.99	13.78	22	0.17	2.01	7.17
7	0.79	2.48	11.44	23	0.17	2.01	10.37
8	0.79	2.47	17.49	24	0.17	2.01	13.61
9	-0.41	1.86	13.22	25	0.17	2.01	16.86
10	-0.60	1.99	4.55	26	0.11	1.79	2.29
11	-0.48	1.93	8.77	27	0.11	1.79	4.73
12	-0.59	1.99	16.89	28	0.11	1.79	7.82
13	-0.59	1.99	20.32	29	0.11	1.80	11.01
14	-0.58	2.00	24.02	30	0.11	1.80	14.23
15	0.80	2.49	1.48	31	0.11	1.80	17.47
16	0.80	2.49	3.74	32	-0.17	1.79	2.28

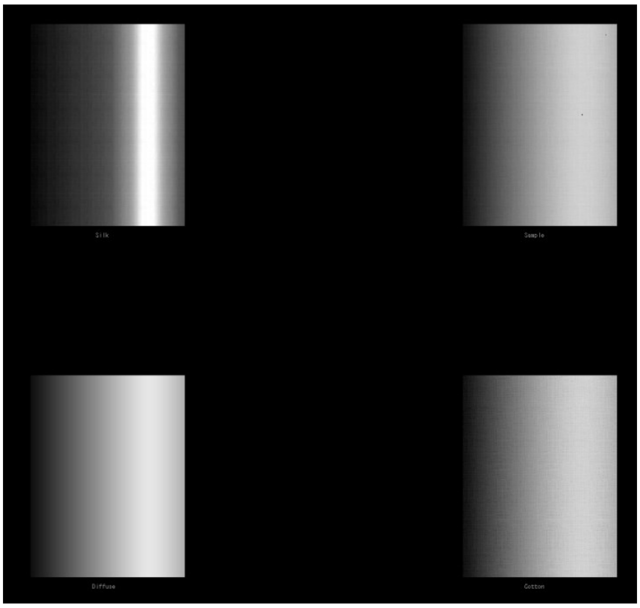


Figure 3: Test sample image for human visualize assessment.

As the parameters, from the gloss parts, cotton, silk, synthetic fabric, diffusing cotton and each respective reflectance profile, and also short and long fabric type textures were prepared to be paired variably for making different stimulations. For these stimulations, the image from the diffusing cotton profile with the 0 intensity of texture was placed on the origin point in XY coordinates, on (X,Y) = (1.0, 0.0) for the image of short fabric type texture from cotton profile, on (X,Y) = (0.0, 1.0) for the image of long fabric type texture form silk profile, on X axis for cotton likeness, on Y axis of the 2 dimensional coordinates for silk likeness, and finally on (X,Y) = (1.0, 1.0) for each given stimulation. For answer process, XY coordinates were shown and mouse clicking over the 2 dimensional coordinates was conducted. In this manner, fabric likeness coincides with the distance from the origin point, cotton likeness with X axis, silk recognition intensity with Y axis, and all of these were alternatively displayed. Also, while answering, there were 4 sorts of answers as following; 1 is cotton recognizing, another is 2 for silk recognizing, 3 for recognizing non-cotton or silk, and the last is 4 for not recognizing any fabric. The subjects in the experiment were 20 with normal eye vision, consisting of male 0 and female 0. 4K display (Samsung, the U32D970Q, 31.5 inch, 16:93820X2190 pixel, 208dpi, 350Cd/m2) was used for indicating display(See Fig 3.).

3. RESULTS AND DISCUSSION

Figure 4 shows the visual assessment test results and the plot results from the whole answers' values. And x and y are the values of answers on 20 points surely gotten from experiments. Also, 20 people were asked to report whether they can recognize or not. From the silk and cotton, there are 2 divisions in area. In the center was either recognizing as other fabric or not recognizing as any fabric. So were cotton and silk in the center and also admitted in the strong gloss area. For the suggested stimulation area, it goes almost up to not-recognition which will be the properly suggested range.

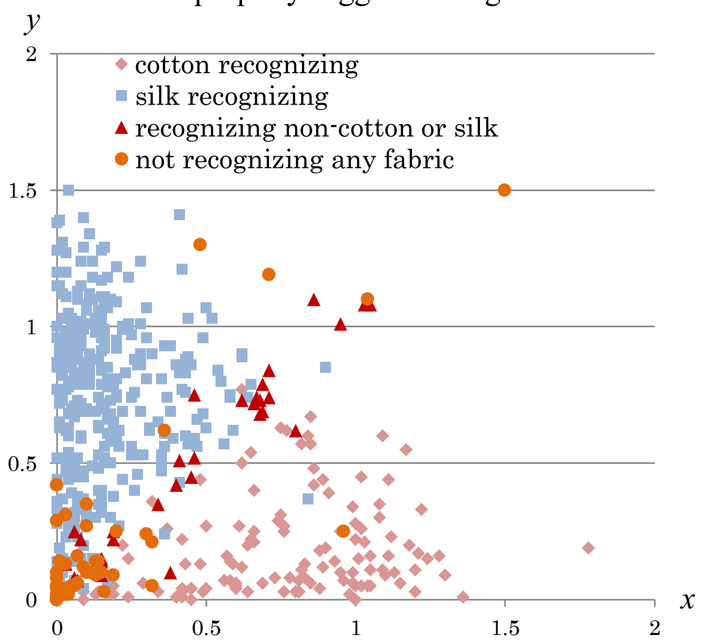
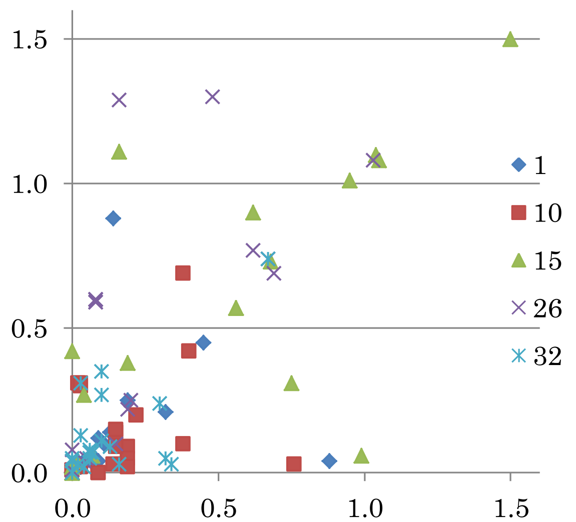


Figure 4: The human visualize assessment test result.

Figure 5 shows what the results of instrumentation would be like if only stimulation revised by one gloss profile is suggested. Above all, the level of recognition was low, and more or less than 48 percent or almost up to half answered that they couldn't recognize any fabric in this stimulation group. This is because the No. 1 matt with gloss profile and the No. 32 with combined by 4 profiles were recognized bad, and these 2 were followed by

72.5% of answers that reported that they were not recognized as any fabrics. However, in the perfect diffusing profile of the No.10, 35% recognized it as cotton, 85% as fabric including cotton and etc. Also, in the high kurtosis profile of the No.15, 35% reported that it was silk, and 65% said it was a fabric, which produced pretty high scores. Either the No.10 or 15 originally starts from fabric gloss profile, and highly likely to be recognized as fabric even though not undergoing texture test. Besides, cotton is reported from perfect diffusing and silk is recognized from high kurtosis. Although the nuance between profiles for matt and perfect diffusing exists, there is a pretty conspicuous difference in recognition as fabric. Figure 6 illustrates which results should possibly come out when the perfect diffusion profile is added and revised by texture parameter. As the texture increased, levels of recognition as textile fabric went up, too, and even a slightest addition of texture was made, levels of recognition as textile fabric rapidly increased. The No.11 stimulation where the perfect diffusion profile is added by a newly produced short type texture was perfectly reported as cotton by every subject. Meanwhile, in case that long type texture was added, levels of recognition as fabric was 100% as same as the one discussed from the No.11. But, for its proportional results, a half of the subjects said that it was cotton, and the other said it was silk. This didn't resort to the trend from gloss profile, but predominantly on types of texture in which cotton equals to short type fabric and silk equals to long type fabric. The short type texture increased, so proportionally did levels of recognition as cotton.



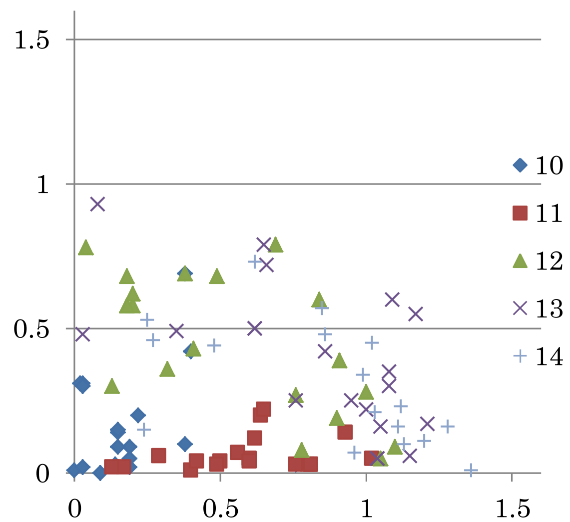


Figure 5, 6: The human visualize assessment test result.

For the next, Figure 7 shows what comes when short type is combined to high kurtosis profile. When the high kurtosis profile was given, the level of recognition as silk was high. Also, herein was reported back as textile fabric by 91% of the subjects placed in this stimulation group, and as silk by 83% in the same group. In addition, even though being the short type, levels of recognition as fabric increased as texture intensity went up. In this case, because gloss far exceeded other parameters in effects, it forcefully affected whether it could be recognized as silk or cotton even though texture was also involved in increases for recognition as fabric. The perfect 100% rate of answers was from the recognition as silk from the No.18 to No.20. Also, Figure 8 indicates the results combined by the compound of high kurtosis profile and the perfect diffusion profile and the short type texture as the one Figure 0 shows. As including the No.15, the 89% rate of answers was from the recognition as textile fabric, and from this, the 78% recognized it as silk. In this step, recognition barely changed, and also the gloss profile was dominant, so the level of recognition as silk was high without depending on texture intensity or its type. There is one interesting fact that when intensity for short type texture fabric increased, it was highly proportionally recognized as silk, so about 100% perfect rate reported it was silk where there was somewhat appropriate texture in these 3 suggested stimulation groups.

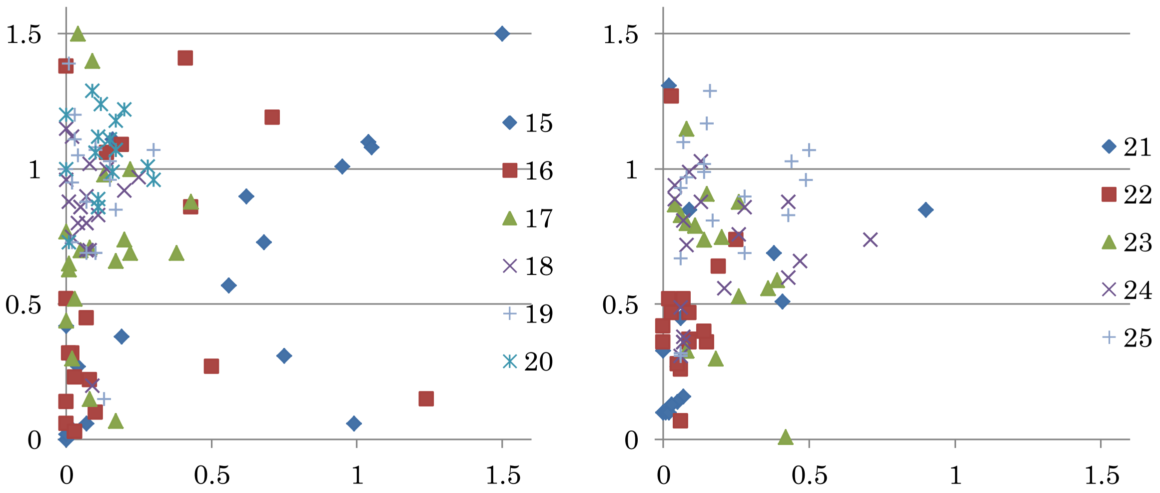


Figure 7, 8: The human visualize assessment test result.

4. CONCLUSIONS

The high gloss textile material has various luminance distribution profiles, so it is recognized as silk without depending on its shape. On the other hands, the low gloss textile material is highly affected by luminance distribution profile in its recognition, and also by the smallest difference of shape without texture. The level of recognition as fabric rapidly increases revised by the texture input. In the diffuse reflection, the types of texture have an impact on recognition of basic fabric material.

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An Experiment on Color Differences Using Automotive Gonioapparent Samples

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ABSTRACT

A panel of 9-11 observers with normal color vision has assessed a set of 61 color pairs in a multiangle color cabinet using a gray scale method. The main goal was to test the potential relationship between perceived lightness differences and lightness flop. The samples in our color pairs were nearly achromatic (C^*_{ab}<10) and with gradual changes of lightness flop in the range 0.5-4.0 CIELAB lightness units per degree. The average color difference in the color pairs was 3.0 CIELAB units. The percentage of lightness difference in the total color difference was above 85% in all color pairs, with an average value of 93.7%. Observers' variability in our experiment was low, with an average standard deviation of visual differences of 0.6 CIELAB units, or an intra- and inter-observer variability of 15.4 and 17.5 *STRESS* units, respectively. The CIEDE2000 color-difference formula provided the best predictions of our visual results with a *STRESS* value of 27.4. However, the predictions made by CIEDE2000 and a set of 11 different advanced color-difference formulas were not statistically significant different, with their *STRESS* values changing in a short range from 27.4 to 33.0 units. Our results show no clear relationship between perceived lightness differences and lightness flop, perhaps because the perceived lightness gradients in the samples in our experiment were small. None of the weighting functions for lightness proposed by recent color-difference formulas (e.g. CMC, CIEDE2000, CAM02-SCD, OSA-GP-Euclidean, AUDI2000, etc.) was particularly useful to predict the results of our visual experiment. However, power functions seem an appropriate option to improve the predictions of current visual results. Specifically, an exponent 0.55 in the CIEDE2000 and AUDI2000 formulas provided *STRESS* values of 18.5 and 18.3 units, respectively, which are considerably lower than the original ones and close to inter-observer variability.

1. INTRODUCTION

Automotive industry needs successful color-difference formulas to establish reliable tolerances in color quality-control. This goal must be achieved for all modern materials employed in this industry, which includes materials exhibiting both homogeneous (solid) and goniochromatic (effect) colors. Goniochromatism can be defined as the property related to the change in any of all attributes of color of a specimen on change in angular illuminating-viewing conditions, without any change in light source or observer. In industrial applications the difference in appearance of a material viewed over two different aspecular angles (i.e. two viewing angles measured from the specular direction) is usually designated as "flop" (ASTM, 1995). Currently, AUDI2000 (Dauser, 2012) is the only color-difference formula considering sample pairs with flop effects in the computation of color differences.

In two previous papers (Melgosa et al., 2014a and 2014b) we analyzed the performance of different advanced color-difference formulas using automotive sample pairs, with particular attention to the performance of the term of lightness flop in the AUDI2000 color-difference formula. In the first paper (Melgosa et al., 2014a), we reported results of an experiment where the sample pairs had a small size of 3.5x3.7 cm and almost random amounts of lightness flop. In the second paper (Melgosa et al., 2014b) we employed samples with a bigger size of 10x10 cm and systematic increasing amounts of lightness flop, but the color differences in a considerable number of these color pairs were not lightness differences. This made difficult to achieve clear conclusions on the relationship between lightness differences and lightness flop, as proposed in the AUDI2000 color-difference formula. The current paper reports a new experiment where, in addition to sample pairs with the highest available size and a systematic increase of lightness flop, the color differences in all color pairs were predominantly lightness differences. Specifically, in all color pairs in the current experiment the percentage of lightness difference (ΔL^*) in the total color difference (ΔE^*_{ab}) was higher than 85%, and the uncertainty in observers' visual assessments was considerably low. In this way, we expect to achieve new conclusions on the relationship between perceived lightness differences and amount of lightness flop, which may be particularly useful to test/improve the AUDI2000 color-difference formula.

2. METHODS

From a set of 476 samples produced by AkzoNobel for the automotive industry, we have selected 61 nearly achromatic color pairs with increasing amounts of lightness flop. Figure 1 shows the average color coordinates and lightness flops of the two samples in each color pair, as measured using a BYK-mac multi-angle spectrophotometer (aperture 23 mm; illuminant D65; CIE 1964 standard colorimetric observer). Our samples had C^*_{ab}<10 and a wide lightness range (Fig. 1, left). For our color pairs, the average values of lightness and the angular lightness flop had a good positive correlation (Fig. 1, right), in such a way that, for example, it was not possible to find color pairs with low lightness and high angular lightness flop. We have defined the angular lightness flop for each color sample as $|L^*_{\gamma i+1} - L^*_{\gamma i}|/(\gamma_{i+1} - \gamma_i)$, where the angles were γ_i=15° and γ_{i+1} =25°, or γ_i=25° and γ_{i+1}=45°, according to the viewing conditions. The two samples in each color pair had very similar angular lightness flop, the angular lightness flop of each color pair being defined as the average. We can note that the angular lightness flop in our color pairs was above 0.5 (i.e. we have not highly homogeneous or solid colors) and covered a relatively wide range (Fig. 1, right). With respect to the color differences in our color pairs, they had average and standard deviations values of 3.0 and 1.9 CIELAB units, respectively. It is important to emphasize that the highly predominant contribution in such color differences was a lightness difference, in such a way that the percentage of lightness difference, measured as $100(\Delta L^*/ \Delta E^*_{ab})^2$, had an average value of 93.7%, with no color pair with percentage lower than 85%.

Each one of the 61 selected color pairs was visually assessed using a byko-spectra effect light booth (BYK Additives and Instruments) placed in a dark room. Specifically, 31/30 color pairs were assessed at the University of Alicante/Granada (Spain) by 9/11 observers with normal color vision, the viewing angles being γ_i=15° for 30 color pairs, and γ_{i+1} =25° for the remaining 31 color pairs. After an adaptation time of around 3 min, the color pairs were presented in random order to each observer, whose task was to judge the magnitude of perceived color differences using the Gray Scale for Change in Colour of the Society of

Dyers and Colourists. This Gray Scale (9 color pairs with color differences in the range 0-15 CIELAB units, approximately) was just placed above the color pairs. The visual sessions never lasted more than 20 min to avoid observers' fatigue. Each observer performed 3 non-sequential assessments of each color pair, in such a way that a total of 1827 visual assessments were recorded in our experiment. The raw gray scale results reported by the observers were transformed into true visual differences (ΔV) in CIELAB units using a fourth degree polynomial function (Guan et al., 1999). We removed as outliers all visual answers below Q1-1.5*(Q3-Q1) or above Q3+1.5(Q3-Q1), where Q1 and Q3 are the first and third quartiles in the population of all visual answers, respectively.

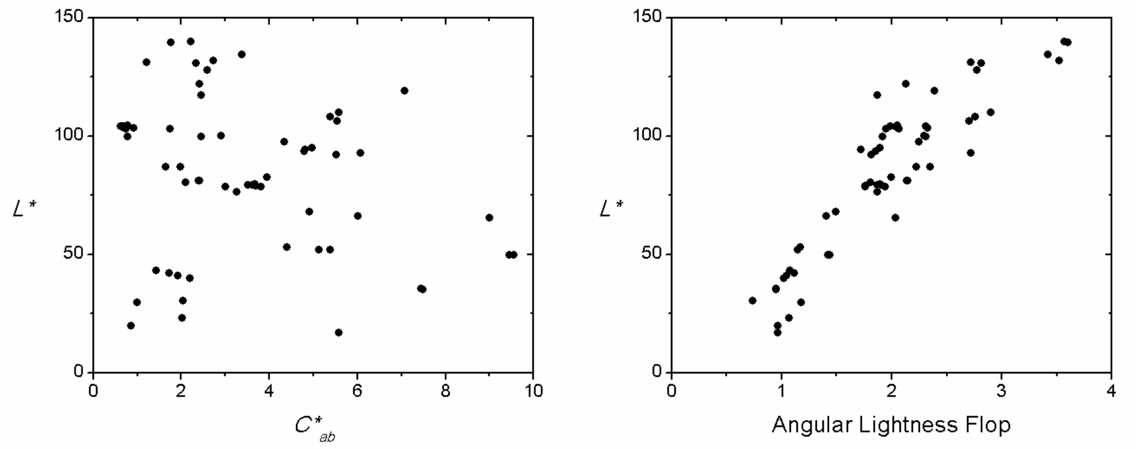

Figure 1: Average CIELAB color coordinates of the two samples in the 61 color pairs (left); average values of lightness against average angular lightness flop (see definition in main text) for the 61 color pairs (right).

We have tested the predictions of the visual results in our experiment by a set of 12 modern color-difference formulas. Detailed information on such color-differences formulas can be found in the original papers or in recent reviews (Melgosa et al., 2013; Melgosa et al., 2014a). The *STRESS* index (García et al., 2007) has been used to measure the merit of each tested color-difference formula, as well as the intra- and inter-observer variability in our experiment (Melgosa et al., 2011). Low *STRESS* values (always in the range 0-100) indicate better performance of a color-difference formula or low observer variability. A color-difference can be considered successful when it achieves a *STRESS* value lower than the ones corresponding to the intra- and interobserver variability.

3. RESULTS AND DISCUSSION

After removing outlier answers, the average standard deviation of the visual differences measured in our experiment was 0.6 CIELAB units. This means that observers' accuracy in our visual experiment was considerably high, in agreement with our values for intra- and inter-observer variability, which were 15.4 and 17.5 *STRESS* units, respectively. Results in Table 1 indicate that predictions of our visual experiment by 12 color-difference formulas were enough similar, as indicated by a short range of *STRESS* values between 27.4 and 33.0 units. Parametric factors in all tested color-difference formulas were assumed as $k_L=k_C=k_H=1.0$. The CIEDE2000 formula, which is the currently CIE/ISO recommended color-difference formula, provided the best predictions of our visual results with a *STRESS* value of 27.4, but it must be indicated that the predictions made by CIEDE2000 and the remaining 11 color-difference formulas were not statistically significant different. It is also important to note that the *STRESS* values for all tested color-difference formulas were at least 10 units higher than the intra- and inter-observer variability in our experiment, which means that the predictions made by all these color-difference formulas were unsatisfactory.

Table 1. STRESS values for 12 tested color-difference formulas (k_L=k_C=k_H=1.0).

CIELAB	CIELUV	CMC	BFD	CIE94	CIEDE2000	DIN99d	AUDI2000	CAM02-SCD	CAM02-UCS	OSA-GP-Euc.	OSA-GP
30.9	31.0	33.0	32.5	31.0	27.4	28.9	32.7	29.3	28.7	31.1	30.0

We have plotted the ratio $\Delta L^*/\Delta V$ against the angular lightness flop for our 61 color pairs (Fig. 2, left), in order to ascertain potential relationships between lightness tolerances and lightness flop. Note that the ratio $\Delta L^*/\Delta V$ is equal to the lightness tolerance (or the weighting function for lightness usually designated as S_L) when the CIELAB chroma and hue differences are null. This last approach is enough acceptable in our current situation of color pairs with highly predominant lightness differences. From the results shown in Fig. 2 left, it cannot be concluded that lightness tolerances increase with angular lightness flop, as proposed by the AUDI2000 color-difference formula. Therefore, optimizing the coefficients in the weighting function for lightness in the AUDI2000 formula with respect to our current visual results seems meaningless. However, there seems to be an enough clear non-linear relationship between our visual results and the predictions made by the AUDI2000 color-difference formula (see Fig. 2, right). Similar relationships can be also found for the other color-difference formulas considered here, suggesting that a simple power function may improve the performance of most color-difference formulas (Huang, 2015).

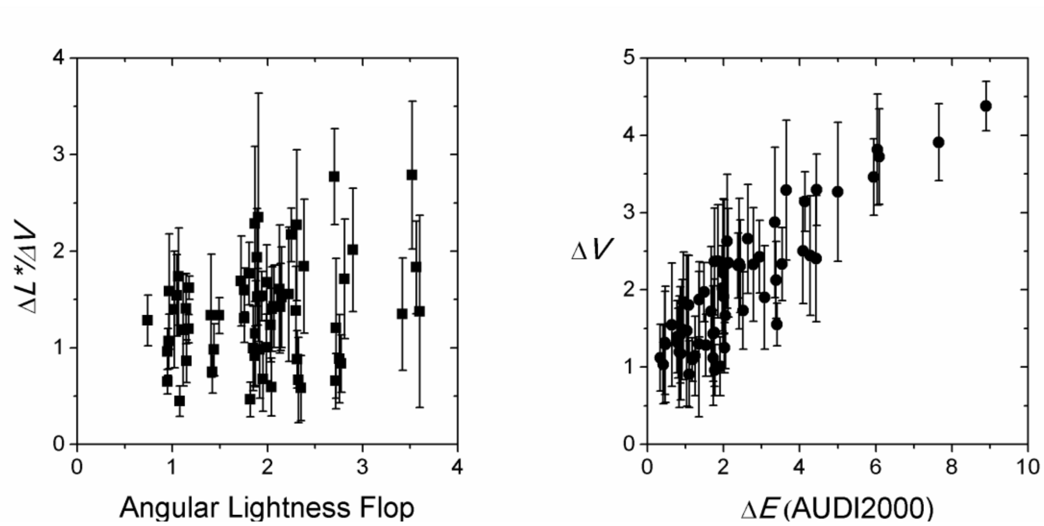

Figure 2: Relationship between approximated lightness tolerances and angular lightness flop (left); visual differences against predictions made by the AUDI2000 formula (right). Error bars indicate the uncertainty associated to the variability in observers' assessments.

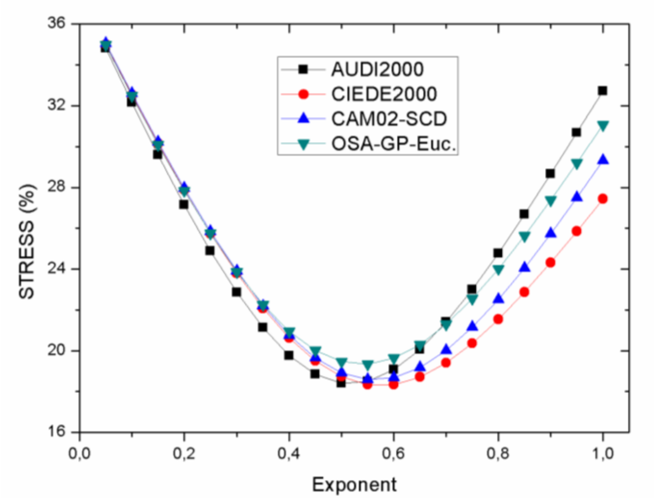

Figure 3: STRESS values for power functions with different exponents in four color-difference formulas, with respect to the visual results found in our experiment.

It can be noted (see Fig. 2, right) that ΔV values are overestimated for very small color differences (perhaps as a consequence of false alarm rates and the fourth degree polynomial function employed to convert from raw to true visual differences), and underestimated for very large color differences. These two deviations may be accounted in color-difference formulas by using simple power functions with appropriate exponents α; that is, simple transforms like $\Delta E'=\Delta E^{\alpha}$. Power functions led to a considerable improvement in the predictions of the visual results found in our experiment by different color-difference formulas, as shown for four specific color-difference formulas in Fig. 3. Note that exponents around 0.5-0.6 considerably decreased the *STRESS* values reported by the original color-difference formulas in about 8-10 *STRESS* units, and the new *STRESS* values are very close to the inter-observer variability in our experiment (17.5 *STRESS* units). Specifically, the use of an exponent 0.55 in the CIEDE2000 or the AUDI2000 color-difference formulas provided values of 18.5 and 18.3 *STRESS* units, respectively.

4. CONCLUSIONS

We have developed a visual experiment where 61 color pairs with mainly lightness differences and different amount of angular lightness flop were visualy asssessed with low uncertainty by a panel of 9/11 observers with normal color vision. From the results in this experiment it cannot be concluded that lightness tolerances increase with angular lightness flop, as proposed by the AUDI2000 color-difference formula, perhaps because the perceived lightness gradients in the samples in our experiment were small. Predictions of our visual results by a set of 12 modern color-difference formulas were not significantly different and unsatisfactory. However, such predictions may considerably improve using power functions with exponent around 0.5.

ACKNOWLEDGEMENTS

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Legibility of printed Thai letters comparison on young and elderly

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ABSTRACT

Elderlies' vision deteriorates by cataract when they are aged. Printed labels represent visual environment and have been found to be expressed by so small letters, which are too difficult for elderlies to read. Design of labels and sign consist of fonts and colors. Thai letters are unique in shape and composition, and can have effect on legibility. The proper color-pairs used for combination of fonts and backgrounds are also needed to guarantee highly legible for efficient vision. This research aimed to compare the legibility of printed Thai letters for young and elderlies in terms of different background contrasts under normal daily situation and illumination. Elderlies aged 60-80 years old and young subjects aged 20-40 years old participated in this experiment. Subjects experimented with adjustment method to find out the legibility of letter charts capable for correct reading. Three achromatic charts of black letters on White, N5, and N4 backgrounds were used for monochrome chart. The charts in different backgrounds each contain 24 lines of Thai letters varying in sizes that are logarithmically even distributed. The viewing distance of 1.2 meter with natural lighting situation in the day time was used for this experimental illuminance. The result showed that for the similar illuminance, legibility of the young not much affected by the darkening of background compare to the substantial legibility decrease of the elderlies when background darkening. The darker background or the lower contrast charts caused higher decrease in legibility for elderlies than the young.

1. INTRODUCTION

Thailand is emerging the elderly society soon as the elderly population in Thailand is increasing substantially. The ageing physical change affect the quality of life, especiallly the visual performance. When people get older they get cataract and their visual performance deteriorates. It is an urgent matter to investigate the performance of elderly vision and to provide proper infrastructure and environment to assure them the quality of life. In this study we pay attention to letter size and background contrast of product labels as the elderly people get information from labels for their daily living. Legibility by elderly people has been investigated by some researchers, Elliott et al. for English, and Ayama et al. for Japanese. They all showed deterioration of the visual acuity by elderly people. But in our knowledge, none investigated for Thai letters and no proposal was made for the Thai letter size recommended for labels to suit elderly people. Thai letters are different from English or Japanese letters.

Legibility at the high contrast stimuli is better than the legibility of lower contrast. Different color pairs of letters and backgrounds also give different legibility which affect the visual performance of elderly and young people differently. We want to know the degree of legibility difference between the elderlies and youngs under normal daily lighting situation in order to set the guideline for graphical labels designing that create by young designers' vision to suit the proper vision of elderlies.

2. METHOD

The adjustment experimental method was used for this study. Subjects were divided into two groups: ten young and eleven elderlies. The elderlies live with their family and performed experiment in their home or in the temple community area during the social gathering event, which was the relaxing atmosphere. Young subjects are recruited from home and office.

2.1 Apparatus

The apparatus for this field experiment composed of test chart and mask, light meter, and measuring tape. The Thai letters test chart was designed to test the legibility especially for Thai subjects. The chart contains 24 lines of Thai letters varying in sizes that are logarithmically even distributed from line to line. There are 3 charts of different backgrounds in White, N5 and N4 to represent different contrast background as shown in Figure 1.

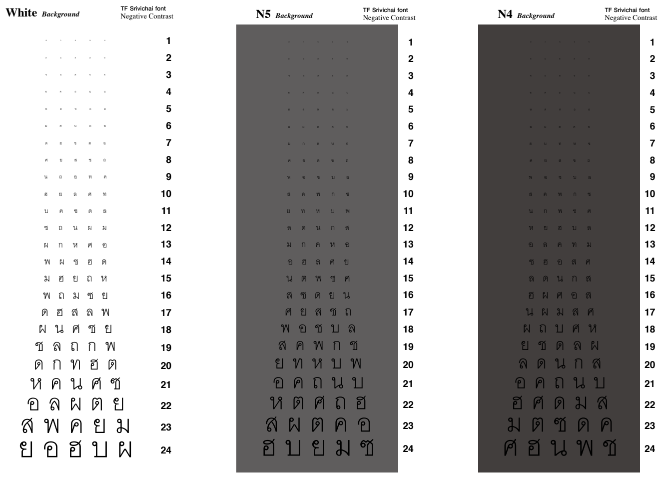

Figure 1. Thai letters test chart in White, N5 and N4 backgrounds.

2.2 Procedure

The subject recruitment was done by two steps. First, check the age to fit in the required range of 20-40 years for young, and 60-80 for elderly. Second, to interview and exclude of any eye decease or abnormal eye condition such as severe cataract. The recruited subjects sat in 1.2 meters distance and illuminance measured. The experiment started with the white background color chart. Mask with window that open to see only one line at a time was used to hide the rest of different letter sizes. The test chart of white background was shown to subject with a mask that open only one line of letters at a time. Subject was asked to tell the overall sharpness of letters shown, and to fine tune to the line that was legible with confident. The larger size letter is shown if subject cannot read correctly, and the smallest line number that fulfill the confident correct reading was recorded. Subjects tell the line number of each chart that can see clearly, and the line number is recorded. The same procedure was done to test chart of N5 and N4 background respectively. Each subject experimented for one time.

3. RESULTS AND DISCUSSION

The legibility data recorded by line number from the experiment was calculated into letter height. The results of legibility are shown by letter height of elderly and young form the three backgrounds test chart and shown in Table 1.

The averaged age for elderly and young are 68.4 and 31.0 years old respectively. There are 11 elderly subjects and 10 young subjects participated in the experiment. The result from all subjects in each groups are averaged in letter height that legible at the distance of 1.2 meter. The illuminance at the experimental area were averaged 913 lx for elderlies and 900 lx for young.

Table 1. Legibility of elderly and young in daily situation on 3 backgrounds

						Letter height (mm)		
	Age (avg)	Subjects	Sex	Lx (avg)	Dist(m)	Nw	N5	N4
Elderly	68.4	11	2M/9F	913	1.2	4.6	6.5	8.7
Young	31.0	10	4M/6F	900	1.2	1.7	2.0	2.2
Gap of difference						2.9	4.5	6.5

The experimental result showed the legibility in term of the letter height that fully legible to the subjects. Legibility of elderlies worse than the legibility of young in all levels of background contrasts. The gap of difference become higher with the darker background from 2.9 mm on white background to 4.5 mm on N5 background and 6.5 mm on N4 background. Figure 2. shows the letter height of elderlies and young in different background contrast charts. The black circle showed legibility of the elderlies, and open circle showed legibility of the young. Lower letter height represents better legibility. This imply that elderlies suffer in higher degree than young people if the contrast of stimuli is decrease.

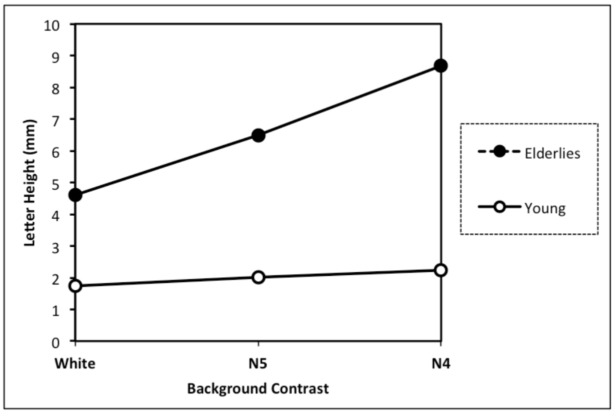

Figure 2. Letter height difference between elderlies and young for test chart in White, N5 and N4 backgrounds.

4. CONCLUSIONS

Legibility of elderlies worse than the legibility of young in all levels of background contrasts. The deterioration increase for the lower contrast of stimuli. This imply that elderlies suffer in higher degree than young people if the contrast of stimuli is decrease. For the designing of graphical labels, legibility of elderlies must be concern. Under the same illuminance and distance conditions, young designers can put the degree of letter height difference or legibility difference shown in this experiment into account for the assignment of letter height suitable for elderlies in their design.

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On the perceived brightness of whites

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ABSTRACT

One of the most fascinating observations in the perception of whiteness is the fact that objects with a slight bluish tint appear whiter than objects with a neutral reflection, which resulted in a widespread use of fluorescent agents in white surfaces. The increased whiteness additionally induces a feeling of increased brightness of the white surfaces. This result, however, is shown to hold for two objects under the same light source. In this work, we explore the relation between the perceived whiteness and perceived brightness of the same surfaces lit by different light sources. Using simultaneous viewing and an interleaved, forced choice staircase procedure, a scene lit by two light sources, producing a chromaticity difference of 0.007 Δu'v', was matched on perceived brightness. The matching was done for three illuminance levels: 150, 300, and 500 lux. The results of 18 participants show a surprisingly large effect of the relatively low chromaticity change on perceived brightness. The illuminance level at which the whiter scene looked equally bright with the reference was found to be on average 20% lower. The effect was influenced by the light level and was smaller (12% at 150 lux) at lower light levels. No effect of age, gender, or lighting expertise was found. However, a small group of participants had markedly different answers and showed no effect of perceived whiteness on their judgment of brightness.

1. INTRODUCTION

Whiteness perception of objects is an important part of the visual experience and has been a topic of considerable interest in the color world. As early as 1979 an overview paper by Ganz (1979) cited more than 300 papers on the topic and Wyszecki and Stiles (2000) give 20 different formulas for measuring perceived whiteness of objects. One of the most fascinating results in the perception of whites is that a perfect white diffuser (with 100% reflectance in the visible wavelength range) can be perceived as less white than an object with a lower reflectance, if the lower reflectance object has a slight bluish tint. If, however, the reflectance of the tinted object is lowered in a way that keeps the amount of tint the same, at some point the perfect white diffuser is perceived as whiter again. Thus, for the perception of whiteness, there is a trade-off between the lightness of an object and the amount of bluish tint that produce the same increase in perceived whiteness. This trade-off ratio can be estimated from whiteness formulas that take both lightness and chromaticity into account, like the CIE Whiteness equation (CIE 2004). Furthermore, participants in whiteness experiments often note that surfaces that appear whiter also appear lighter or brighter.

The increase of the perception of whiteness by shifting the chromaticity towards blue has been used in the paper and textile industry, where the natural tint of the raw material is yellowish. From using blue dyes, as early as 1929 (Krais, 1929) the industry has shifted to using fluorescent whitening agents (FWAs). FWAs transfer part of the ultraviolet and violet part of the electromagnetic spectrum (λ < 430 nm) to the blue-cyan part of the spectrum of visible light (for which the human eye is more sensitive), thus shifting the chromaticity of the surface towards blue and increasing perceived whiteness.

Most of the classical work on whiteness has been on the perception of whiteness of objects and the illumination has always been treated as a given. The newly rekindled interest in whiteness, however, has been driven by the influence of the illumination on the appearance of white surfaces. In particular, the influence of LED lighting on the appearance of white surfaces containing fluorescent whitening agents was brought to attention by among others Zwinkels and Noel (2011). As most LED light sources do not emit ultraviolet and violet light, the FWAs in the white objects are not activated which results in poorer whiteness rendering compared to daylight and other electric light sources.

The difference in whiteness rendering of different electric light sources also brings differences in the perceived brightness of whitened surfaces. This brings the interesting question of the influence of whiteness rendering of an electric light source on the perceived brightness of the environment that the source illuminates. In this work, we present an experiment designed to explore the effect that the increased perception of whiteness, due to activation of FWAs, has on the perception of brightness of a simple scene containing white surfaces.

2. EXPERIMENTAL METHOD

To find the effect of increased whiteness on the perception of brightness, we designed a brightness matching experiment using LED light sources with and without FWA activation. The illuminance in the center of a simple scene was used as a correlate of brightness and the brightness matching was done using simultaneous viewing. The light source with no FWA activation, called the reference light source, was presented at three preset light levels and the intensity of the light source with FWA activation, called the test source, was tuned using a staircase procedure until an equal perceived brightness was achieved. Additionally, to check the measurement error of the method, the same procedure was used to match the brightness of two reference sources.

2.1 Experimental setup

The experiment was conducted using two identical viewing boxes with the experimental light sources mounted in the center of each box. Both the vertical and the horizontal planes of the boxes were covered with standard office paper from the same batch and having the same FWA properties. All the outside edges of the box were covered with black cardboard perpendicular to the edge. This included the edge between the boxes and ensured a separation of at least 10 degrees of visual angle between the two sides of the stimulus.

Each box had two different LED light sources. The first, reference, light source was a standard warm white spot light module with chromaticity on the black body locus of u'v' = (0.252, 0.521) and did not activate FWAs. The second, test light source, was a spot light module with added violet radiation to activate FWAs. Both modules were positioned at a close distance to each other at the center of each box and were used without a reflector. The difference in the chromaticity of the light reflected from the paper under the light sources was 0.007 Δu'v'. The light sources were driven using a 16 bit DMX driver connected to a computer. The setup was calibrated and checked for thermal effects. Within the ranges of light levels used in the experiment, the thermal effects were negligible. Based on the calibration measurements, a transfer function was fitted modeling the illuminance at the target position for a given DMX control value for each module/driver combination.

2.2 Stimuli and procedure

From the viewing distance of 1 meter from the viewing boxes, the participants simultaneously observed both stimuli. Each box had a size of 60 degrees visual angle with a 10 degree visual angle black separator between the boxes.

The brightness matching was done at three reference illuminance levels of 150, 300 and 500 lux. For each reference light level, a range of light levels for the test light source were defined and a staircase procedure was used to traverse over the levels. Two staircases per reference light level were used: one with the reference on the right side; and one with the reference on the left side. Additionally, two staircases were added with both sides showing the reference source and changing one of the sides to produce a brightness match. All staircases started from a random light level of the test source ranging from 50% to 150% of the reference light level. All staircases were presented randomly interleaved to account for possible reference bias of the participants. At each staircase step, the participants had to indicate which box was perceived as having a higher brightness using the left and the right arrow keys on a keyboard. The procedure was explained to the participants before the beginning of the experiment. The term brightness was not explained such that all participants had their own interpretation of the term.

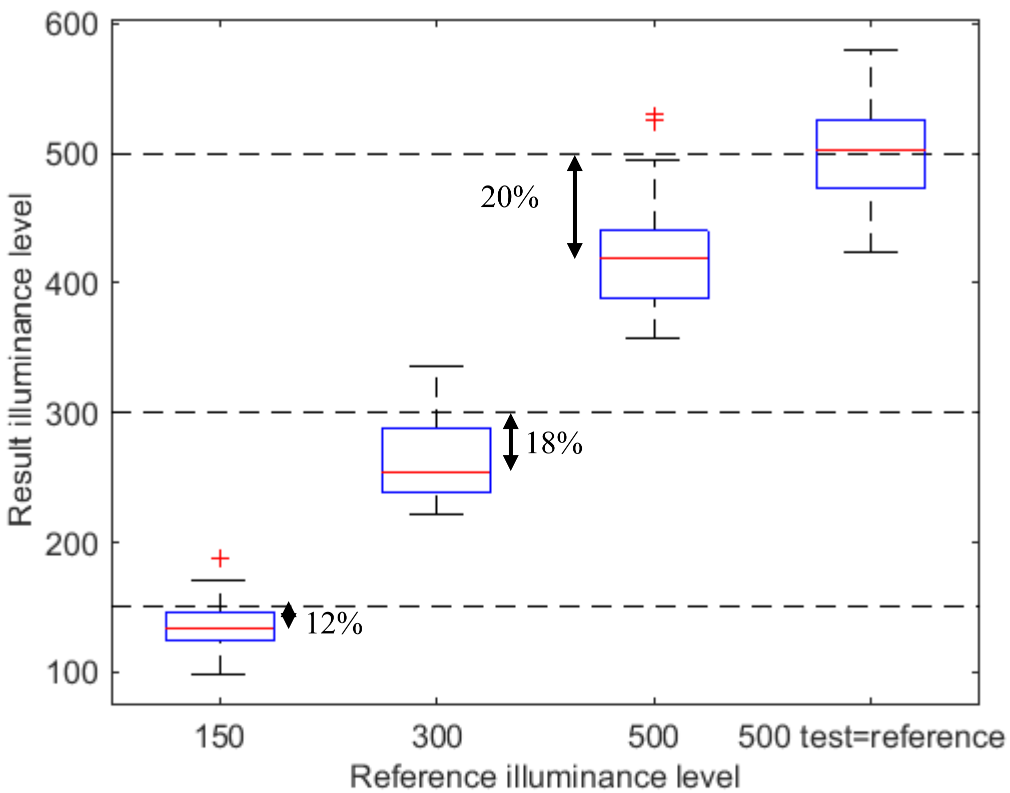

Figure 1: A boxplot of the resulting matched illuminance levels for the three reference illuminance levels (150, 300, and 500 lux) in the experiment.

2.3 Participants

18 participants with ages from 22 to 58 took part in the experiment. Five participants were female and twelve of the participants were lighting professionals. All participants were members of the staff or interns of Philips Research in Eindhoven, the Netherlands.

3. RESULTS AND DISCUSSION

The results of the experiment are expressed as the illuminance level produced by the the test source at the center of the scene for a given illuminance level of the reference source. Figure 1 gives an overview of the obtained results. The difference in illuminance between the reference source and the median illuminance of the test source for which an equal brightness was obtained was 12%, 18% and 20% for reference illuminance levels of 150, 300, and 500 lux, respectively (see Figure 1).

The clear effect of the chromaticity change on perceived brightness, as visible in figure 1, is also supported by statistical testing. All single sample t-tests for the cases with different chromaticies showed a significant difference from the mean illuminance of the reference source ($p < 0.001$ in all cases). For the additional staircases with the same test and reference light source, a single sample t-test did not show a significant effect ($p = 0.798$). The measurement error also depended on the light level and ranged from 19 lux for the lowest light level to 41 lux at the highest light level. There was also no difference between the measurement error in the regular cases and the additional case where the reference light source was used both as a reference and as a test source.

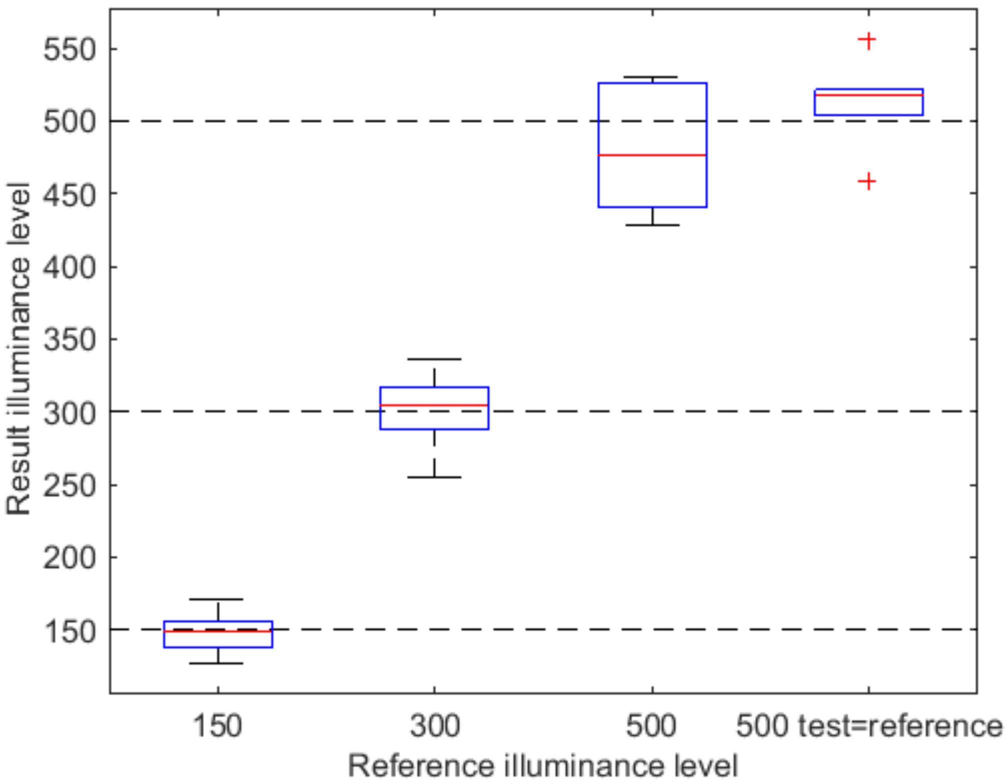

Figure 2: A boxplot of the resulting matched illuminance level for the illuminance levels in the experiment for the group of 3 participants not showing a significant effect.

No significant effects of age, gender, or lighting expertise were found using an ANOVA procedure. A hierarchical cluster analysis procedure identified a small group of three participants with markedly different answers than the rest of the participants. The results of the participants in this group were significantly higher than the other participants and showed no significant difference from the illuminance of the reference source for all light levels. Figure 2 depicts the result of this group of participants. It is interesting to estimate the size of this group in the general population as the size estimated from this experiment can be biased due to the selection of the participants in the experiment.

The results show that for an average observer, the activation of FWAs not only increases the perception of whiteness of surfaces, but also the overall brightness of the surrounding that contains white surfaces. Consequently, an equivalent brightness impression can be obtained by using up to 20% less intensity. This result can be particularly important in applications where both the perceived brightness and the natural whiteness rendering of surfaces is important, as for example is the case in fashion retail. In this case, only using the illuminance in the space could be a poor indicator of the suitability of a light source. For more accurately predicting the object as well as space appearance, whiteness rendering and in particular the activation of FWAs have to be taken into account.

4. CONCLUSIONS

We present results of an experiment that was designed to explore the change in brightness appearance caused by change of illumination that results in a change in whiteness perception. A LED light source that activates fluorescent whitening agents was shown to match the brightness of a LED light source that does not activate FWAs with up to 20% less intensity. No effect of age, gender, or lighting expertise was found. However, three participants had markedly different answers and showed no effect of perceived whiteness on their brightness judgment. The presented results show the need of taking the whiteness rendering of electric light sources into account when comparing the perceived brightness they produce.

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Smart lighting providing different optimal visiual illumination for different objects

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ABSTRACT

Unlike commonly mentioned smart lighting with the purpose of energy saving, the optimal visual smart lighting can provide different CCT conditions of lights for different scenes to achieve the best visual preference which is given as $\text{Preference} = W_1 \cdot \text{Lightness} + W_2 \cdot \text{Saturation}$.

1. INTRODUCTION

When mentioned "Smart lighting", it always denotes the lighting provides different energy saving functions depending on different purposes. In this energy saving smart lighting, it contains a white light illumination and a sensor system to sensing the environment to give more light or less light for energy saving. However , in this article, we mean the smart lighting that will provide illuminations of different color temperatures, and the detemination of which illumination is suitable for a given scene depending on the preference of the scene shined by different color temperatures of lights.

2. METHOD

This smart lighting contains two major parts, namely the color sensing unit and dynamic LED lighting unit. The dynamic LED lighting unit is composed of 4-channel LEDs that can provide the light conditions of CCTs 2700K、3000K、3500K、4000K、4500K、5000K、5700K、6500K、9000K and 12000K. The corresponding color rendering indexes of these lighting conditions are greater than 85. The color sensing unit has RGB sensors to collect the raw data of the responded values of the R-, G-, B- sensors of the scene illuminated by different CCT of lights, followed by a process of converting these R-, G-, B-values to the tristimulus values, X, Y, and Z of the scene by a correcting matrix obtained from a training set of 35 pictures, the correcting matrix is as follow:

$$B = \begin{bmatrix} 4358.3024 & 1609.936151 & 2725.901567 \\ 1508.600055 & 6270.02137 & 1625.804137 \\ -1489.288606 & -7835.489888 & 21395.36667 \end{bmatrix}$$

$$\begin{bmatrix} \hat{X} \\ \hat{Y} \\ \hat{Z} \end{bmatrix} = B \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

, where $\hat{X}, \hat{Y}, \hat{Z}$ are the calculated tristimulus values of the scene obtained from the sensor. These values are to approximate the true tristimulus values of the scene. Then the calculated tristimulus values are transfered to saturation, lightness, and Chroma, thru a simplified formula which can be executed by 8051 microprocessor. Lightness L^* is given as $L^* = W_L \cdot \hat{Y} + W_o$,where W_L and W_o are weighting factors and different CCT has different weighting factors. Saturation is given as $\mathrm{S} = a_2 D_i^2 + a_1 D_i + a_0$, where $D_i = |\hat{x}_i - \hat{x}_n| + |\hat{y}_i - \hat{y}_n|$. Thus, the values of the preference of the scene lighted by the ten light conditions are obtained according to saturation, lightness, and Chroma as $\mathrm{Preference} = W_1 \cdot \mathrm{Lightness} + W_2 \cdot \mathrm{Saturation}$. The light with the largest preference value is the best one. The block diagram the smart lighting is show in Fig.1 .

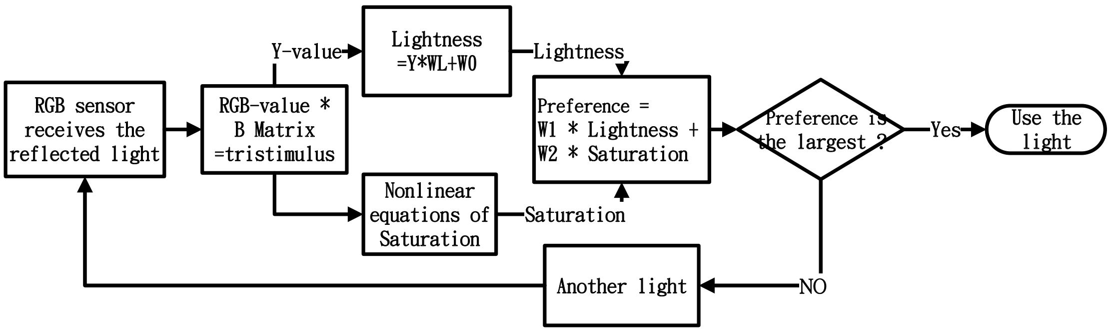


Fig.1 The block diagram of the smart lighting.

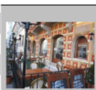
An experiment is conducted by 15 subjects to evaluate the preference score ranged from 1 to 6 of a picture illuminated by different lighting condition. This subjective evaluation result is the same as the result obtained from the proposed LED smart lighting.

3. RESULTS AND DISCUSSION

Light	L	S	By Preference	By subjective method
3000K	16.3465	0.164717	56.4527	0
4000K	17.2814	0.119807	59.3057	23.07692308
5000K	18.0860	0.132568	**62.1165**	**46.15384615**
6500K	17.4197	0.13599	59.8857	19.23076923
7000K	17.2438	0.244627	60.0416	7.692307692
8000K	17.68257	0.121796	60.6769	3.846153846
9000K	17.62066	0.117943	60.4408	0

Light	L	S	By Preference	By subjective method
3000K	16.4280	0.34982	58.0085	0
4000K	18.4476	0.19025	63.7388	11.538462
5000K	18.8790	0.16308	65.0108	26.923077
6500K	19.6493	0.23361	**68.1053**	**30.769231**
7000K	18.4708	0.21149	63.9643	23.076923
8000K	19.15526	0.10344	65.5333	0
9000K	19.14104	0.10209	65.4758	7.6923077

Light	L	S	By Preference	By subjective method
3000K	18.12557	0.08966	61.9537	11.538462
4000K	19.80246	0.24447	**68.6985**	**34.615385**
5000K	19.63744	0.13432	67.3784	19.230769
6500K	19.4456	0.12581	66.6705	11.538462
7000K	19.15356	0.14842	65.8386	7.6923077
8000K	19.64262	0.13077	67.3714	11.538462
9000K	17.62066	0.117943	60.4408	0



Light	L	S	By Preference	By subjective method
3000K	16.42798	0.3539	58.0367	11.538462
4000K	18.93377	0.21413	**65.5493**	**26.923077**
5000K	18.73747	0.06517	63.8549	11.538462
6500K	18.60633	0.05612	63.3485	23.076923
7000K	18.18996	0.20488	62.9684	19.230769
8000K	18.79869	0.0556	63.9959	3.8461538
3000K	16.42798	0.3539	58.0367	11.538462

Light	L	S	By Preference	By subjective method
3000K	16.58972	0.32635	58.3934	0
4000K	18.51785	0.24989	64.3892	11.538462
5000K	19.63744	0.30126	**68.5329**	**30.769231**
6500K	18.96093	0.10146	64.8620	23.076923
7000K	18.60951	0.16739	64.1288	19.230769
8000K	19.22571	0.1468	66.0715	0
9000K	19.2102	0.1516	66.0522	15.384615

Five test pictures are for testing to see whether the selected optimal CCT is the same as the method selected by 26 subjects. As we can see the CCT selected by calculative preference according to L^* and S is exactly the same as selected by subjective method.

4. CONCLUSIONS

An LED smart lighting with 10 different CCT conditions and a color sensing system is proposed. For different scenes, the smart lighting determine the optimal lighting CCT condition based on the best preference value of the given scene shined by the ten lighting CCT conditions. Thus, for a giving scene, the smart lighting selects a lighting condition with the best preference for the scene.

ACKNOWLEDGEMENTS

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Prediction of acceptable lightness difference in painting on automobile surface with different materials based on multi-angle measurement

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ABSTRACT

It is difficult to judge whether variation in color occurring at a coat formation process is within an acceptable range. Even if we examine parts visually and their color appears fine, it would appear different when they are assembled into a car. Moreover, we often judge their color using color measurement apparatus, the measurement cannot necessarily reflect the color acceptance correctly. Since the measured color is only reference information, we always have to look at and check a car actually assembled. This is inefficient and cause many restrictions when we supply those parts from distant factories. It will be a great help to engineers in those factories if we can predict whether the color of parts is correct only by a measured color difference.

Paints for cars appear to be different color when a viewing angle changes. One of reasons why an inaccurate judgment for the color of paints is because the difference is judged only by a color measured with a fixed angle. Therefore, it would be effective to use a multi-angle measurement. I analyzed the color measurement data of vehicles made at a factory, and examined the relation between lightness L* and acceptable delta L* of the painted surface of metal-body and plastics-parts .

The range of acceptable delta L* changes with painted colors. Some paints shows larger acceptable delta L* range than others. When L* is high, the number of colors with large acceptance range of delta L* increases in general, but there are some exceptions. Lightness observed at five angles differ. They become higher if the measuring angle is close to a specular reflection angle, and vice versa. Not only L* of the brightest and the darkest angle differs, but the upward approximate curves of L* in a middle angle range differ.

The boundary of acceptance and unacceptance was compared to the combination of these features.

As a result, it is suggested that three features can explain the acceptance range of delta L* of five angles, and each angle's coefficient is calculated based on angle difference from specular reflection angle.

1) For a color with a big difference of L* between the brightest and the darkest angle, the acceptance range of delta L* becomes larger.

2) If L* from a middle angle goes up rapidly, the acceptance range of delta L* becomes larger.

3) If the L* of surface is higher in each angle, the acceptance range of delta L* becomes larger.

Color measurement apparatus usually obtain color difference based on data at a particular angle in spite of angle dependency in color. Misunderstanding would be caused if a color difference is calculated by CIELAB solely based on those data .Difference of delta L* near actual appearance may be predicted by correcting calculation using this method.

1. INTRODUCTION

An automobile usually uses both metal and plastic as the exterior material. For example, a bumper is made of plastic, while a rear fender is made of the same material as a body structural part; and thus these will be painted in separate processes.

Once completed, a car should appear to be a single color product, and so we strive to have the colors on two different materials look the same now and in the future.

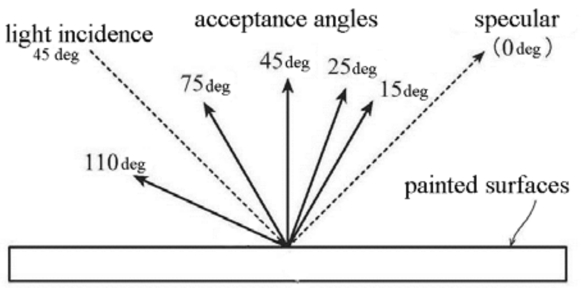
It is said to be ideal to use a color measurement apparatus to quantitatively evaluate color variations that can be generated during the manufacturing process, so that the variation can eventually be brought below an acceptable level and made less noticeable. This method, however, fails to coincide with the result of visual inspection, and needs to be improved.

In the current study, I formulated an equation to estimate the acceptable range in the lightness of any painted color, based on a comparison between visual inspection and a measured color value. The equation includes inclinations between acceptance angles and looseness as the parameters. Some other consideration other than the lightness correction might be needed for a perfect formulation, though, hopefully the method I propose here will help control any color variation which might be generated during the manufacturing process.

2. MULTI-ANGLE COLOR MEASUREMENT

Many paints used for automobiles change lightness or color if looked at from different angles. To prevent such variation, the painted surfaces are often examined using color measurement performed at multiple acceptance angles and entrance angles. At most automobile manufaturing companies, a portable type spectroscopic multi-angle color measurement apparatus with 45-degree incidence and five acceptance angles, X-Rite MA68 (Figs. 1 & 2), is used.

【Fig. 1 X-RiteMA68】

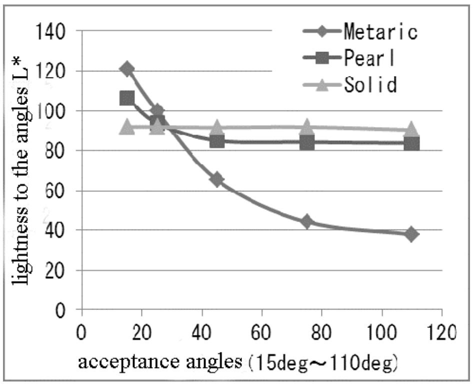


【Fig. 2 Optical System of Color Measurement Apparatus】

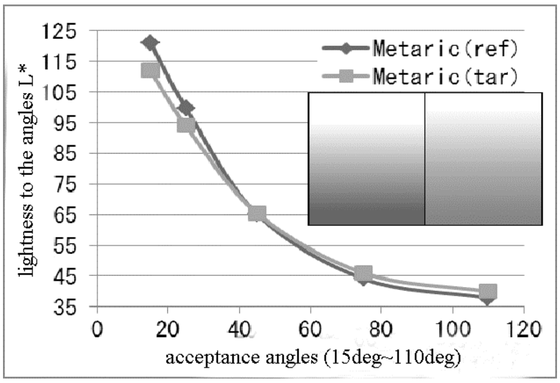
Measurement using this apparatus provides higher reflection intensity at an acceptance angle of 15 or 25 degrees, which is closer to the specular direction, rather than at the angle of 45 degrees, which is perpendicular to the painted surface; and lower reflection intensity at an acceptance angle of 75 or 110 degrees which is farther away from the specular direction.

The reflection intensity experimentally obtained for each wavelength is converted using tristimulus values Y to a certain value, which is then converted in terms of L* to get the relation of the lightness to the angles as shown in Fig. 3.

The case of a silver metallic color shows a highly-curved line over all the angles between 15 and 110 degrees. The case of white pearl shows a line where the lightness increases beyond 45 degrees, and solid colors show a flat line.



【Fig. 3 Silver Metallic, White Pearl, and Solid】



【Fig.4 Example of Change in Silver-Metallic Process】

3. CHANGE DURING PAINTING PROCESS

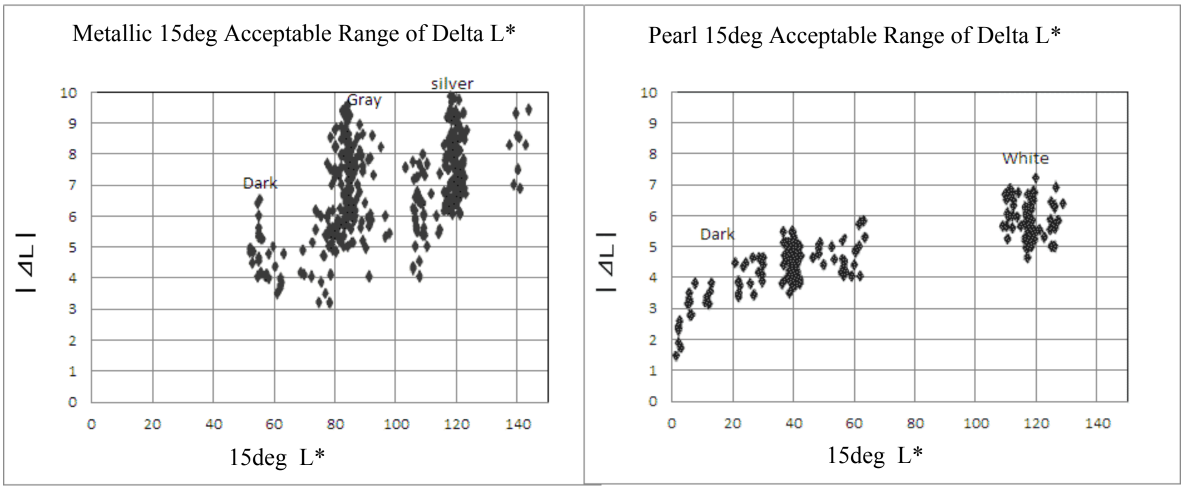
Paint of the same color might end up on painted surfaces as different colors due to many factors in a painting process.

The most significant change appears in lightness, which is hardly ever uniform over all the acceptance angles. The color measurement shows, for example, that L* at 45 degrees changes only by 0.3, while L* at 15 degrees changes more than 3.0. If we used an apparatus which could measure only at 45 degrees in order to establish a threshold, we couldn't make a right judgment, because intrinsically a color space coordinate is defined so that a delta L* shall not exceed 0.3. Fig. 4 shows color differences in silver metallic colored paint when the painting conditions are changed. Target samples "tar" decreases at 15 and 25 degrees than "ref", but increases at 75 and 110 degrees adversely.The difference in lightness that is typical of metallic colored paints can be said to have become smaller.

4. DIFFERENCE BETWEEN DIFFERENCE IN LIGHTNESS (⊿L*) AND ACCEPTABLE RANGE

Color measurement can detect differences, yet even a difference of 3.0 in the delta L* in automotive paints doesn't usually come across as a big difference upon visual inspection, which is sometimes seen as a failing. However, by classifying the visual inspections and results of color measurement according to the kind of paint, I found that although there was a relationship between the delta L* value at which visual inspection resulted in a No Good judgment and the lightness of the paint, the type of paint involved had an even bigger impact.

Fig. 5 has a vertical axis with the delta L* value for multiple automotive parts that passed visual inspection and, of the various acceptance angles at which paint lightness was measured (for example, L* = 65 at 45 degrees, L* = 99 at 25 degrees, and L* = 120 at 15 degrees), charts the results for 15 degrees only.



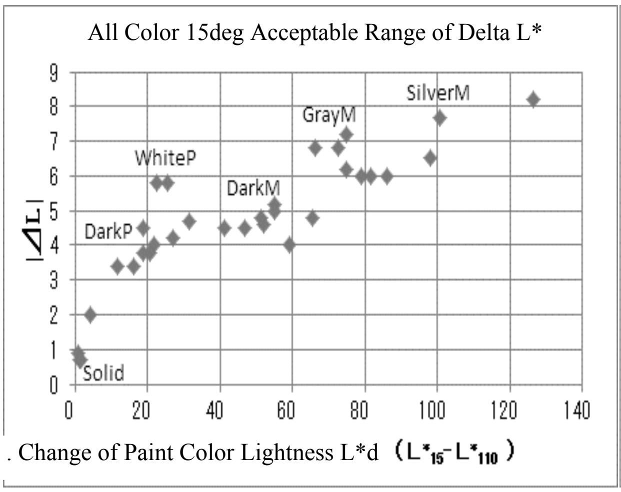
【Fig. 5 Acceptable Range of Delta L* vs. Paint Color Lightness L*. Left: Metallic, Right: Pearl】

Even if there is difference in color measurements, visual inspection may show no difference, allowing the painting to pass the inspection.

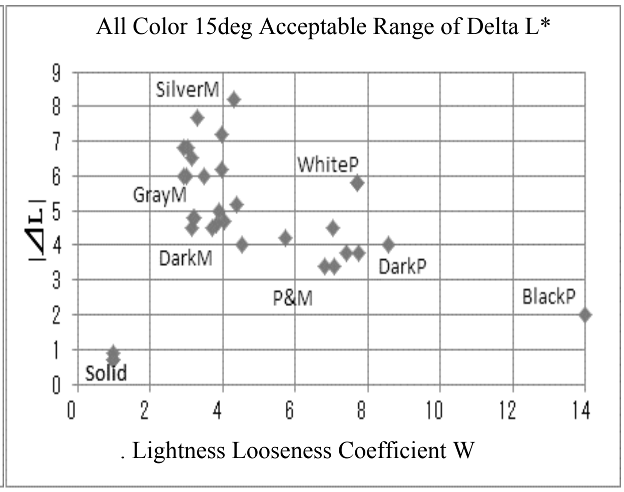
The difference is less noticeable for the metallic painting than for the pearl painting.

5. CHANGE OF LIGHTNESS OF PAINT COLOR (15 TO 110 DEGREES) AND ACCEPTABLE RANGE OF DELTA L*

I looked into the possibility of explanatory factors other than the relation among paint color type, L*(Paint Color lightness), and acceptable range of delta L*. The extent of the change of lightness depends on the paint color. A comparison of the acceptable range of delta L* with L*d, which is the difference between the lightness at 15 and 110 degrees and is substituted into the horizontal axis (Fig. 6), showed that the larger the L*d, the larger the visually acceptable range of delta L*.



【Fig. 6 Acceptable Range of Delta L* vs. Change of Paint Color Lightness L*d】



【Fig. 7 Acceptable Range of Delta L* vs. Lightness Looseness Coefficient W】

6. LOOSENESS COEFFICIENT FOR LIGHTNESS CHANGE CURVE AND ACCEPTABLE RANGE OF DELTA L*

The five acceptance angles can provide information not only on the maximum and minimum lightness but also on changes partway.

Since the curved line is similar to a catenary, I formulated Equation (1) with an angle as a variable; using Ld, which is the change of paint color lightness ($L^*_{15} - L^*_{110}$) as discussed in the previous section, as a gradient; and L^*_{110} as an intercept. The looseness coefficient W was then obtained from the values L^*_{25}, L^*_{45}, and L^*_{75}.

$$L^*_r = Ld * \gamma_{(r)} + L^*_{110} \cdots (1)$$

where $\gamma_{(r)} = |\cosh(W \cdot D_r) - \cosh(W \cdot D_0)| / \gamma_0$

$\gamma_0 = |\cosh(W \cdot D_1) - \cosh(W \cdot D_0)|$

$D_r = (r-110)/(110-15)$

$D_1 = D_{15} = -1,\ D_0 = D_{110} = 0$

The results show that W≈1 for the solid color, W≈4 for the silver metallic color, and W≈8 for the pearl white color, which shows a sharp upward curve. The visual acceptable range of delta L* shows that the relations seem to be inversely proportional, except in the case of the solid color.

7. ESTIMATING ACCEPTABLE RANGE OF DELTA L* USING THE RELATION BETWEEN DIFFERENCE OF LIGHTNESS AND CURVE SHAPE

A multiple regression analysis was conducted. Only L*d, L*r, and W were significant as shown in Fig. 8. Saturation was insignificant.

The size of the significant L*d, L*r, and W may help accurately predict the relation

	$L^*_{15} - L^*_{110}$ L*d	each deg L* L* i	Looseness Coefficient W	chroma C'max	chroma C'
15deg R^2=0.9697	** P:0.0000	* P:0.0255	** P:0.000	P:0.1685	P:0.1689
25deg R^2=0.9580	** P:0.0000	P:0.4671	** P:0.0023	P:0.1704	P:0.1765
45deg R^2=0.9705	** P:0.0000	** P:0.0100	** P:0.0083	P:0.2381	P:0.2234
75deg R^2=0.9565	** P:0.0000	** P:0.0020	** P:0.0011	P:0.0745	P:0.0640
110deg R^2=0.9601	** P:0.0000	** P:0.0000	** P:0.0002	P:0.4482	P:0.2069

【Fig. 8: Multiple regression analysis of acceptable range of lightness/saturation of paint viewed from five angles.】

between the difference perceived in visual inspection and the delta L* obtained from measurement.

If each coefficient for the acceptance angle r is expressed as S_{dr} , S_{Lr} , and S_{wr},

$$|\Delta L^*|_{r=} S_{dr} * L^*d + S_{Lr} * L^*r + S_{wr} * W \cdots (2)$$

Equation (2) indicates an estimated value.

The coefficients for r=15, r=25, r=45, r=75, and r=110 obtained by multiple regression analysis are expressed in Equations (3) to (7), which all consist of positive values.

|⊿L*| 15＝+0.0481 L*d + 0.0140 L*15+ 0.3309W…(3)
|⊿L*| 25＝+0.0443 L*d +0.0081 L*25 + 0.1336W…(4)
|⊿L*| 45＝+0.0277 L*d +0.0097 L*45+ 0.0526W… (5)
|⊿L*| 75＝+0.0183 L*d +0.0105 L*75 + 0.0547W… (6)
|⊿L*| 110＝+0.0128 L*d +0.0115 L*110 + 0.0666W… (7)

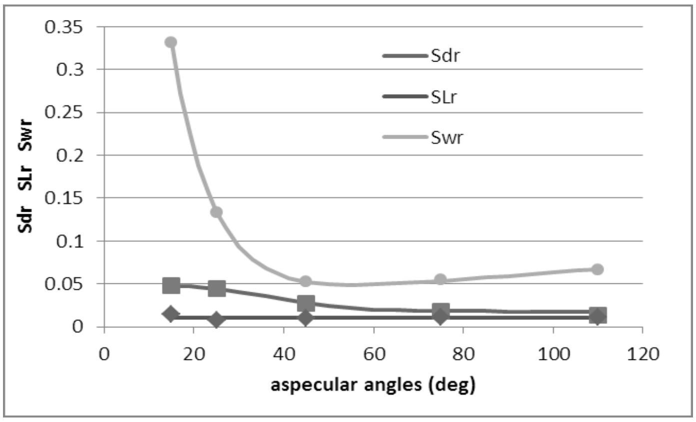
To express the relation between an arbitrary aspecular angle (r degrees) and S_{dr}, S_{Lr} , and S_{wr}, an equation using the exponent function is formulated.

The relation between Ld and r is approximated by a sigmoid function to get Equation (8).

S_{dr} =0.03234/(1+EXP(6.6637*(RAD(r) −0.661)))+0.017875…(8)

The relation between S_{Lr} and r shows an almost straight line.

S_{Lr} = 0.01…(9)



【Fig.9: Relation between Each Coefficient and Aspecular Angles】

The relation with W is expressed using the combination of an exponent and a primary expression.

Swr = 1.558*EXP(−6.27*RAD(r))+0.023*RAD(r)+0.023…(10)

The results of Equations (8) to (10) are plotted in Fig. 9.

8. CONCLUSIONS

The closer the aspecular angle is to specular (0), the brighter the reflected light is for visual inspection and the more difficult the recognition of difference of lightness is. One of the objectives of the current study is to propose how to interpret the difference of lightness obtained by multi-angle color measurement.

Here, I showed that aspecular angles allow the calculation of lightness, change of the lightness, and weighted amount of the speed of the change for the measured aspecular angles. This method will help estimate the acceptable range of lightness with significantly better accuracy.

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Visual Perception and Criteria for Good Lighting

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ABSTRACT

The study is conducted as a subproject in a PhD-project titled Criteria for Good Lighting. The overall aim of the study is to, based on visual qualities - rather than physical measurements - research the possibility of creating lighting environments that inspires comfort and meets function while providing energy efficiency. The study's specific objective is to identify and formulate criteria for a good light environment based on visual qualities, and to create a light simulator based on these criteria.
This paper describes the implemented pilot study and the basis for the full-scale study in the next phase. The method has been designed from the perspective of light and colour as two factors that collectively create visual impressions and experience of the room.

The background is that lighting design today follow lighting standards and norms that often are based on photometry. Photometry describes the eye's sensitivity to light in different frequencies of light radiation and how well it is possible to discern details in different amounts of light radiation. As a tool for lighting design the photometry and thus current standards are partially inadequate because it is mainly based on the detail vision's need of high light levels, but it is through the peripheral vision we understand the space, and it occurs primarily when the eye registers differences between contrasts in brightness and colour. A new definition of lighting criteria needs to be based on an understanding of how the visual perception functions; how to meet both the detail vision's need of higher light levels and the peripheral vision's need of a legible spatiality.
The study is conducted in two phases. The first phase is a pilot study where small groups of people is interviewed in their work environments in order to find out how they experience their work place and to what extent the lighting affects the experience. A literature overview was carried out on relevant research in the field of light, colour and visual perception. In the second phase, a full-scale studies are conducted in an office environment where the subjects are interviewed in different room-settings.

1. INTRODUCTION

The objective is to better understand human visual perception in order to create more efficient lighting design adapted to human needs. The aim is to find quality measures that relate to human perception and experience and develop criteria for good lighting based on the human visual perception.

1.1 Levels of perception

We receive and process the impressions of the outside world through all the senses, on several levels - simultaneously. Biologically and physiologically, all humans are quite similar, but we are also social and cultural beings and also with individual preferences, needs and experiences. An environment that is created based on human needs should include all these aspects. (Fig. 1)

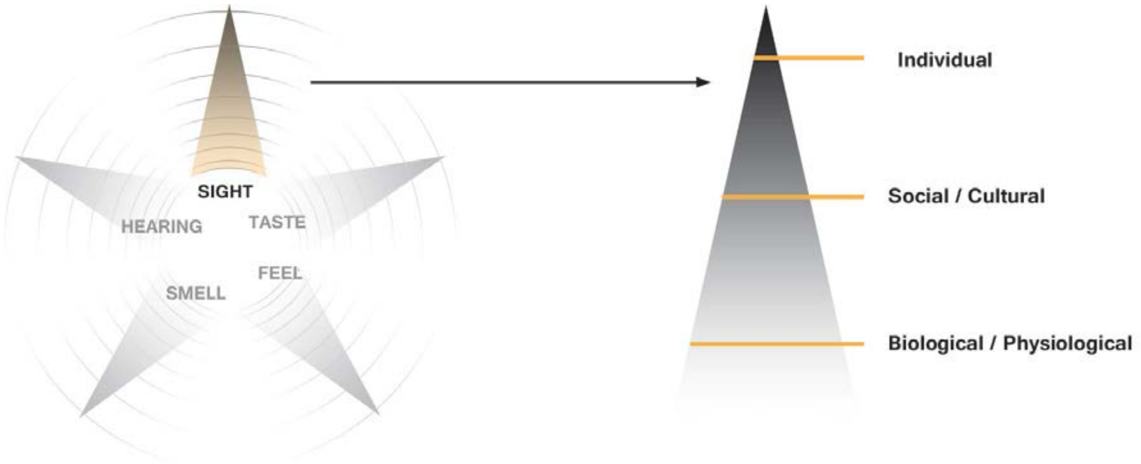

Figure 1: Levels of Perception (J. Enger)

The perception of light and colour is a complex process that is not yet completely understood, and it can not be explained solely by the eye's sensitivity to different levels of light radiation. Light radiation emitted from light sources and from reflecting surfaces with different colours and textures hits the retina and is converted to visual impulses of light and creates perception of space. Visual perception combines the impression of direct light and reflected light, which together create the overall appearance of the room and the light and colour experience. Light radiation is a physical concept and can be measured in absolute terms, whereas the experience of light is a relative experience created by the visual perception. Simultaneous contrast is a well known example of how the perception of brightness is created in the visual sense when a colour gives the impression to vary in brightness relative to the surrounding colour tone. (Fig. 2)

Our perception of light and colour also has an emotional aspect. While the perception of light is a prerequisite for us to orient in a space, the character of light also create an atmosphere of the room that affects us both as cultural and social beings belonging to a particular group, and also as individuals. This aspect may be as important as the physiological for the experience of an environment. If the experience of light is considered to be a sensuous process that takes place on several levels, a holistic perspective is needed in order to define criteria for a good light environment.

Figure 2: Simultaneous contrast. The grass has a solid grey tone but seems to shift in hue depending on the gradient in the background.

2. METHOD

2.1 Pilot study

In a preliminary study six people of mixed gender aged 30 to 60 years were interviewed, about their experience of the environment and lighting conditions of their workstations. Several typical offices were represented in the pilot study, such as private offices and office landscapes. At each occurrence the illuminance was also measured both at the workplace and in the center of the room. The aim of the study was to obtain a basis for the planning of the full-scale test rooms of the project's second phase.

The interviews began with a survey in which the subjects were asked to answer open questions about how they perceive their work environment in general and the lighting situation in particular. This was supplemented with a form in which they were to answer questions about the character of light in the room. The questionnaire was based on the method of analysis PERCIFAL (Klarén 2011). The respondents were asked to answer questions about, for example, perceived light level and perceived light colour, shadows and light distribution. A more detailed analysis of the same type with a detailed description of the room was then carried out by the interviewer in order to obtain comparative material.

2.2 Scenarios

The aim of the full-scale study is to examine the overall experience of light, colour and space based on the three levels of perception. The objective is to identify a number of different variables that together affect the light and spatial experience, to categorize them and to explore how these relate to the photometric values.

In the study, emotional values are of equal relevance as the perceptual impression. The study is conducted in office rooms of standard type and designed to create a distinct atmosphere with the Nordic light as a theme.

2.3 Nordic Light

The Nordic light is used as motif for the design because it offers great dynamics and varying light situations between seasons and different times of day that can be transferd to scenarios. The scenarios also relate to several examples of typical interior lighting that appeals to different groups of people.

In the essay *Nordic Daylight* Professor Barbara Matusiak investigates the character of the Nordic light in order to find out whether and how it differs from the light in other geographical locations (Matusiak B., Fridell Anter K. 2013). The study describes the artists' rendering of the Nordic light as well as estimations of the sun's angle over the year and climate data for the northern hemisphere. The conclusion is that it is possible to identify certain characteristics of the light at northern latitudes. A large part of the year, the sun appears from a low angle which creates distinct shadows in landscapes and textures and gives a warm light colour when the light is refracted in the atmosphere. The blue hour is a concept that is associated with northern countries and it also has its physical explanation. As the sun goes down under the horizon it continues to light up the sky that reflects a bluish light to the earth. Another feature that characterizes the light in the Nordic countries are long periods of overcast sky that gives a diffused and contrast-free, neutral light.

In test rooms the different light characters are portrayed in four different scenarios: 1. Sunset: vertical light with warm light colour that gives long shadows, and materials with a muted colour palette of warm tones. 2. Blue Hour: indirect bluish light, low light level. Low placed light sources with warm light. 3. Overcast: diffuse neutral and contrast-free light. Colours are painted in shades of gray with dark gray and black accents. 4. Midsummer: High level of light from a light source with high placement. Relatively warm light colour and distinct shadows. Materials in vivid mostly bright colours. (Fig. 3)

Figure 3: Nordic Light Scenarios (J. Enger)

2.4 Visual concepts

Several researchers and other individuals with knowledge of light have identified the need to formulate concepts that describe the visual impression of light in an environment. Yet there is still no widely accepted or complete system of concepts for light experience.

Christopher Cuttle has studied the relationship between light and visual perception and presents two groups of concepts that can be used as a tool in the design process. An important observation is the distinction between the light's spatial distribution described with flow and sharpness, and the light's ability to render object: shading, highlight and shadow. (Cuttle C. 2013)

The Nordic research project SYN-TES developed a method to analyse and describe light and spatial experience called PERCIFAL (Perceptual Spatial Analysis of Colour and Light). The method is not to evaluate the quality of light, but to analyse the character of light without evaluating the results. The visual concepts used in the method are: light level, light distribution, shadows, light patches, specular reflections, glare, colour of light and surface colour. (Klarén U. 2011).

2.5 Sensory science and Kansei Engineering

Other disciplines have created methods to not only analyze the character of a sensory experience, but also quantify and assess the outcome. The two examples described here has been developed to provide a basis for product development and ultimately marketing. The purpose of this study is not specifically focused on marketing strategies, but the analyses used in Sensory Science and Kansei Engineering are very suitable and possible to adapt in this context.

Sensory Science is described as "the science of what we can experience with our senses" and includes methods to express, evaluate and categorize the sensory experience (Gustafsson IB. Et. al. 2014). The discipline has a strong connection to gastronomy and the

food industry and can be described as the link between a product's chemical, physical and technical characteristics in relation to the affective and perceptual experience of it.
A product can be evaluated, for instance by having a test panel that compare various makes of food products. The participants evaluate the character of the respective products based on, for example, concepts such as richness, sweetness, acidity, etc., and also rank them according to preference. The result can be compiled into charts that provide information about which products panel prefer. It is also possible to draw conclusions about the qualities many people are attracted to or dislike.

The market's rapid feedback on different products and brands appeal has driven the development of knowledge on consumer behavior and product identity. A product's functional properties and technical performance is not sufficient to ensure success in the market, as consumers often choose product based on emotional values.

Kansei Engineering, also known as affective engineering was originally developed in Japan and it is a method used to evaluate products affective values. The dissertation *Engineering Emotional Values in Product Design* the author makes the definition: ”The main task is to translate feelings, perceptions, individual experiences and understandings into ‘hard’ measurements and mathematical models which in turn have to be falsifiable using both qualitative and quantitative methods.” (Schütte S. 2005)

The methodology makes it possible to identify cognitive, emotional and perceptual impressions of a sensual stimuli by studying both behaviours, physical reactions and verbal expressions. The result is valuable information that can be combined with a technical specification to optimize the design of a product to meet both the spoken and unspoken needs a specific target group.

2.6 Experimental Procedure

The full-scale study is carried out in small offices with identical layout and furniture of standard type. The lighting design and the colour scheme is based on the four scenarios described above, but the furniture and other inventory are neutral. Careful measurements of photometric values is made in every room.
The group of respondents consists of 30 individuals of mixed ages and gender about half of which have professional knowledge of light and the rest are laymen. The subjects respond to a questionnaire with the same design as that used the pilot study for evaluating the room's light character with given concepts. The following stage is based on the analysis methods developed in Sensory Science and Kansei Engineering but adapted to the context. An interview is carried out where the subjects are stimulated to describe the experience of the room's atmosphere and light character in their own words and concepts.

3. RESULTS AND DISCUSSION

The outcome of the pilot study made it clear that awareness of light and the need a good light environment varied between different people, and also personal preference in terms of light character in the work environment. Some people clearly expressed that they wanted an even light and high light level in the room, while others preferred a subdued light from many low-set light sources. Some of the interviewees were able to clearly define their needs, while others argued that light does not have much effect on the working environment. The results of the analysis form also showed that the interviewees and the interviewer usually had the same experience of the room's light level but that the measured illuminance not always corresponded with that.

Throughout all the interviews it became clear that the interviewees are not always separated the experience of light character from a functional or technical aspects of lighting. When asked about the overall experience of the environment, several persons used the concept of light in a broader sense. One room was for instance experienced such as light and airy. A plausible interpretation is that it does not refer to illuminance but rather to a sense of space that can be created by combining bright colours and sparse furniture.

The Full-scale study is not completed but the result is expected to provide is an extended knowledge about the experience of light and colour in relation to spatial context. More specifically, the results will give indications of the relationships between emotional experience, perceived light level and photometric values. The material from the interviews can provide a basis for an expanded system of concepts of light, colour and spatiality that can be used as a basis to formulate criteria for good light environments.

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Space brightness affected by a scenic view through a window

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ABSTRACT

There has been an increasing demand in the use of daylight through windows for maintaining bright visual environments while saving lighting energy. Recent studies have reported that although the horizontal illuminance is increased by daylight, space brightness is not as efficiently increased as expected by the illuminance. The purpose of the present study was to investigate the effects of daylight from a window on space brightness perception when various colors and objects outside a window, i.e., a scenic view, was visible. In an experiment, we used two scale models simulating an office: one was a room with a window (test room) and the other was one without it (reference room). Two types of scenic view, i.e., natural or urban landscape photographs behind the window, were used with or without a human-shaped board covered with full-length photograph of adult male. Daylight was simulated by fluorescent lamps and its intensity was manipulated by changing the number of the lamps. A room illuminance from ceiling lights without daylight (base illuminance) was also manipulated. Participants viewed the two models repeatedly and estimated brightness for the test room relative to that for the reference room. The results revealed that although the space brightness increased with increasing daylight intensity, the efficiency was much lower than that expected by the horizontal illuminance. The comparisons between the present results and the findings of a previous study revealed that brightness enhancement by daylight was lower with a scenic view than without it. Although a pattern of results was quite similar whether the human-shaped board was present or absent, the variance of brightness reported by participants was smaller in the human-shape board present condition than in the human-shape board absent condition.

1. INTRODUCTION

Although the diversification of lighting methods enables us to create various visual environments, recent studies have reported many situations in which horizontal illuminance (generally used as a brightness index) does not correspond to human perception. For example, a room with low horizontal illuminance is sometimes perceived as brighter than that with high horizontal illuminance. Many studies have examined human space brightness and proposed some indices corresponding to human perception (Yamaguchi & Shinoda 2007; Yamaguchi, Shinoda, & Ikeda 2002). In most of those studies, however, daylight from windows has not been taken into account. Considering that in real life situations, we are exposed to visual environments with windows, daylight should affect space brightness.

Several studies have investigated this topic by measuring magnitude estimation (ME) of perceptual brightness for a scale model of room with or without daylight from a window, and reported that the brightness become lower for a room with daylight than without it (e.g., Yamaguchi & Shinoda 2014). To our knowledge, most of those studies used frosted glass as a window and thus the scenic views from a window were invisible. Therefore, research on this topic using a window with a scenic view was scarce. In this study, we extended the previous findings by investigating the effects of daylight and various landscapes (that was viewed through a window) with or without the human-shaped board on space brightness by using ME method.

2. METHOD

In the experiment, we used two 1/8 scale models (Figure 1). Each model simulated an office with approximately 62 square meters. The size of each model is 800 mm (width) × 1,200 mm (depth) × 340 mm (height). The interior was all achromatic. The two models were located side by side: one was a room with a window (test room) and the other was one without a window (reference room). We simulated daylight from a window by using 8 fluorescent lamps attached outside the test room. The daylight intensity was munipulated by the number of lamps: 8, 4, 2, 1, or 0 (no-daylight). Behind the window, we attached one of four landscape photos (urban-distant view, natural-distant view, urban-near view, and natural-near view) with or without the human-shaped board covered with full-length photograph of adult male. The horizontal illuminance (base illuminance) of the test room without daylight was either 100, 300, or 1000 lx. The reference room was identical to the test room except that the room was illuminated only by artificial lighting from the ceiling witout simulated daylight (no window).

At the beginning of each trial, participants sequentially viewed the rooms. The task of participants was to estimate the brightness of the test room relative to that of the reference room. Participants were told that the brightness of reference room set to a value of 100. In addition to the experimental condition, we also conducted a control condition in which brightness of the test room was measured without daylight. The task was identical to that in the experimental conditions. There were 4 trials for each condition of daylight and base illuminance intensities, landscape, and human-shape board. The order of conditions was randomized across participants. Before the experiment, participants practiced several trials until they were familiarized with the task. Participants were five individuals. Two of those had experience of brightness evaluation experiment (Tanaka, Shinoda, & Seya, 2014).

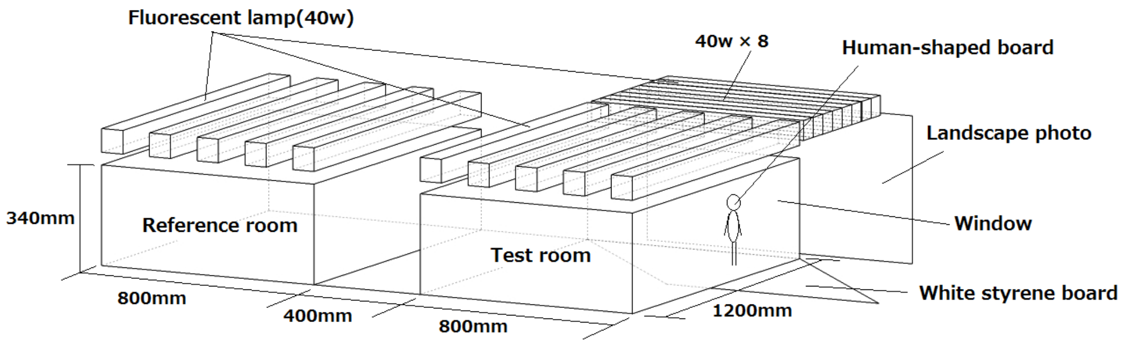

Figure 1: Experimental apparatuses.

3. RESULTS AND DISCUSSION

Figure 2 shows the mean ME values as a function of averaged horizontal illuminance separately for each daylight intensity and type of scenic view in the absence (left panels) or the presence (right panels) of human-shaped board. Upper, middle, and lower panels indicate the 100-lx, 300-lx, and 1000-lx base illuminance conditions, respectively. Square markers indicate ME values in the urban-distant view (solid line) and urban-near view (broken line) conditions. Circle markers indicate those in the natural-distant view (solid line) and natural–near view (broken line) conditions. Cross markers indicate ME values in the control condition (i.e., base line).

As seen in the figure, in the 100-lx and 300-lx base illuminance conditions, the ME values increased with increasing the horizontal illuminance, but they were lower in the daylight conditions (i.e., square and circle lines) than in the control condition (i.e., cross base line), irrespective of the scene view and human-shape board conditions. This indicates that although the participants perceived higher brightness with increasing daylight intensity, the efficiency of brightness enhancement was lower than that expected from the horizontal illuminance. On other hand, in the 1000-lx base illuminance condition, the rate of brightness enhancement was almost the same as that in the control condition, suggesting that, beyond a certain intensity of base illuminance, the efficiency of brightness enhancement would not be affected by daylight effects observed in low base illuminance conditions. These results are consistent with the findings of previous studies using a frosted glass as a window (Yamaguchi & Shinoda 2014).

The comparisons between the human-shape board absent (Figures 2a, c, e) and present conditions (Figures 2b, d, f) revealed that, overall, brightness was lower in the presence of the human-shape board than in the absence of it. The reason for the differences in the ME values with or without the human-shaped board is not clear. One possibility is that the board may have served as a cue indicating a room space and, as a result, participants may have been able to clearly separate spaces beyond and in front of a window. Consequently, participants may have been capable of estimating space brightness independently of the brightness outside a window.

Two participants had participated in our previous experiments in which the effects of daylight were investigated without a scenic view in the absence of the human-shape board. To further examine the effects of scenic view on space brightness, we compared the present results with the findings of previous study. Figure 3 shows the mean ME values as a function of averaged horizontal illuminance separately for each daylight intensity with (the present study) or without a scenic view (the previous study) in one participant. Upper-left, upper-right, and lower panels indicate the 100-lx, 300-lx, and 1000-lx base illuminance conditions, respectively. Square, circle, and cross markers indicate the results of the present study (Figure 2). Triangle markers indicate ME values without senic view (the frost glass was used as a window). The comparisons between the results with or without a scenic view revealed that, overall, brightness was lower with a scenic view than without it. The difference between the results of the two studies could be due to the participants' recognition of window. In the previous study, participants may have recognized a window of frosted grass as a light source, resulting in enhancement of space brightness. On the other hand, in the present study, the participants could separate spaces beyond and in front of a window. We consider that this participant more easily estimated space brightness.

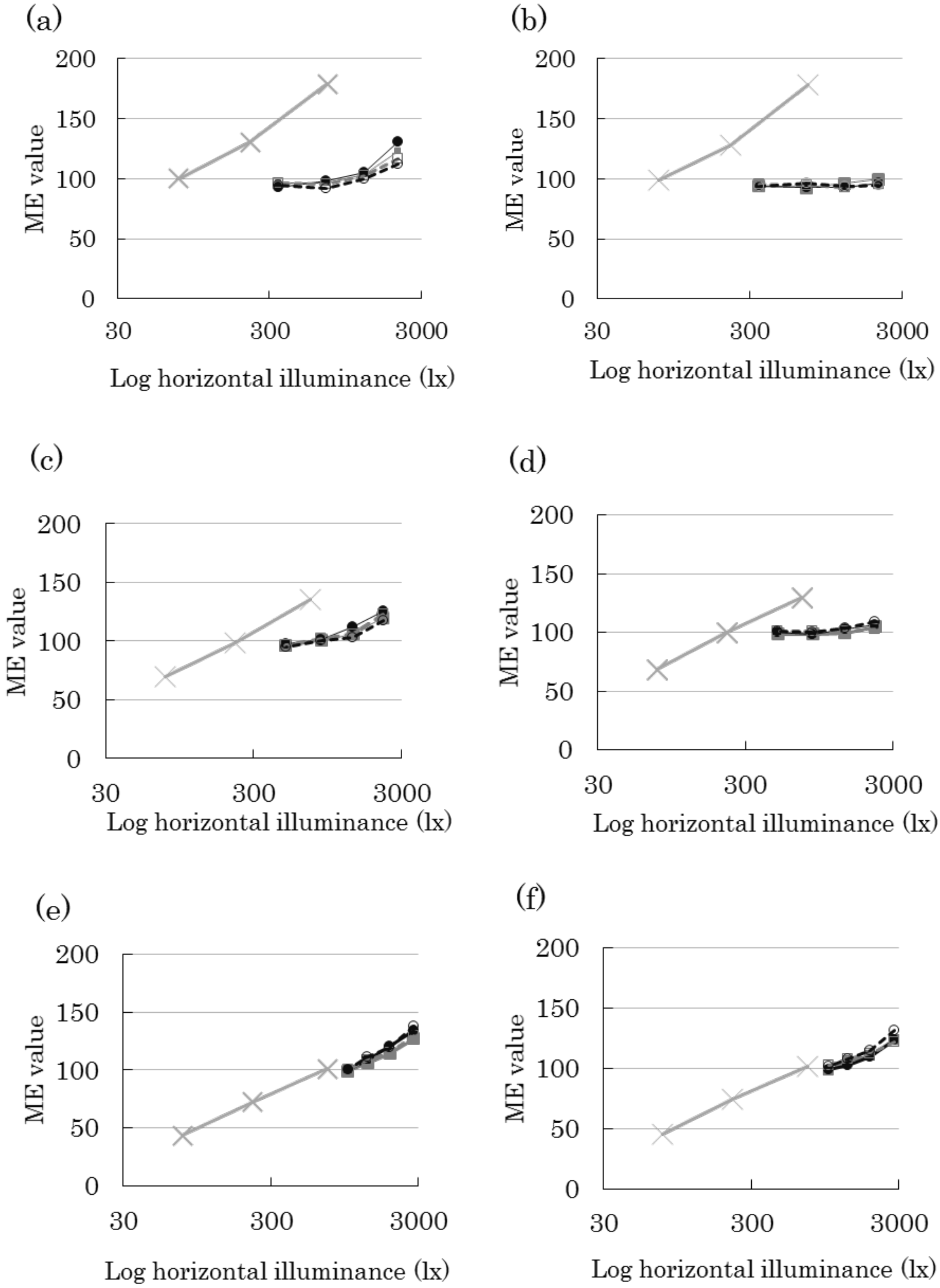

Figure.2: Mean ME values as a function of horizontal illuminance.

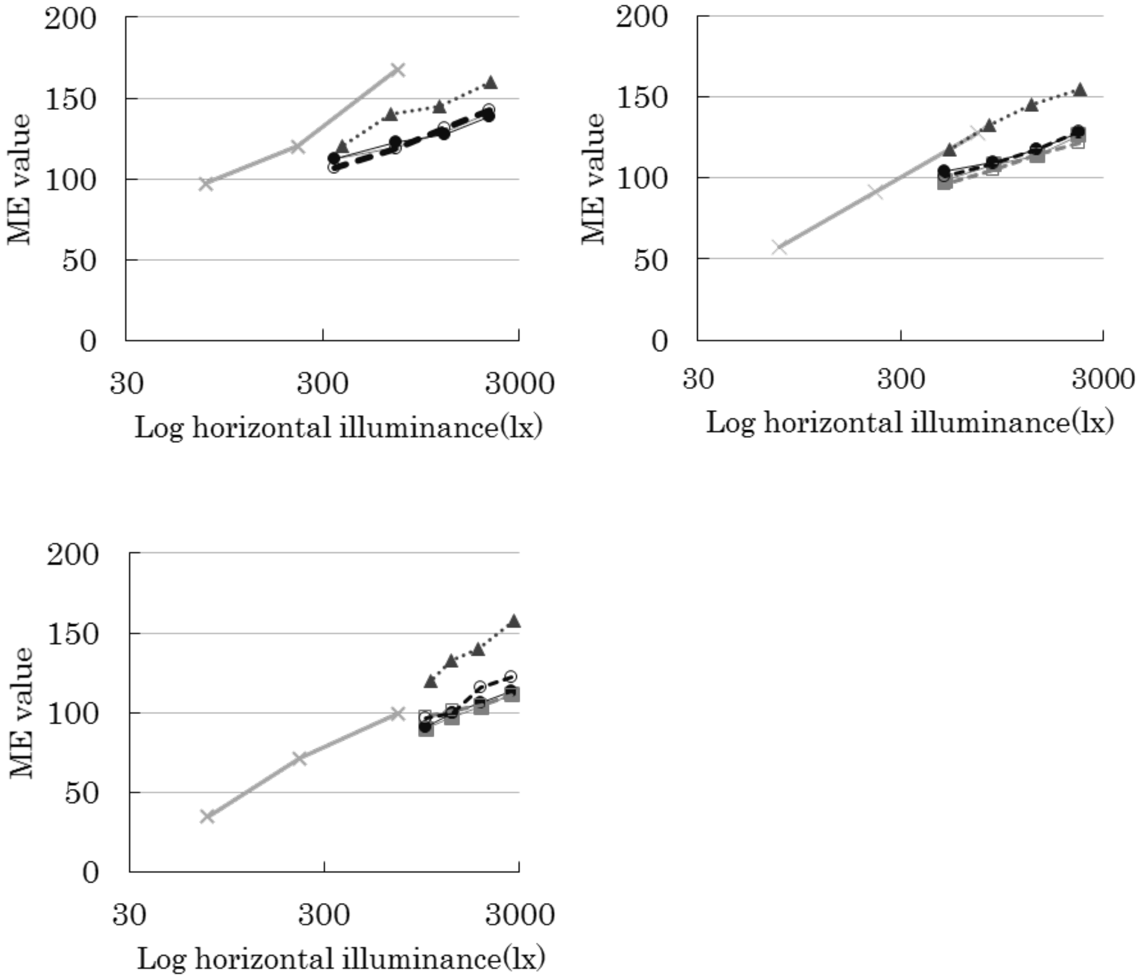

Figure.3: Mean ME values as a function of horizontal illuminance in one participant.

4. CONCLUSIONS

In this study, the effects on space brightness were investigated for various types of scenic view. Results showed increases in brightness with increasing horizontal illuminance by daylight, but the rate of brightness enhancement with a scenic view was lower than the rate of brightness enhancement without it. No difference between scenic views was found. Moreover, in the presence of the human-shaped board near the window, the brightness became lower than the case of space without the human shaped-board. Especially, for lower base illuminance, the tendency was more remarkable.

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Influence of Surface Properties on Material Appearance

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ABSTRACT

Color Research has developed prosperously in these years, particularly on "color appearance", which had made a significant breakthrough. Among them, textures, which is intimately related to color appearance, has got few attention. Features of textures possess enormous influences on surface color perception. Interactions between colors and surface materials have big stake on the accuracy of color display. Recently, the uprising of "material perception" researches have gradually filled up the insufficiency.

This research aims to explore the influences of material properties on the appearance of colors. By adopting the Cesia's theoretical mode (Caivano, 1996), based on three elements of material properties: Permeability, Lightness, and Diffusivity, with the utilization of a rotary color mixer device, in adjustment with properties combined of various ratios of mirror surface, matted surface, and transparent surface, we investigate each element's influences on objects' surfaces' color appearance and inspect influences of various texture on subject's psychological feelings. The aim is to know how those influences perform? What are the influences formed on people's mentality?

The purpose of the present research is to perform a quantitative survey on perceptions about material surface features in systematic ways, and to deliver results of practical data for subsequent researches on Cesia theory. The findings can provide advises on experimental operation, and broaden knowledge about influences of surface features on color appearance.

Key Words: Color Appearance, texture, Cesia, Permeability, Lightness, Diffusivity, material surface

1. INTRODUCTION

Color Research has developed prosperously in these years, particularly on "Color Appearance", which had made a significant breakthrough. In order to make out effectively, several business corporations have adopted colors as tool for marketing. However, most domestic research focuses on colors' influences on human mentality, and few has focused on texture's influences.

Texture, which is intimately connected to color appearance, has got rare attention. Features of texture possess enormous influences on color. Interactions between colors and surface material have big stake on the accuracy of color display. If we figure out patters of connection between texture and color, it's not only beneficial to our future generations in texture research; also, it can be practically applied to business commodity.

Regardless of the color, different textures have different effects on human mentality when people are looking at certain objects. Smooth and reflective objects like mirror, glass, etc. make people feel tough, heavy, and cold; whereas objects with rough surface like wooden furniture and fabric give people feelings of softness, lightness and warmth, and other uncountable emotions. Feelings aroused by objects are also experiences accumulated within human's mind.

Studies demonstrate that, surface material of products directly affects sales consequences, which indicates besides color, texture is another important factor affecting user's psychology. Texture itself is a huge research issue, and it will be bigger and intriguing when adding into color factor. There are thousand kinds of combinations as objects are composed of different colors and textures, but no previous research had figured out the variation or tendencies of this phenomenon. In this research, we intend to figure out patterns of connection by probing into mutual influences between colors and textures and contribute to advanced studies.

2. MEASUREMENTS ON SURFACE FEATURES

Former chairman of International Color Association (AIC) and Dr. Caivano in 1991 quoted "cesia" in his thesis available in the journal *Color Research and Application*, which refers to the system describing the optical property of texture, and the system was initiated by Jannello in the 1960s.

With Dr. Caivano's effort, cesia has been used as the system to describe Visual Textures, especially features concerning gloss and brightness. From physical measurements perspective, cesia can be presented with light's permeability and diffusivity, plus luminosity factor, forms a three-dimensional cesia space composed of permeability, diffusivity, and absorption. Just like Color Order Systems such as NCS and Munsell, cesia is an Order System describing surface characteristics.

Dr. Caivano's "cesia" is basically a way of describing visual sensation. Under different illumination and observing conditions, different cesia PDA indexes will turn out, and representing different visual sensation toward surface characteristics. Under standard measuring conditions, cesia data can be used as surface sensation index, besides trichromatic theory.

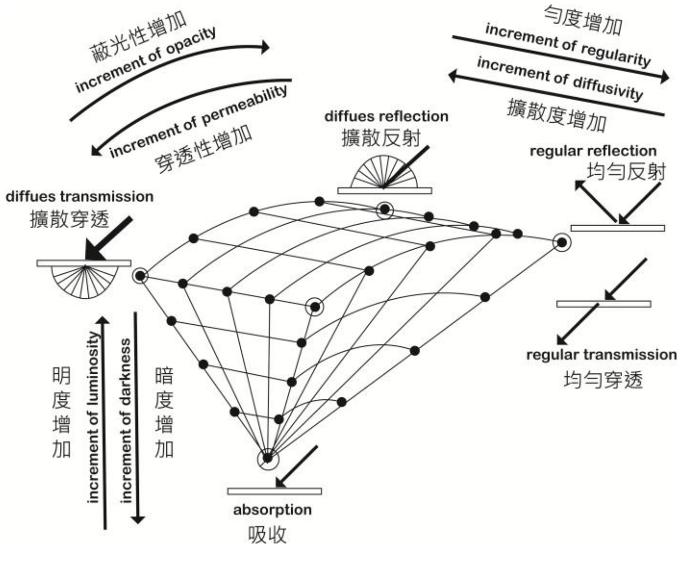

Figure 1: The solid of Cesia with the five primary sensations and the three kinds of variation.（Caivano, 1994）

3. EXPERIMENTAL METHODS

After entering experimental circumstances, experiment subjects will read the instruction first, and listen to the introduction of cesia system.

Experiment starts. The experiment includes five steps in response to five different combinations. These combinations are composed of different ratios of diffuse reflection, regular reflection, diffuse transmission, and regular transmission. In each step, a rotary table one the right side will be placed 100% texture, and another one on the left will be texture of different ratios in the random order (87.5%, 75%, 50%, 25%, 12.5%......).

In the first step, as the machine runs, we will begin to ask questions to our experiment subjects. Suppose texture on the right side is 100%, what is the ratio of texture on the left side? For instance, when it is 100% regular reflection on the right side, how many percent of regular reflection is on the left side? After they finish the questionnaire, we will change textures into different ratios without informing our experimental subjects, and ask them to make judges again. In all the five steps, ratios of experimental textures are random and nonrepetitive in every single step. Experiment ends as we finish all five steps.

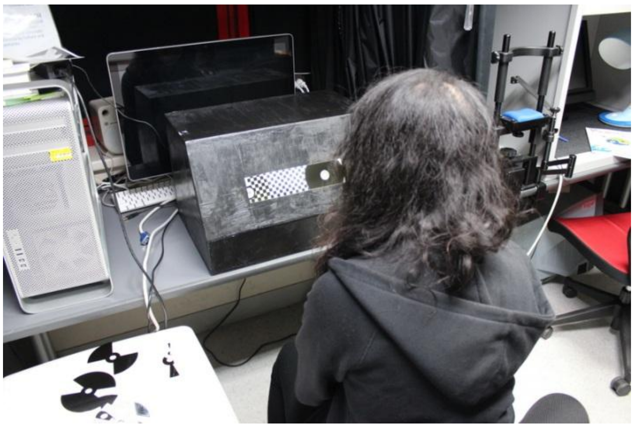

Figure 2: Experimental environment

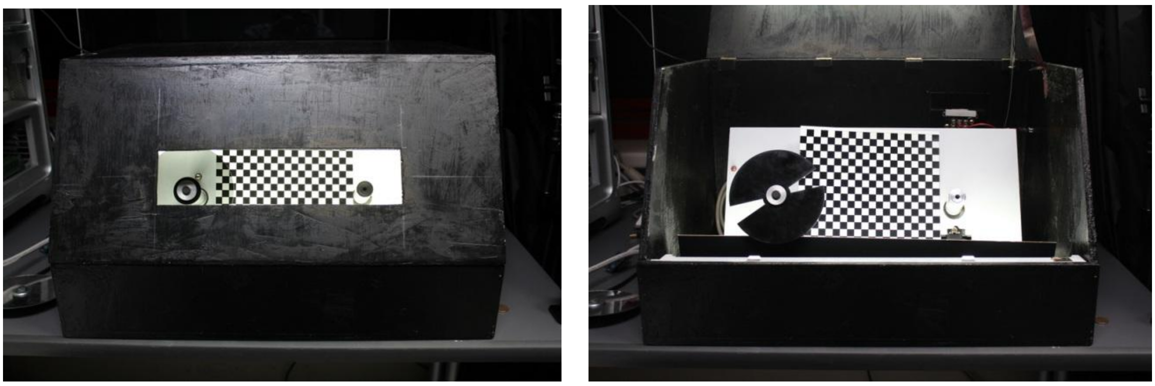

Figure 3: color mixer in special box

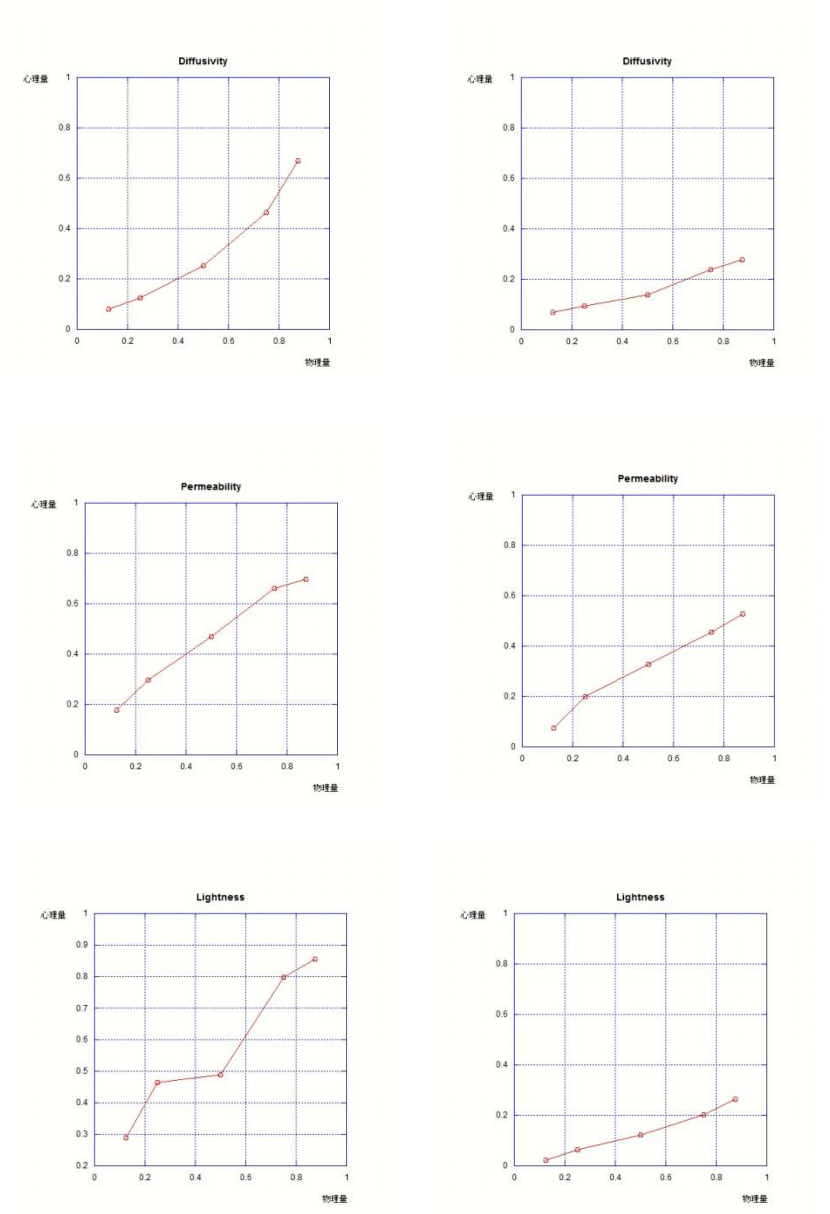

Figure 4 : The results of Permeability, Diffusivity and Lightness

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Visual evaluation of a wooden-finish room and the colorimetry of wood

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ABSTRACT

The use of wood as a building material or interior finish is known to induce a favorable psychological and physiological effect. There are many desirable aspects of wood, including the visual naturalness of wood grains, tactile warmth, tactile smoothness, natural smell, and others[1)2)3)4)]. Furthermore, the color and gloss of wood produced by aging are often desirable traits. Therefore, wood has long been used as internal and external building material in many circumstances. Although these effects are acquired by natural wood, the use of interior finishing paper with a printed image of wood grain[5)6)7)] has also increased. In this case, can we expect the same effect as seen for natural wood?

In this study, we begin by reporting the results of an experiment on the subjective visual evaluation of a wooden-finish room. Next, we provide an analysis of the spatial frequency of wood grain based on two-dimensional colorimetry. Furthermore, we consider the relationship between the evaluation of the wooden finish and the characteristics of the wood surface.

1. INTRODUCTION

It is generally considered that the visual impression of a wooden finish in a room depends on the surface color, difference of grain blend, and mutual influence of the proportion of wood-finish area and surface color[8)9)].

The purpose of this study was to clarify the factors influencing variation in the visual evaluation of wood color and area of wood finish in a room.

2. METHOD

2.1 Sample Preparation

Eleven types of wooden wallpaper samples[10)11)] with different colors were selected as the interior finish of a room (Table 1).

A 1/20-scale model that was finished with a reduced photocopy of wooden wallpaper was made for subjective evaluation. The scale model consisted of a living room, dining room, and kitchen. The area of wood finish in the rooms was changed in three conditions (Figure 1). The area of wood finish in the room was calculated from an indoor photograph taken from the subject's viewpoint. The subjective evaluation was accomplished under all 33 conditions corresponding to combinations of the 11 colors and 3 area proportions of the wooden finish.

Table 1: Wood Samples.

No	Tree species		Munsell color	L*	a*	b*
A	chestnut		2.5Y9/1	74.1	4.5	17.7
B	maple		10YR8.5/3	75.3	8.0	24.5
C	birch		5YR7/4	65.9	14.7	23.6
D	oak		7.5YR7/4	63.0	8.1	23.6
E	European walnut		7.5YR5/6	46.4	14.3	23.2
F	walnut		7.5YR5/3	64.8	7.9	22.2
G	teak		7.5YR4/4	42.5	12.5	19.9
H	European cherry		2.5YR5/6	59.1	10.8	21.1
I	mahogany		5YR3/3	32.7	7.2	7.8
J	black walnut		5YR4/2	28.0	2.1	1.5
K	plum		7.5YR2/4	47.3	28.1	31.9

41% *52%* *56%*

Figure 1: Examples of the scale model with different proportions of the wooden finish area

2.2 Experimental Procedure

The horizontal illumination on the desk of the scale model ranged from 800 to 900 lx. Forty-five students of Mukogawa Women's University participated in the experiment. The 45 observers used binoculars to provide subjective impressions of the scale model room through an observation window (65 × 250 mm). They based their evaluations according to a 7-step semantic differential scale using 9 pairs of adjectives, as listed in Table 2. The experiments were carried out from December 12th to 17th of 2013.

Table 2: Evaluation adjectives.

light	-	somber
spacious	-	cramped
bright	-	dark
classy	-	cheap
healing	-	not healing
warm	-	cool
natural	-	artificial
likable	-	dislikable
harmonious	-	disharmonious

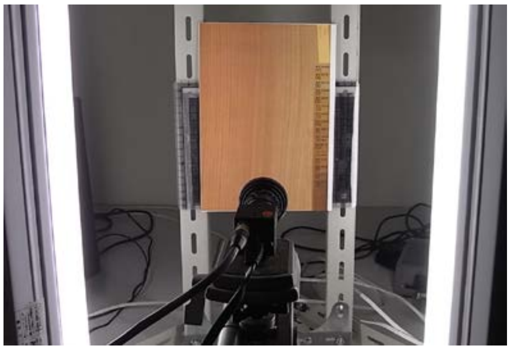


Figure 2 : Measurement equipment.

2.3 Colorimetry

The surface colors (CIE-XYZ) of the wallpaper samples were measured in a orthogonal direction by a luminance and chromaticity uniformity analyzer (UA-10, Topcon; Figure 2). The two-dimensional colorimetric distribution of the wood surface was determined with reference to previous studies[12)13)]. Specimens were illuminated by two fluorescent lamps with the same spectral distribution and the same light diffusion as the subjective evaluation experiment. Measurement specimens were eleven types of wooden wallpaper samples same as the subjective evaluation experiment. Wood grain on the specimens was the original size, not minified. Measurement area was 1280×960 pixels (200×150mm), and 256 × 256 pixels (40 × 40mm) of it was analyzed. This size was same as visual angle of the front wall observed by subjects in the subjective evaluation experiment.

3. RESULTS AND DISCUSSION

3.1 Factor analysis of the subjective evaluation

Factor analysis was performed to investigate the most relevant factors contributing to variation in the visual evaluations of a scale model room with a wood finish based on the adjectives provided (Table 2). As shown in Table 3, 2 main factors were extracted, Lightness and Harmony, which showed a cumulative contribution rate of 84.83%. There was barely any difference in the individual contributions of Lightness and Harmony, indicating that these 2 factors show equivalent efficacy on the subjective visual evaluation of a wooden-finish room.

Table 3. Factor structure.

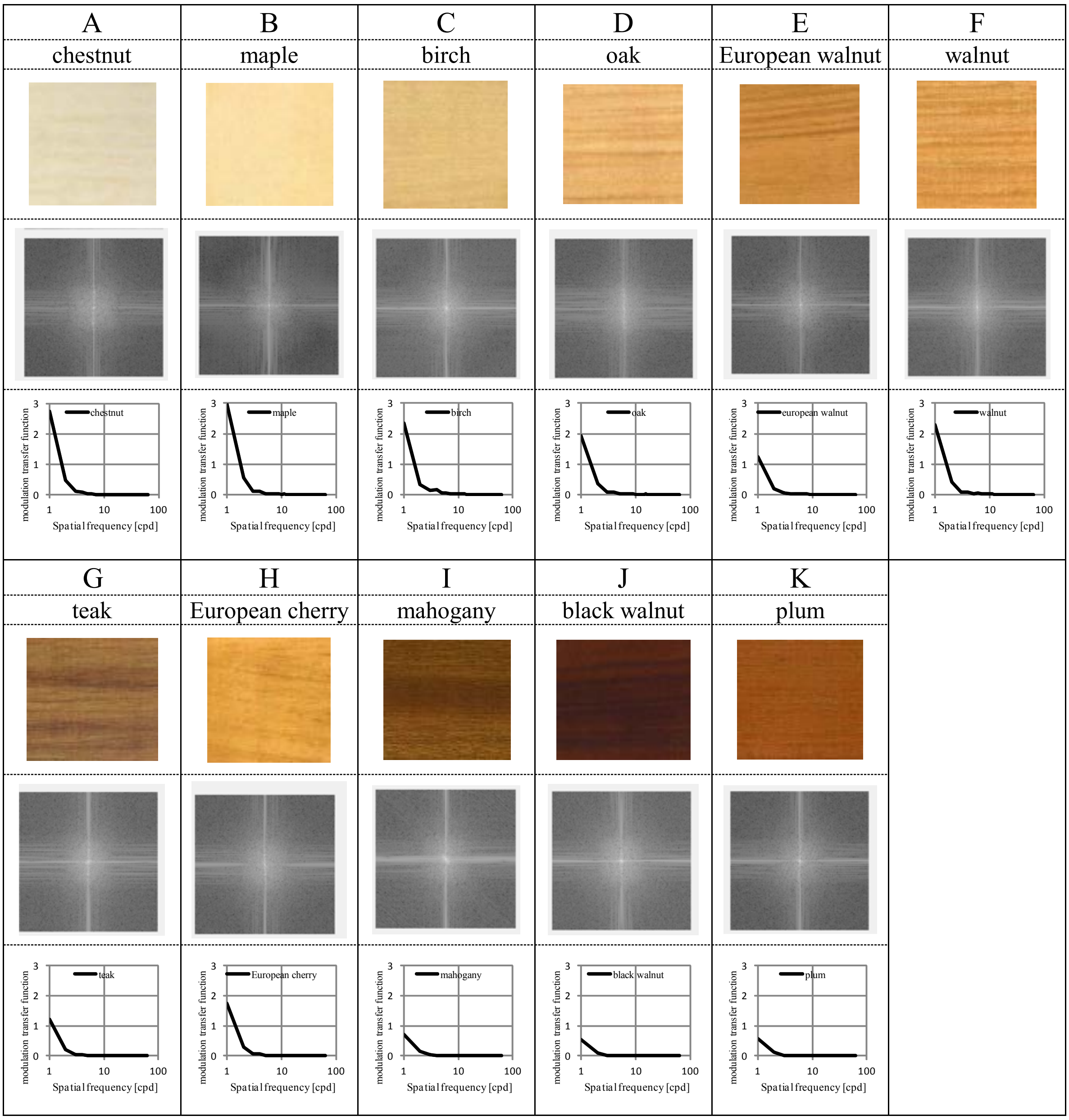
		factor loadings		commonality
		1 Lightness	2 Harmony	
1	light	0.9932	0.0748	0.9921
	spacious	0.9874	0.0765	0.9808
	bright	0.9827	0.0834	0.9727
	classy	-0.9292	0.0437	0.8654
2	healing	0.1527	0.9650	0.9545
	warm	-0.0076	0.9232	0.8524
	natural	-0.1203	0.9225	0.8654
	likable	0.2289	0.8530	0.7800
	harmonious	-0.0020	0.6091	0.3710
eigenvalue		3.8809	3.7534	
contribution rate		43.12%	41.70%	
accumulated contribution rate		43.12%	84.83%	

3.2 Results of colorimetry and image analysis with the Fast Fourier Transform method

The CIE-XYZ value was obtained by two-dimensional colorimetry. The Y value is considered to correspond to the interval or contrasting density of the wood grain. Therefore, the Y value on each pixel of the input image was analyzed by the Fourier transform algorithm. The middle rows of Figure 3 show the images of specimens applied to Fourier transform analysis.

In addition, the spatial frequency from the center of the image outward was analyzed. The Hamming window function was applied as an approximation of spatial frequency. The bottom rows of Figure 3 show the relationships between spatial frequency and the modulation transfer function for each wood color. According to this relationship, the spatial frequency ratio was calculated to describe the characteristics of the wood grain, and was considered as an index of wood grain.

Figure 3 : Fourier transform and spatial frequency characteristics



3.3 Relationship between subjective evaluation and colorimetry

The relationship between the two-dimensional colorimetric distribution of the wood surface and the factors of subjective evaluation was examined through multi-regression analysis, and the results are shown in Table 5. Lightness was influenced by the L* value and the proportion of wooden finish area in the room. Harmony was influenced by the proportion of wooden finish area, wood color (a* and b*), and wood grain.

Table 4 : Result of multi-regression analysis

	multiple correlation coefficient	partial correlation coefficient				
		L*	a*	b*	Spatial frequency ratio	area
F1 Lightness	0.9150	0.7398**	0.1767	-0.3648	0.1436	-0.6963**
F2 Harmony	0.7553	-0.2755	-0.5012**	0.5694**	0.3171	0.5435**

**: p<0.001

4. CONCLUSIONS

To clarify the influences of wood color and wood grain on the subjective evaluation of a wooden-finish room, we conducted a study to associate the results of a subjective experiment to those of image analysis based on two-dimensional colorimetry of wood.

These results lead to the conclusion that subjective evaluation of a room with a wooden finish consists of 2 factors: Lightness and Harmony. The lightness value of wood color and the proportion of wood area in the room influence the Lightness factor. Wood color and wood grain influence the Harmony factor. In addition, our results show that two-dimensional colorimetry and spatial frequency analysis with a Hamming window function seems to be an appropriate method for analyzing the characteristics of wood color.

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Total Appearance of Metallic Coatings using a Stereo Capture System

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ABSTRACT

This paper describes a study which aims to define the total appearance of metallic coatings and then objectively characterise it. Total appearance here refers to the combination of three properties of perceptual attributes of the surface: glint, coarseness and brightness. This study took into account one specific viewing angles only when irradiated by an intense directed light source. 54 metallic panels were visually scaled and a computational model capable for predicting three perceptual attributes was developed.

1. INTRODUCTION

Over recent decades, textured coating provided by metallic surfaces has been an important factor in attracting customers of the automobile industry. This has meant that quantifying the appearance of coating products is essential for product development and quality control. The appearance of these coated products strongly depends on the viewing geometry, giving rise to a variety of properties of perceptual attributes such as texture, colour and gloss. Due to the visually-complex nature of such coatings, there remains an unsatisfied demand to develop techniques to measure the total appearance of metallic coatings. This study focused on characterising not only one dominant attribute, glint, but also minor attributes, coarseness and brightness, with an intense directed light source. The measurement of the total appearance of metallic coating was conducted from an investigation of the relationships between the three perceptual appearance attributes judged by observers and the physical parameters extracted by a stereo capture system.

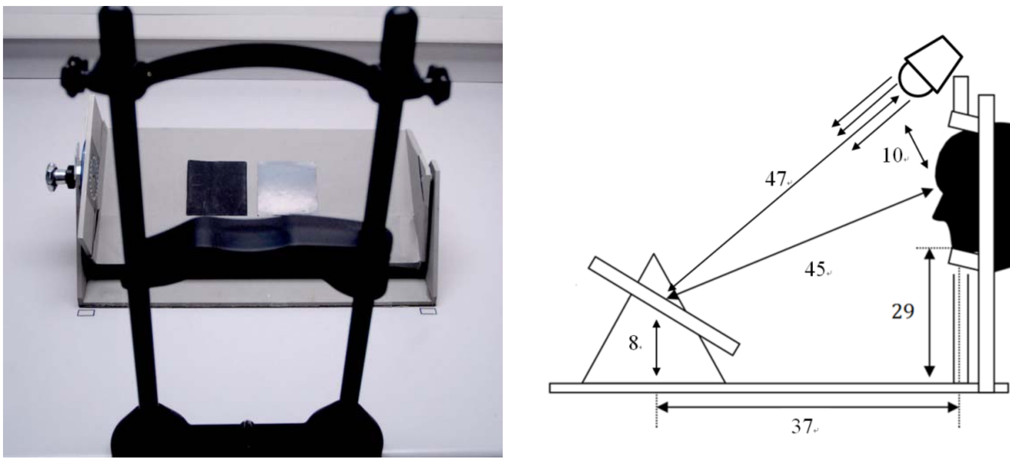


Figure 1: Experimental setup for total appearance – real setup (left) and schematic diagram of viewing condition (right).

2. PSYCHOPYSICAL EXPERIMENT

Visual assessments were carried out to quantify three properties of perceptual attributes of metalic-coagting panels: glint, coarseness and brightness. Ten observers with normal (or corrected to normal) visual acuity and colour vision participated in the assessments. They judged three perceptual attributes of 54 metallic panels under directional illumination by comparison with a reference sample. The session was carried out twice, each on a different day, in order to test repeatability. Each session lasted around 35 minutes, but was limited to 45 minutes so as to avoid visual fatigue. Figure 1 shows a LED spot light was used as the light source and it was located closely above the observer's head to minimise the angle between light source and observer.

3. DIGITAL IMAGING ANALYSIS

A computational model was developed to relate the results from the visual assessments to data obtained from the stereo capture system. This is a new alternative technique aimed at solving one of the most challenging problems in computer vision: stereo matching (Zhou and Boulanger, 2011). In the system, two images are captured by a same camera under two different lighting conditions to mimic stereoscopic vision. This not only addresses the problem of stereo matching (i.e. to find the corresponding pixels between two images) but also enhances the effect of perceptual attributes, especially glint. After capturing two images, digital imaging processing was implemented to extract relative features of perceptual attributes of metallic texture under directional light source.

3.1 Stereo Capture System

The stereo capture system consists of a digital camera and two LED spot lights shown in Figure 2. The system was designed to mimic human stereo vision. In the system, one digital camera was used as an image detector in contrast to a striking way with general type of stereo capture system with two or more lenses with a separate image sensor. Nevertheless, the system can reproduce the effective images of stereo perception without the big problems in stereo matching. This advantage of this system comes from illumination set up. Two LED spot lights are located at different lateral positions and Each LED source plays a role as each eye of human vision. Two scenes illuminated by two different lights are different due to illumination angle. The angle between a digital camera and light source was fixed as that of viewing geometry in visual assessment. In practice, two slightly different images for one sample were captured under two different lighting conditions: each image with single light on.

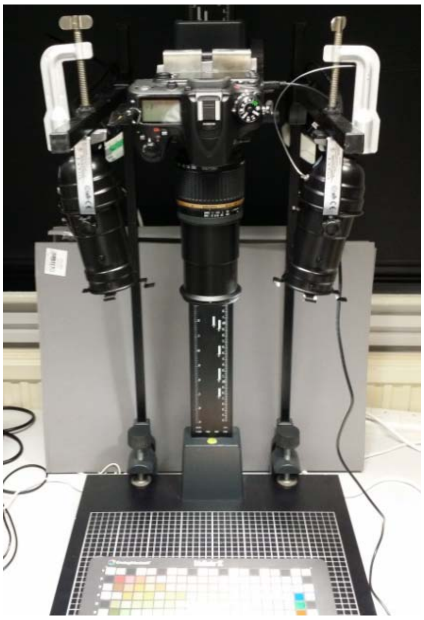


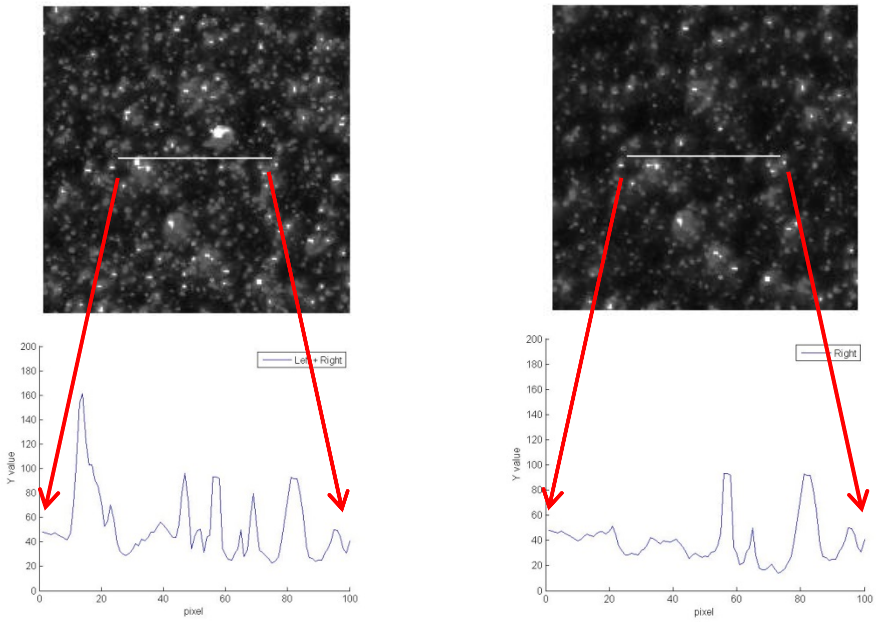
Figure 2: Stereo capture system.

3.2. Digital Image Processing

A camera characterisation method was applied to transform device-dependent RGB values to device-independent CIE XYZ tristimulus values. Luminance Y value of the images was used for the feature extraction. Illumination uniformity method was performed to minimise the effect of non-uniformity of the illumination intensity caused by the nature and geometry of spot light source used. The top-hat transform of an image was then employed to remove minor scratch of metallic-coating surface while leaving others undisturbed (Gonzalez *et al.*, 2004). Feature extraction starts on the assumption that the intensity distribution of the solid coating panels may be normal and symmetric histogram. This indicates that metallic-coating panels with the aluminium flakes have excessive part of histogram due to bright regions. According to assumption of normal distribution of the solid coating panels without aluminium flakes, Gaussian function was fitted to simulate the histogram and differential portion between both histograms was found. A global thresholding technique was applied to separate bright parts of metallic-coating panels. Two images obtained by these steps were combined into one image which is the largest elements of two images. Consequently, the image is the result which is similar to scene of stereo vision for digital image analysis.

4. RESULTS AND CONCLUSIONS

Figure 3 shows a comparison of two images; image (a) reconstructed by stereo image technic and image (b) captured by general image system with single camera. Two images represent not only the same metallic-coating panel but also exactly same area of the sample. Nevertheless, two images show different scene each other. Image (a) is similar to perception of human being with two eyes and gives more visual information than image (b). Intensity histogram of stereo image (a) testifies their difference in detail.



(a) (b)

Figure 3: The intensity comparison of two images captured from general acquisition and stereo capture system.

Observer variability of the three perceptual attributes: glint, coarseness and brightness was quantified using observer accuracy and repeatability. The statistical methods used in data analysis were the coefficient of determination, R^2, and coefficient of variation, *CV*. Table 1 shows that the observer accuracy and repeatability. Repeatability of coarseness was similar to that of glint but another was lower to that. The results of brightness do not provide signified statistics due to very low R^2 values obtained. It can be concluded that only glint of appearance attributes of metallic-coating panels is a meaningful property under specific viewing angles only when irradiated by an intense directed light source.

Table 1: A summary of observer accuracy and repeatability measures for all the samples.

			Accuracy			**Repeatability**	
	Logarithmic Scale	Glint	Coarseness	Brightness	Glint	Coarseness	Brightness
R^2	Mean	0.90	0.71	0.09	0.90	0.75	0.52
	Median	0.91	0.71	0.08	0.90	0.75	0.52
CV	Mean	13.67	12.15	4.26	10.42	11.76	4.64
	Median	12.49	10.33	3.50	10.89	10.09	3.49
	Raw Scale	Glint	Coarseness	Brightness	Glint	Coarseness	Brightness
R^2	Mean	0.85	0.74	0.58	0.82	0.75	0.52
	Median	0.87	0.76	0.59	0.85	0.77	0.47
CV	Mean	30.09	29.75	19.72	-	-	-
	Median	24.94	26.19	14.04	-	-	-

Using digital image processing, a dominant property of the total appearance of metallic coatings, glint, was extracted and compared with perceptual grade of observers in terms of twelve features: number of pixels, sum of those pixel values, number of particles, sum of mean value of each particle, pixel percentage against background, area percentage and six properties which are divided by the threshold t value (Kitaguchi, 2008). As shown in Figure 4 (h), sum of those pixel values divided by threshold value represent the highest correlation between both.

There are several statistic features with high correlation with perceptual glint along with representative property (h). To develop the model predictions, non-linearity step was applied and the performance of model was evaluated. Finally, power form using the property (h) gave the best performance.

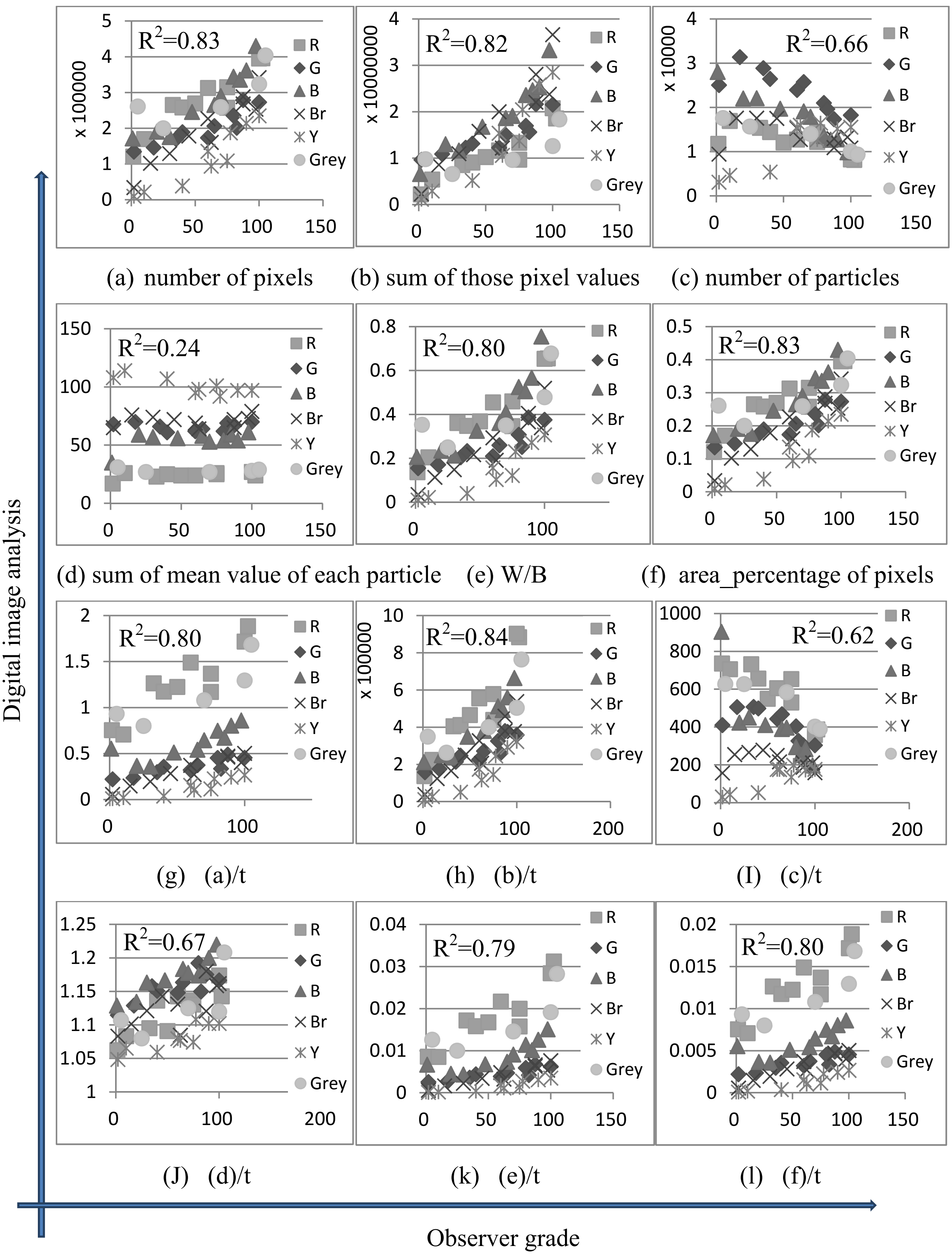


Figure 4: Observer grade VS digital image analysis

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Statistical Image Analysis for Evaluating Face Shine: Cosmetic Research

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ABSTRACT

Cosmetics, particularly base-makeup items such as foundation, are expected to provide beautiful shine with faces. In the process of cosmetics development, therefore, it is critical to understand features of face shine. In this study, we evaluate the feature using a novel statistical facial image analysis that characterizes the spatial distribution of brightness (texture) appearing on facial images. Since statistical methods require large amounts of facial images for learning data, we employed a facial image database designed for cosmetic purpose (the database is composed of facail images of Japanese females with and wtihout foundation). Then, to evaluate the features of face shine from the standpoint of facial "texture", we normalized each facial shape in the database to a mean shape by using a warping technique. These "shape-normalized facial images" are used as learning data for statistical texture analysis. We used principal component analysis to calculate eigenvectors of the facial texture. Each eigenvector represents a specific feature of the texture. Therefore, the facial image with different texture can be reconstructed by the combination of these eigenvectors. In this method, we first reconstructed facial images that had different acumulated cover ratio (ACR). Information regarding the differences between the reconstructed facial images was then used to extract textures that determined the features of face shine. By using this method, textural features of facial images with different types of face shine were evaluated. The results showed that texture that appeared in ACR of 82% ~ 97 % especially related to the deterioration of face shine. Since local unevenness of the facial skin such as pores are expressed in ACR 82% ~ 97 %, this result suggests that the local unevenness deteriorates face shine.

1. INTRODUCTION

As an important function of cosmetic foundation, which is a typical base-makeup, achieving a desirable cosmetic finish (face impression with makeup applied) has long been noted[1)]. In this regard, the importance of controlling the appearance of the face and its skin has been gathering interest in recent years[1)]. Among the efforts being made, study on face shine is particularly important. For example, as reported in a previous study[2)], the impression of a face can be flexibly controlled by varying the angular pattern of reflection from the skin, which suggests that feature of face shine is one of the key factors for controlling facial appearance. As is well known, the cosmetic finish is altered through skin sebum secretions, which cause an undesirable type of face shine (oily shine)[3)-5)]. In other research, the relationship between skin shine and skin age perceptions were investigated[6), 7)], and the result provides insights in designing cosmetics. As these previous cases show, study concerning face shine has been one of the most critical topics in cosmetic research.

In order to control feature of face shine with cosmetics, textural factors of face that generate the differences of the feature need to be assessed. In this study, a quantitative evaluation method for textural features concerning face shine is first proposed. Here, principal component analysis (PCA), which is useful for the analysis of facial images, was employed. Then, by using the method, the texture control points for achieving the desirable shine is identified.

2. EXTRACTION METHOD OF TEXTURE FROM FACIAL IMAGES

A novel method for the extraction of facial texture was developed by applying the Eigenface method[8], statistical image analysis based on PCA.

2.1 Facial Image Database for Learning

PCA requires large amounts of facial images for learning data. We, therefore, employed a facial image database designed for cosmetic research named "Multi-angle View Illumination Cosmetic Facial Image Database: MaVIC [2]. Facial images in MaVIC were captured Multi-angle Image Capturing System[2] (Figure 1), which allows us to capture facial images from 20 directions under various illumination conditions. MaVIC is composed of facial images of 420 Japanese females. MaVIC possesses 100 pairs of facial images with and without foundation. In this study, frontal facial images illuminated from the frontal direction were chosen from MaVIC.

Figure 1: Multi-angle Image Capturing System.

Cosmetic foundation achieves desired appearances by controlling texture such as skin imperfections (*e.g.* pores and freckles) and face shine. Therefore, in the evaluation of facial appearance for the purpose of foundation development, analysis focused solely on facial texture (NOT facial shape) is crucial. For this reason, as the facial image database (DB) for statistical learning, we prepared a "shape-normalized facial image DB" in which facial shapes (contours, positions of noses and eyes, etc.) of the images chosen from MaVIC were entirely unified by a warping technique[9] (Figure 2).

2.2 Eigenface Method

Employing the learning data of the aforesaid shape-normalized facial image DB, we computed eigenspace using the Eigenface method[8]. In this method, facial image $\mathbf{x}$ is described using basis functions (eigenvectors) $\mathbf{v}_i$ and their coefficients y_i:

$$\mathbf{x} = \mathbf{m} + y_1\mathbf{v}_1 + y_2\mathbf{v}_2 + \ldots + y_{n-1}\mathbf{v}_{n-1} + y_n\mathbf{v}_n \qquad (1)$$

Here $\mathbf{m}$ represents the mean vector of all facial images, and n is the total number of eigenvectors (n = 307). The reconstruction of facial images based on Equation (1) showed that facial texture was restored as the accumulated cover ratio (ACR) increased (Figure 3).

2.3 Identification of ACR bands related to face shine

A method for extracting the feature of face shine from the reconstructed facial images with different ACR levels was developed. As is evident in the comparison between

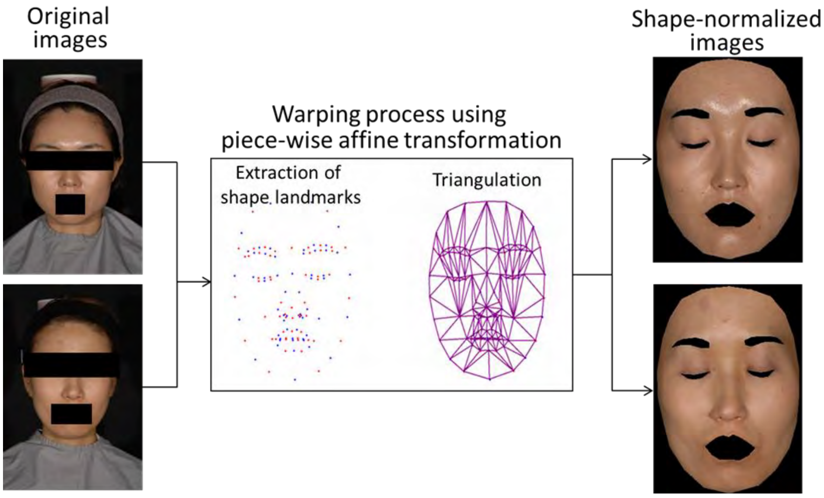

Figure 2: Shape-normalization via the warping technique.

reconstructed facial images with different feature of face shine shown in Figure 3 (a) to (c), the differences did not clearly emerge for the "low-order" reconstructed images with low ACR (for example, ACR = 50% in Figure 3). The differences, however, are clearly recognized for the "high-order" reconstructed images with high ACR. Thus, textural factors that determine the feature of face shine can be emerged at specific high-order ACR bands. Consequently, we attempted to identify the ACR bands according to the following 6 steps:

1. Subjective evaluation was carried out to score the level of face shine for 19 facial images;
2. For the 19 facial images, reconstructed facial images were synthesized by varying ACR according to Equation (1) (ACR varying increment was 3%: Figure 4(a));
3. Residual images between adjacent reconstructed facial images were computed (Figure 4(b));
4. Variance of the computed residual images were calculated (Figure 4(c));
5. The obtained variances for various ACR bands were accumulated.
6. The cumulative values obtained in step 5 were compared with subjective scores obtained in step 1, and then ACR bands that have high correlation to the subjective scores were identified.

In this study, the computational process represented in the above steps (Figure 4) is named "Eigen subspace selection method".

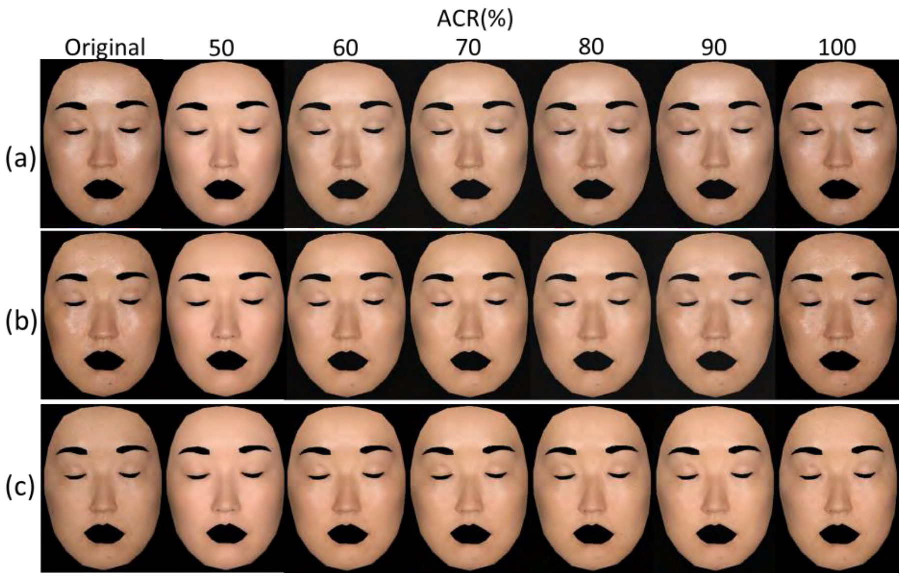

Figure 3: Reconstructed images of faces with different types of facial shine.

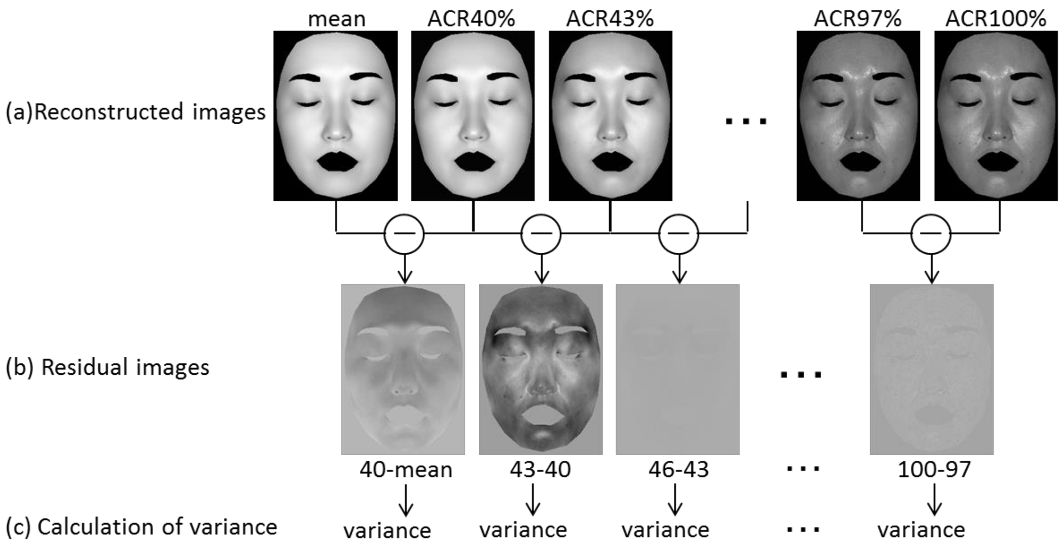

Figure 4: Computational process for the quantification of facial texture (“Eigen Subspace Selection Method”).

3. RESULTS AND DISCUSSION

The subjective scores for the level of face shine are, as shown in Figure 5, highly correlated to the cumulative values of the variance for the ACR bands ranging from 64% to 97%. In particular, the correlation reaches the maximum at the ACR band from 82% to 97%. Therefore, face shine can be efficiently quantified by cumulative variance value at the band of ACR 82% ~ 97%. Figure 6 shows the example of facial images reconstructed using the eigenvectors of the ACR 82% ~97%. Interestingly, textures derived from face shine as well as fine (local) skin unevenness such as pores are clearly extracted in the reconstructed facial image.

Next, we evaluated the relationship between the cumulative values of variance at the ACR band from 82% to 97% and the desirability of face shine scored via subjective evaluation (the number of test images is 19). Consequently, as shown in Figure 7, the following results were obtained:

1. Facial images with undesirable shine have large cumulative variance at the ACR band;
2. Facial images with excessively matte impression have small cumulative variance at the ACR band;
3. Facial images with desirable impression like “perceived translucency” have an intermediate cumulative variance at the ACR band.

With respect to 1, facial images with both face shine and local skin unevenness such as conspicuous pores have a large cumulative ACR variance from 82% to 97%. This suggested that local skin unevenness is one of the main factors that deteriorate face shine. With respect to 2, the cumulative ACR variance from 82% to 97% becomes small when both face shine and local skin unevenness are excessively absent. In this case, the faces look unnatural, and consequently give negative impression even though skin unevenness is restricted. Finally, with respect to 3, the result shows that a moderate level of shine with suppressing local skin unevenness provides a favorable impression of facial appearance. These discussions provide us with important insights for the design of foundation: in order

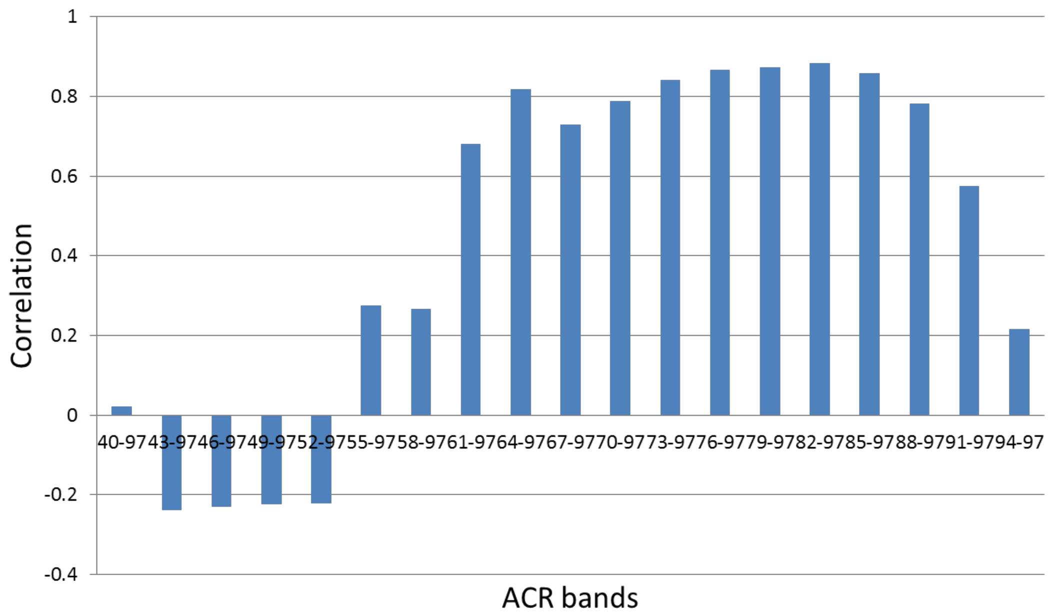

Figure 5: Correlation between the cumulative values of variance at various ACR bands and scores of the subjective evaluation for the level of face shine.

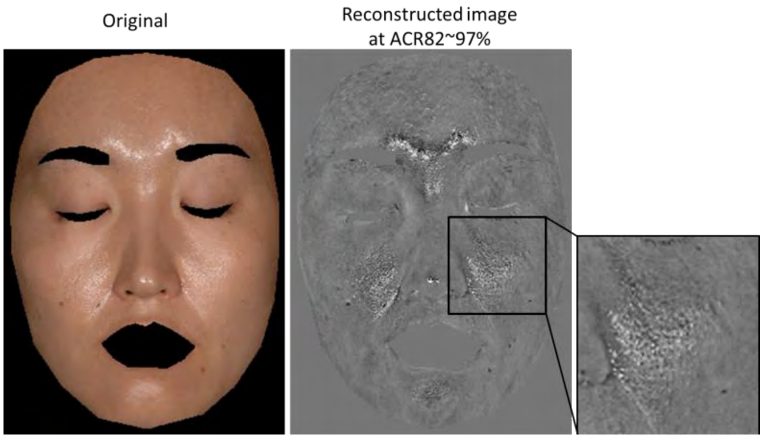

Figure 6: A typical facial image with shine (Original) and its reconstructed image at ACR 82~97%. In this ACR band, local skin unevenness such as pores is clearly extracted in the area of face shine.

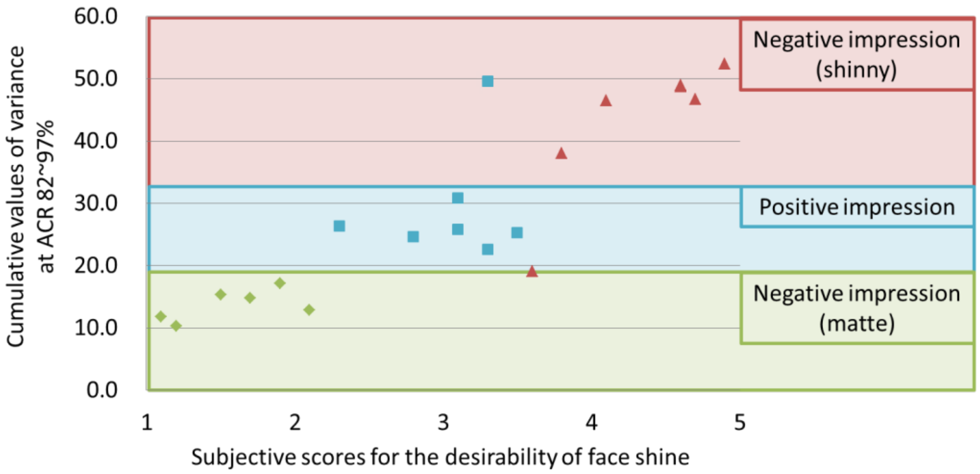

Figure 7: Relationship between subjective scores for the desirability of face shine and computational values via the proposed method ("Eigen subspace selection method").

to develop foundation that achieves desirable facial appearances, it is critical to effectively restrict local unevenness of facial skin with providing moderate shine.

4. CONCLUSIONS

We evaluate features of face shine based on the new-developed technique, “Eigen subspace selection method”. In this method, facial images that have different ACR are first reconstructed using PCA. Then, the variance of residual images from the reconstructed facial images is used to quantify textures that determine feature of face shine. The results show that texture extracted at ACR band from 82% to 97 % relates to the feature of face shine. At the band, local skin unevenness such as pores is mainly expressed. Therefore, the result suggests that restriction of the unevenness with providing moderate face shine is important for the development of foundation that achieves favorable facial appearances.

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High Dynamic, Spectral and Polarized Natural Light Environment Acquisition

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ABSTRACT

In the field of the image synthesis, the simulation of material's appearance requires a rigorous resolution of the light transport equation. This implies taking into account all the elements that may have an influence on the spectral radiance, and that are perceived by the human eye. Obviously, the reflectance properties of the materials have a major impact in the calculations, but other significant properties of light such as spectral distribution and polarization must also be taken into account, in order to expect correct results. Unfortunately real maps of the polarized or spectral environment corresponding to a real sky do not exist.

Therefore, it seemed necessary to focus our work on capturing such data, in order to have a system that qualifies all the properties of the light and capable of powering simulations in a renderer. As a consequence, in this work, we develop and we characterize a device designed to capture the entire light environment, by taking into account both the dynamic range of the spectral distribution and the polarization states, in a measurement time of less than two minutes. We propose a data format inspired by polarimetric imaging and fitted for a spectral rendering engine, which exploits the "Stokes-Mueller formalism."

Keywords: global illumination, spectral rendering, polarization, HDRI, Stokes vectors, Mueller matrix

1. INTRODUCTION

The fundamental rendering equation (1) proposed in 1986, [Kajiya, 1986] formulates the mechanism of light/matter interactions.

$$L_o(x,\vec{\omega},\lambda) = \int_{\Omega} L_i(x,\vec{\omega}',\lambda) f(x,\vec{\omega},\vec{\omega}',\lambda)(\vec{\omega}'.\vec{n})d\omega' \qquad (1)$$

Wherein:

- L is the light information.
- f is the Bidirectional Scattering Distribution Function (BSDF), characterizing the goniometric behavior of matter with a light hit.
- the additional factor is the indicator's angle on the impacted shape.

Obviously, this equation confirms the essential role of light. To expect a correct resolution, it is essential to take into account the totality of the physical nature of light, ie:

- *Intensity, wavelength, phase, polarization.*

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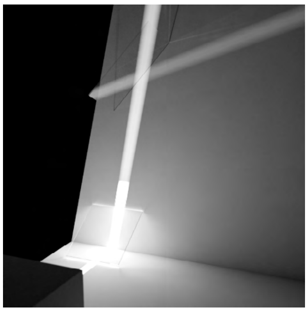
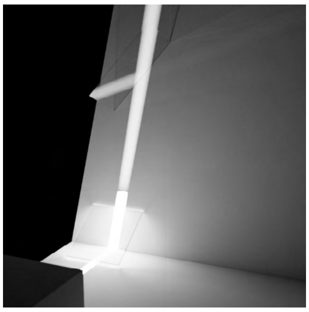
Unfortunately, with a very few exceptions, in the current synthesis imaging softwares, the spectral composition and especially the light polarization is neglected. Sometimes this is justified by some simplifications, or by the unavailability of the necessary informations for rendering methods. This leads to inaccuracies, or worse, to significant errors as shown in figure (1) or just impossible image calculations.



(a) *No polarization*



(b) *With polarization*

Figure 1: *Brewster experience simulation. At an incidence equal to the Brewster angle θ, the TM wave (p polarization) is totally transmitted and the reflected beam disappears.*

In order to answer this need, we propose the development and characterization of a device for the acquisition of the natural light environments, taking into account the range of light intensity, the spectral distribution and the polarization. The obtained informations will be processed and stored in a specific format to make them usable in a spectral renderer adapted accordingly based on the ”Stokes-Mueller formalism”.

2. LIGHT ENVIRONMENT MODELS

2.1 Light Environment Models Classification

Since the first observation instruments seeking to discover the organization of the sky and understand the optical phenomena that take place there, several descriptions and models have been proposed and nowadays many scientific fields are involved in this knowledge. In figure (2) we propose a classification of models and tools currently available. We excluded works on specific visual phenomena as clouds, rainbows, halos ... and focused on the only influence of the couple sun/sky on objects for an observer at a place and at a specific time.

We will see that although used in the synthesis imaging tools, with a few exceptions, they are either oversized or suffer from limitations.

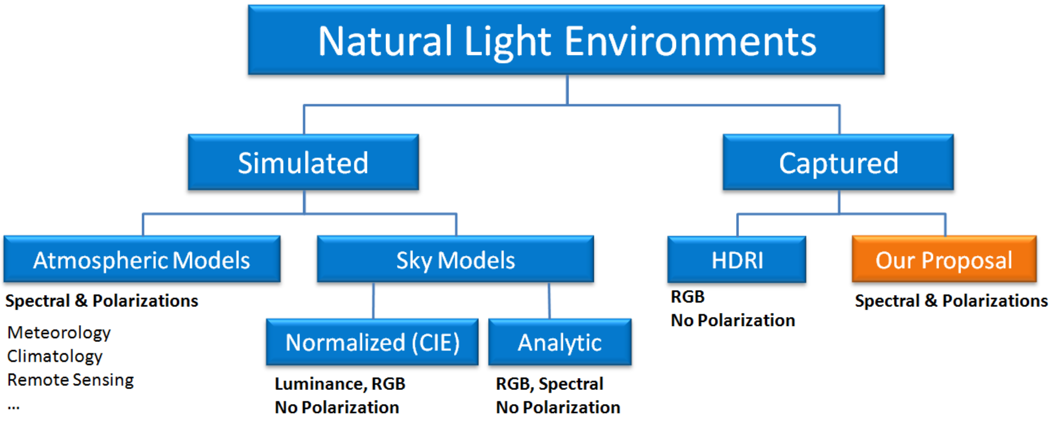


Figure 2: *Proposed classification of existing works on Light Environments*

2.2 Fundamentals

- Rayleigh scattering
  At the end of the 19th century, [Rayleigh, 1899] developed a theory of atmospheric scattering caused by the molecules of air. The results of his work formulate and specify the influence of this diffusion to the blue dominant color in the sky and the light polarization levels, follows a λ^{-4} rule.
- Mie scattering
  It is caused by particles whose size is in the same order of magnitude as the light wavelength [Horvath, 2009], such as water droplets, volcanic ash, mist ... It does not vary significantly with the wavelength and is anisotropic. When there are relatively much larger particles in the atmosphere, the sky whitens, this phenomenon being especially common in the clouds or fog, which we perceive as white or gray.

2.3 Simulated Models

2.3.1 Atmospheric Models

In scientific fields such as: meteorology, climatology, astronomy, remote sensing ... a lot of relevant models are available. They are based on different mathematical techniques for solving the radiative transfer equation and usually specialized in the study of very specific problems. In fact, they are inadequate or completely oversized for our proposal. Limited to operational solutions in the frequency band of the visible spectrum and taking into account the polarization, without being exhaustive, we can cite the software suite: libRadtran [Mayer and Kylling, 2005], MODTRAN-P [Pust and Shaw, 2011]. All these tools are used to model a majority of atmospheric conditions with high precision: direct solar spectral irradiance, diffusion, atmospheric transmission, and polarization states with input data such as: location, date and time, weather conditions, observation positions, temperature. All these tools have been widely validated by many experiments and observations in particular with the data tables proposed by Coulson [Coulson, 1988] as a reference. All these models produce synthetic skies that correspond to theoretical or ideal conditions.

2.3.2 Participating Media and Sky Models

In 1976, [McCartney, 1976] provides extensive data on diffusion phenomena in different weather conditions, characterized by the turbidity (T) parameter. In 1982, [Blinn, 1982] developed methods for simulating light scattering in volumes. This approach, based on results obtained in other scientific fields allows the computer graphics to benefit of these other sciences. Blinn was the first to apply the radiative transfer theory in application to the synthesis image generation in a participating environment. Many methods are available using analytical skies: [Nishita and Nakamae, 1986], [Tadamura et al., 1993], [Nishita et al., 1993]. More specifically, in the field of computer graphics, in 1999, [Preetham et al., 1999] proposed a model based on turbidity and designed for realistic rendering, that calculates the sky appearance under different conditions taking into account atmospheric perspective. In 2012, [Hosek and Wilkie, 2012] introduced a new and more accurate model improving the Preetham model. In almost all of the existing analytics sky models usable in synthesis imaging, polarization is neglected, with the exception of [Wilkie et al., 2004], to our knowledge.

2.3.3 CIE Models

The CIE models are particularly important as a reference and are very generic, therefore, they do not represent the reality for a given time and place as some simulation scenarios require.

CIE Standard: *Overcast Sky and Clear Sky* [Illumination, 1996] shows two extremes sky conditions, but of course in most cases, the reality is somewhere in between. In 1997, a new luminance distribution model has been proposed by CIE, which ranks all the skies in fifteen categories. In 2001, [Igawa and Nakamura, 2001] proposed to standardize all sky conditions by providing their own luminance distributions. A numerical equation then is introduced with the absolute values of the luminance and distribution of all types of sky, the clear skies and overcast, can be estimated. This sky proposed as an advanced normalized sky is called: *All Sky Model*. By in against all these models, the polarization is completely ignored.

2.4 Captured Models (HDRI)

The principle of high dynamic range imagery (HDRI) exists independently of computer graphics. The use of HDRI in renderer has been proposed [Debevec, 1998] and many publications are available on this subject. The HDR technique captures all the light information of a scene and reproduce all the details contained in both dark areas and bright ones whose dynamics exceeds that of the digital camera sensor.

2.4.1 Acquisitions

The traditional technique of capturing high dynamic images [Stumpfel et al., 2004] is the combination of several acquisition exposure time of the same scene with a Digital Still Camera (DSC), by setting a film sensibility, and a fixed aperture. We adopt this technique for the device that we propose, in addition it is important to note here that the HDRI cannot be viewed as such and are inseparable from the ”Tone Mapper” operators.

2.4.2 Limitations

Although often used in computer graphics, HDR images are insufficient, they are coded in a trichromatic system and provide no information about the polarization.

3. CAPTURE SYSTEM

The polarization of the light of sky itself has been the subject of many theoretical and experimental studies, literature is important: [van de Hulst, 1948], [Chandrasekar, 1950], [Coulson, 1988], [North and Duggin, 1997], [Voss and Liu, 1997]. Several solutions ensuring the capture of a sky with some or all the required features are available. All the existing devices are used in measurement of the sky polarization, or location-based applications. None thought of as capturing light environment system for synthesis of imaging applications. In 1997, [Voss and Liu, 1997] shown a system based on a Charge Coupled Device (CCD) to measure the distribution of the polarized radiance of the light of the sky. In 2006, [Pust and Shaw, 2006] proposed a comprehensive system based on ”Liquid Crystal Variable Retarders” (LCVR). In 2014 [Zhang et al][Zhang et al., 2014] proposed a similar system also based on LCVR, focusing mainly on settings and calibrations LCVR.

3.1 Adopted solution

After an accurate analysis of the information available in the literature, we discarded the solutions using LCVR, for reasons of electronic complexity. So we focused on a device similar to the one proposed in 2010 [Miyazaki et al., 2010], by supplementing it with measurements by spectral bands rather than only trichromatic. We focused on an optical system assembly with motorized filter wheels and slave as shown in figure (3).

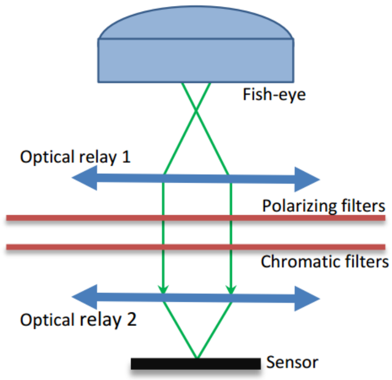


Figure 3: General principle of the proposed capture device

3.2 Hardware

The fish-eye is an objective of the brand ”SUNEX” with a NIKON mount type (F), focal length: 5.6 mm, fixed aperture: F / 5.6, field of view: $185°$, image circle: 14.5 mm. The optical relays have been specially designed with a particular care for ensuring an optimal collimation of the rays before the passage of the filters, as well as their focus on the sensor plane. Filters are carried by two servo motor and wheels, the first wheel comprises seven combinations of polarizing filters and an empty space. The distribution is as follows:

- $0°$ Polarizer: one polarizer at $0°$ orientation
- $45°$ Polarizer: one polarizer at $45°$ orientation
- $90°$ Polarizer: one polarizer at $90°$ orientation
- $0°$ Polarizer $45°$ WP: one polarizer at $0°$ orientation + one wave-plate at $45°$ orientation
- $0°$ Polarizer $135°$ WP: one polarizer at $0°$ orientation + one wave-plate at $135°$ orientation
- $90°$ Polarizer $45°$ WP: one polarizer at $90°$ orientation + one wave-plate at $45°$ orientation
- $90°$ Polarizer $135°$ WP: one polarizer at $90°$ orientation + one wave-plate at $135°$ orientation

The second wheel comprises 16 color filters from 400 to 800 nm with a pitch of 25 nm. The sensor is a CCD (KAI-08670) of the brand ”ON Semiconductor,” a resolution of 3600 (H) x 2400 (V) pixels (APS-H optical format). Connections to an external computer are made via an USB interface, both for the camera control and for the filter wheels, a specific program was carried out accordingly. The GPS coordinates, and the date/hour of use are recorded. An accelerometer measures the potential vertical faults. All these informations are automatically saved in a file for future use.

3.3 Calibrations

The following characteristics are taken into consideration, which describe the influence of the acquisition device on the incident light, by both the optics, the various filters and the sensor.

- The Mueller matrix of the fish-eye in function of the light incidence angle from the optical axis.
- The fish-eye angular distortion, ie the angular distance relative to the zenith angle of incidence, in theory they are equal.
- The sensor radiometric response.
- Light intensity evolution of the sensor as a function of incidence angle.
- Polarizing filters transmission according to the wavelength.
- The response curves of the color filters.

To determine the changes undergone by the incident light through the system, we must determine its Mueller matrix: $M(\theta)$ as a function of incidence angle θ. In the general case, this amounts to determine 16 values: $M_{1,1}(\theta)$, $M_{1,2}(\theta)$, $M_{1,3}(\theta)$ ... In our case, it is not necessary to determine all of the elements. The sensor is only sensitive to the incident light intensity, only the first line ($M_{1,1}(\theta)$, $M_{1,2}(\theta)$, $M_{1,3}(\theta)$, $M_{1,4}(\theta)$) must be determined. Generally the sky light is not circularly polarized [Coulson, 1988], so we do not need to acquire $M_{1,4}(\theta)$, anyway we will do it, at least to check.

4. SPREAD OF LIGHT BEAMS IN A RENDERING ENGINE

Simulation polarization effects in image synthesis has until recently been generally overlooked. One of the main reasons why the polarization has been neglected is the general feeling that the polarization effects have minimal contribution to the appearance of a scene. However, many real-world scenes present significant polarization effects; such as the brightness of the glazing, large water surfaces, discoloration metallic objects and thoughts. All things being equal, the rendering engine will be adapted accordingly:

- Ray Tracing conventional
  - Scalar intensity
  - Scalar reflection and transmission
- Ray Tracing polarized
  - Stokes vectors (4D)
  - Mueller matrices (4x4)

This requires a specific treatment rendering engine level, considering a vector mathematical formulation and not scalar. Very few articles are available.[Wolff and Kurlander, 1990], [Freniere et al., 1999], [Wilkie and Weidlich, 2010]

5. CONCLUSION

To provide an answer to the problem of inconsistency in terms of the nature of the data in traditional synthesis imaging tools, it is essential to have all the information in the same formulation. The light is obviously the key point. We propose a capture system for the light measurement designed for computer graphics to adapt and complement current methods of resolutions of the rendering equation. We hypothesize that the knowledge of this data, operating in a rendering engine, will:

- Improve trick play of colors and aspects.
- Simulate specific effects (absorption, dispersions, diffractions, interference...).
- Anticipate the phenomena of metamerism.
- Improve the match between real environments and simulations in augmented reality applications.

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Development of skin reflectance prediction model using skin data

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ABSTRACT

A skin spectra prediction model was developed to transform camera RGB of skin image to skin spectral reflectance. Skin colour measurement and skin image capture were conducted for 61 Caucasians and 71 Chinese. Rather than using a standard colour chart, skin colour of subset of subjects were used to fit the model. Using the remaining subjects skin colour data, the proposed model were evaluated using CIELAB colour difference between device measured skin spectra and model predicted spectra under three typical illuminations (D65, CWF and A). Results showed that using small numbers of subject skin data, a satifistory colour reprpodcution can be achieved when a linear transform from camera RGB to CIE XYZ tristimulus values was applied.

1. INTRODUCTION

Interest in the spectral reflectance of human skin has been greatly stimulated by the increased need for accurate human skin colour for various industrial and medical applications, including skin colour reproduction for graphic arts, skin pigmentation prediction for cosmetic industry, skin colour measurement for the diagnosis of cutaneous disease and skin colour matching for body and maxillofacial soft tissue prostheses. While CIE Colorimetry is useful for defining skin colour under a particular illumination condition, skin spectral reflectance data contain all the necessary information to predict, model and simulate skin appearance under any illumination condition. Furthermore, skin spectra can also be linked to skin chromophores and therefore provide an opportunity to extract important health-related information using only optical, non-invasive skin measurements.

It has previously been shown that three basis functions obtained by Principal Component Analysis (PCA) are sufficient to accurately describe the spectral reflectance of human skin, thereby allowing the formulation of an algorithm for the estimation of the spectral reflectance of each pixel of an RGB image [1]. However, since human skin is a non-flat multi-layer material with non-uniform colour properties, we found large predictive errors on using a conventional method (i.e. a standard colour chart) for camera colour profiling. This could be caused by material differences between the skin colour chart and the human skin, and lack of uniformity (in both, the colour chart and the subjects' faces).

The aim of this study is to develop a new skin reflectance re-construction model to predict skin reflectance from facial images. Facial images from 132 subjects (71 Chinese and 61 Caucasians) were captured using a Nikon camera system under controlled viewing conditions. The reflectance of their skin from four facial areas was also measured using a Konica Minolta CM 700d spectrophotometer. Rather than using a standard colour chart, a reflectance re-construction model was developed using the skin colours of a subset of the subjects, and evaluated using the remaining subjects. The effect of the selection of training colours was investigated.

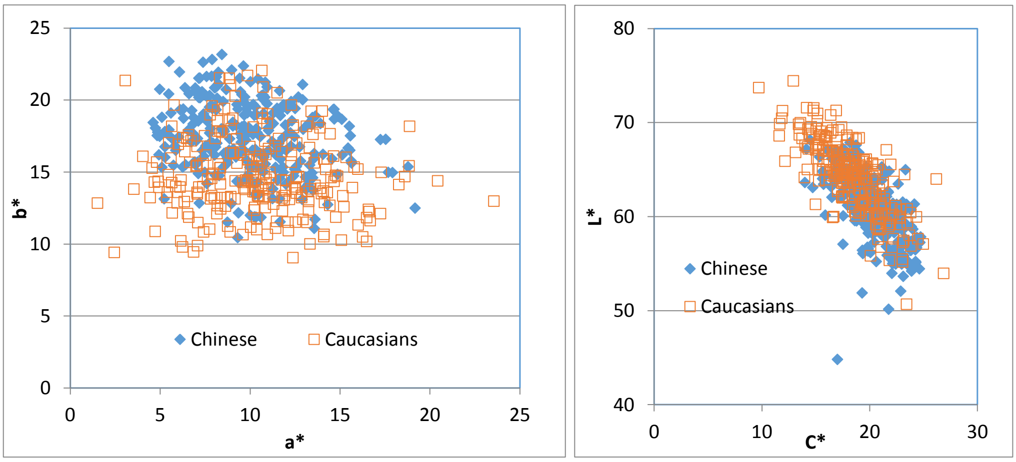
2. METHOD

2.1 Skin colour database

A skin colour database was collected at the University of Liverppol in collaboration with the University of Leeds. A Konica Minolta CM-700d spectrophotometer using the CM-SA skin analysis software was used to obtain skin colour measurements and spectral reflectance data in the range 400nm to 700 nm, sampled at intervals of 10nm. During the measurements, a viewing geometry of d/8 (diffuse illumination, 8-degree viewing) was used, with the specular component included and the aperture size set to 3mm. For each subject, skin colour measurements were obtained from four body areas - forehead, cheek, cheekbone and neck. Information on age, gender and ethnicity was also collected.

Subsequently, each subject sat in a Verivide facial image viewing cabinet with a diffused D65 lighting, and their facial image was captured by a Nikon D7000 DSLR camera. Verivide Digieye software was used to manually control camera setting, such as exposure, focus, ISO. Each facial image was saved as a camera RGB image.

To date, skin colours of 132 subjects (61 Caucasians and 71 Chinese) have been obtained. Figure 1 illstrutrates the chromaticities and lightness of skin colours in both the Chinese (solid diamonds) and the Caucausian samples (open squares) in CIELAB colour space [2]. Figure 1(a) shows the measured colours in the CIELAB a*-b* chromaticity diagram, whereas Fig 1(b) shows the same data in a chroma (saturation) - lightness diagram.



(a) (b)

Figure 1: Colour specifications of the new skin colour database.

2.2 Skin reflectance prediction model

Skin spectral reflectances were predicted from the camera RGB values by a two-step model. In the first step, camera colour characterisation was performed to transform RGB to to CIE XYZ tristimulus values using equation 1. Here, ζ (equation 2) denotes the relative colour density calculated from the CIE XYZ coordinates, ρ_k denotes a vector composed of power-products of device-dependent RGB coordinates up to the kth degree, and M denotes the required transform [3]. Three forms of ρ_k as shown in equations 3, 4 and 5 were considered. These correspond to linear, 2nd and 3rd order regression models respectively. The performance of these regresssion models was compared.

$$\zeta = \rho_k \bullet M \tag{1}$$

$$\zeta = \begin{bmatrix} \log\frac{X}{X_w} & \log\frac{Y}{Yw} & \log\frac{Z}{Zw} \end{bmatrix} \tag{2}$$

$$\rho_1 = \begin{bmatrix} R & G & B & 1 \end{bmatrix} \tag{3}$$

$$\rho_2 = \begin{bmatrix} R & G & B & R^2 & G^2 & B^2 & RG & GB & BR & 1 \end{bmatrix} \tag{4}$$

$$\begin{aligned} \rho_{31} &= [R\ G\ B\ R^2\ G^2\ B^2\ RG\ RB\ GB\ RGB] \\ \rho_{32} &= [R^2G\ R^2B\ G^2R\ G^2B\ B^2R\ B^2G\ R^3\ G^3\ B^3\ 1] \\ \rho_3 &= [\rho_{31}\ \rho_{32}] \end{aligned} \tag{5}$$

In the second step, reflectance spectra were reconstructed, i.e. the spectra were derived from the CIE XYZ tristimulus values. Principle component analysis was performed using our new spectral skin database [4]. Using the basis functions (B) and the ASTM coefficient matrix (M_{ASTM}), spectral reflectance of skin colour can be predicted from the CIE XYZ tristimulus values using equations 6 and 7. M_{ASTM} combines spectral power distribution of the illuminant and the CIE 1931 colour matching function.

$$\beta = (M_{ASTM}B)^{-1}\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \tag{6}$$

$$r \approx \beta_1 b^{(1)} + \beta_2 b^{(2)} + \beta_3 b^{(3)} = B\beta \tag{7}$$

2.3 Selection of skin colour database

Three skin colour databases (Chinese, Caucasian and combined) were used. For each individual database, a subset of skin colours was used as the training set to develop the model, and the remaining spectra were used as the testing set to evaluate model performance. For the camera characterisation model, there is always a tradeoff between selection of training colours and the accuracy of the model performance. In general, a larger number of training colours provides a better model; but in most applications, a small number of training colours is desireable. To investigate the effect of the number of training colours, sub-sets ranging from 1% to 50% of the total number of samples were used for training. Training colours were chosen randomly from a uniform distribution and 400 iterations were performed.

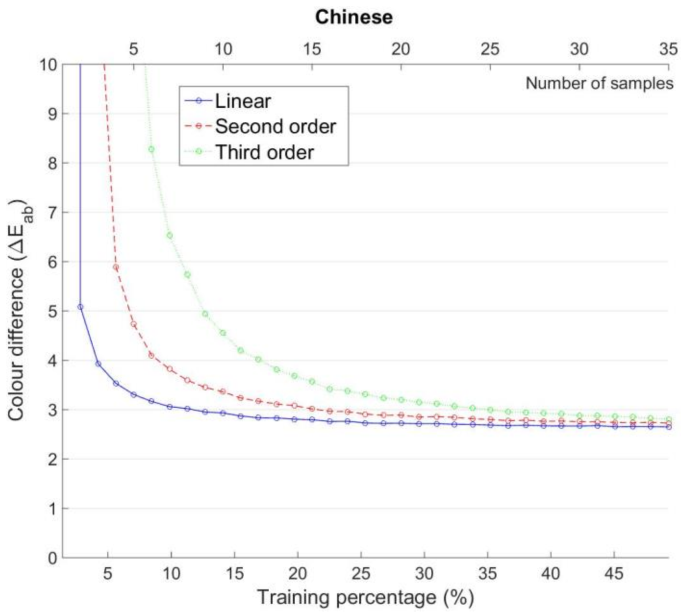
2.4 Evaluation of the skin spectral prediction model

To evaluate performance of the skin reflectance re-construction, test skin colours were used to predict the skin spectral reflectances for each model. Colour differences for each pair of skin spectral (measured vs. prediced skin spectra) were calculated for three typical Illuminants (D65, A and CWF) using the CIELAB colour difference formular. A median mean was calcuated to represent model performance for all testing colours.

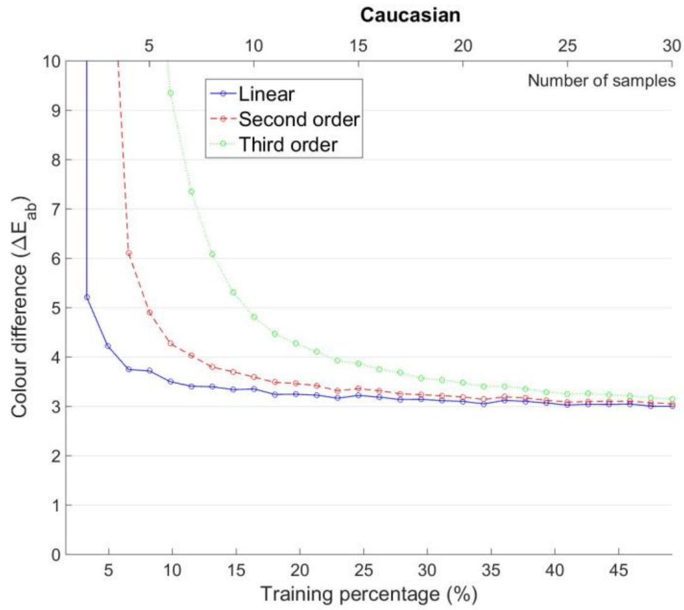
3. RESULTS AND DISCUSSION

For each level of training percentage (i.e. the proportion of skin spectra used as the training set), the goodness of the skin prediction model was evaluated using the remaining set of spectra as a test set. Figure 2 shows the mean colour difference (CIELAB) as a function of the training percentage, for the three different model assumptions: the linear transform (blue solid line), 2nd order polynomial regression (red dashed lines) and 3rd order polynomial regression (green dotted line). Results for the chinese, caucasians and cobmined database are shown in figures a,b and c respectively.

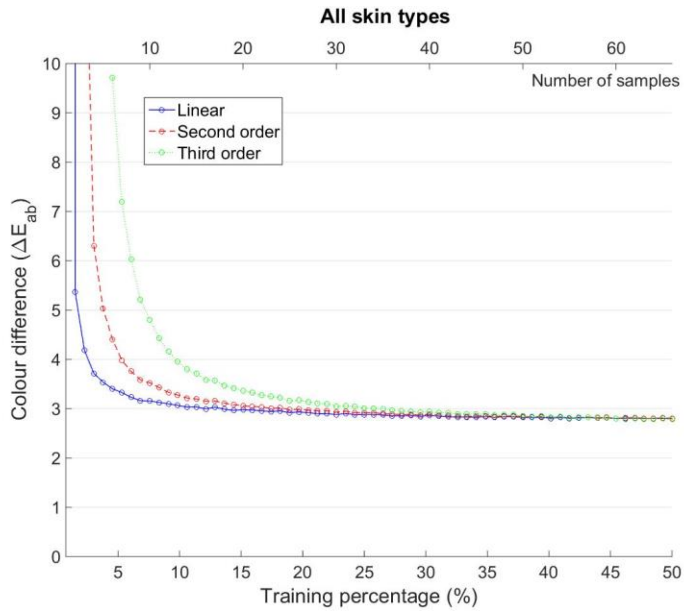
Our main result is that all three models converge to about 3ΔE^*_{ab} preditive error, indicating that, in princple, an acceptable colour reproduction can be achieved [5]. The linear model converges much faster (at about 5%) than the 2nd order and 3rd order models (at about 10% and 20% respectively). The performence is very consistent across different ethnicities ; fastest convergence occurs for the combined skin data set which makes use of both the chinese and the caucasian skin spectra.



(a)



(b)



(c)

Figure 2 : Model performence for different training set percentages .

4. CONCLUSIONS

Using a large set of spectral skin data, a skin spectral prediction model was developed and evaluated using different proportions of training and test data. The best performance is achieved by assuming a linear transform from device-dependent camera RGB to device-independent CIE XYZ tristimulus values. Convergence is slighltly faster when skin spectra from both chinese and caucasian ethnic groups together with the linear transform are used.

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Comparing CSI and PCA in Amalgamation with JPEG for Spectral Image Compression

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ABSTRACT

Continuing our previous research on color image compression, we move towards spectral image compression. This enormous amount of data needs more space to store and more time to transmit. To manage this sheer amount of data, researchers have investigated different techniques so that image quality can be conserved and compressibility can be improved. The principle component analysis (PCA) can be employed to reduce the dimensions of spectral images to achieve high compressibility and performance. Due to processing complexity of PCA, a simple interpolation technique called cubic spline interpolation (CSI) was considered to reduce the dimensionality of spectral domain of spectral images. The CSI and PCA were employed one by one in the spectral domain and were amalgamated with the JPEG, which was employed in spatial domain. Three measures including compression rate (CR), processing time (Tp) and color difference CIEDE2000 were used for performance analysis. Test results showed that for a fixed value of compression rate, CSI based algorithm performed poor in terms of ΔE_{00}, in comparison with PCA, but is still reliable because of small color difference. On the other hand it has lower complexity and is computationally much better as compared to PCA based algorithm, especially for spectral images with large size images.

1. INTRODUCTION

In last two decades, demand of high speed data transfer and high level of data compression have increased and it has been a hot topic of research in the area of signal processing and communications. As images are always a reasonable part of data that is being transmitted or stored, image compression techniques play an important role to compress such data. The visual information is compressed by human visual system and still it provides high quality of image and true color information. This information motivated researchers to compress visual data or images in a way that the compressed information should be reliable and color information should not change. Almost the same rate of compression was achieved in early 90's for the color images.

Concerning multi-spectral or hyper-spectral imaging which have a number of spectral bands, their accessibility is hindered by the communication bandwidth and image size. These limitations may be alleviated by efficient image compression. J. Delcourt et al., proposed an adaptive multi-resolution based multispectral imaging technique substituted with JPEG algorithm (Delcourt 2010). Markas and Reif proposed two coder schemes, one to remove spectral redundancy and another wavelet based coder to remove special redundancy, in the multispectral images (Markas 1993). N. Salamati et al., proposed a coder that puts a threshold on DCT components due to high correlation between visible color RGB and near-infrared components of four channel multispectral images. They also compared their results with JPEG and PCA based compression techniques and found almost the same compression rate (Salamati 2012). Canta and Poggi, proposed address predictive vector quantization based technique for multispectral images (Canta 1997). In this work both spatial and spectral dependencies were exploited. L. Chang used Eigen-based segmentation for multispectral image compression (Chang 2004). M. Cagnazzo, et al., proposed classified transform coding based spectral image compression technique in order to lower the computational complexity (Cagnazzo 2006). Q. Du and J. E. Fowler, amalgamated PCA with JPEG for hyper-spectral image compression (Du 2007).

The joint photographic experts group (JPEG) proposed an algorithm called JPEG which is the most commonly used image compression standard. By selecting a tradeoff between image quality and rate of compression, it can achieve a degree of compression that is desired depending on the application (Skodras 2001). The cubic spline interpolation (CSI) is a best polynomial based interpolation technique that is smooth on the edges due to its strict constraint of continuity at second derivative. It is a computationally simple and robust technique. It can be combined with JPEG for image compression.

In the current work, we continued our previous research on color image compression (Safdar 2014), we have incorporated cubic spline interpolation (CSI) into the JPEG algorithm to compress multispectral images. The CSI was used to compress spectral domain while JPEG was employed to reduce spatial dimensionality. The results of both methods were compared and analyzed on the bases of computational complexity and quality of the image reduced due to compression.

2. METHOD

The principle component analysis (PCA) has widely been used for spectral reduction and spectral de-correlation in multivariate data analysis (Du 2007). PCA practically provides optimal and excellent de-correlation in statistical sense. At the time of training of all PCs, PCA is commonly known as the KarhunenLo`eve transform (KLT), in which case a hyper-spectral image with N spectral bands produces an N×N unitary KLT transform matrix. Because of being data dependent matrix, it must be communicated to the decoder in any KLT-based compression system. Alternatively, corresponding to the P largest eigenvectors, by training in the KLT transform matrix PCA can effectuate dimensionality reduction. The data volume passed to the encoder then has $P < N$, rather than N, spectral components, and the resulting N×P PCA matrix is communicated to the decoder.

The JPEG 1992 standard was used in the current work. The PCA transform matrix and data mean vector were generated in MATLAB; the Kakadu encoder performs the spectral transform (implicitly reducing the spectral dimensionality if $P<N$) and then embeds the mean vector as well as the inverse transform matrix into the JPEG2000 bit-stream. The encoder automatically allocates rate simultaneously across the P PCs to be coded; i.e., post-compression rate-distortion (PCRD) optimization is applied simultaneously to all code blocks in all PCs to optimally truncate the embedded bit stream for each code block. In the reconstruction process, the Kakadu decoder automatically extracts the transform matrix and mean vector and then applies them appropriately after the bit stream has been decoded (Du 2007).

Due to processing complexity of PCA, a simple algorithm is needed to reduce dimensionality of spectral data. The cubic spline interpolation (CSI) was considered here to reduce the dimensionality of spectral domain of multispectral images (MSIs). The CSI was employed in the spectral domain along with the JPEG that was employed in spatial domain. Down sampling stage before the baseline JPEG was skipped to avoid the loss of sheer information in both the algorithms. The performance results of both algorithms were then compared in terms of compressibility, processing complexity and reliability.

3. RESULTS AND DISCUSSION

Four spectral images were selected to test both compression algorithms. Selected four images that include human skin color, natural objects, dark colors and most widely used test color checker chart, are shown below (Figure 1). The images were named as Caucasian male, red rose, tomatoes and Macbeth color checker lab, respectively. Three measures including compression rate (CR), processing time (T_p) and CIEDE2000 were used for performance analysis. The CIEDE2000 is CIE color difference formula which is best correlated with the human visual perception (Luo 2001).

Figure 1: Selected test images

The images were calculated using MATLAB. The compression rate was fixed at 8 and performance of both algorithms was tested in terms of quality of visual performance and computational complexity. The average results of image calculations have been shown (see Table 1). The results in (Table 1) show that ΔE_{00} for PCA based algorithm is much lower as compared to CSI based algorithm. And both algorithms have different performance for different images of same size that is the effect of spatial non-uniformity on the compressibility. The Fig. 2 shows the logarithmic values of processing time of two algorithms at different image sizes. It can be seen from Fig. 2 that increasing the image size processing time of PCA based algorithm increases rapidly, while CSI based algorithm does not add that much computational complexity with the increase of image size.

Being color scientists, we believe that color difference less than 1.0 ΔE_{00} units is tolerable. Test results showed that for a fixed value of compression rate, CSI based algorithm performed poor in terms of ΔE_{00}, in comparison with PCA, but is still reliable because of small color difference with the original image data. On the other hand it has lower complexity and is computationally much better as compared to PCA based algorithm, especially for spectral images with large number of pixels that may take several minutes to process even on a powerful computer. With the increase of image size, complexity of PCA increases rapidly and hence takes more time to process.

Table 1. Summary of the results from spectral compression

Algo. Name	caucassian	Red Rose	Tomotoes	Macbeth
CSI and JPEG	0.5	0.8	0.7	0.6
PCA and JPEG	0.2	0.3	0.2	0.2

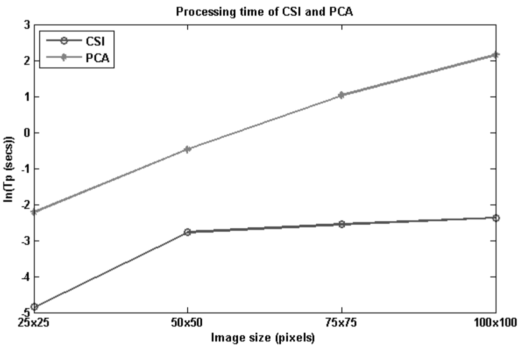

Figure 2: Processing time plotted against image size.

4. CONCLUSIONS

Two different techniques cubic spline interpolation (CSI) and principle component analysis (PCA) were employed one by one in the spectral domain and were amalgamated with the JPEG, which was employed in spatial domain. The performance results of both algorithms were then compared in terms of compressibility and processing complexity. Test results showed that for a fixed value of compression rate, CSI based algorithm performed poor in terms of ΔE_{00}, in comparison with PCA, but is still reliable because of small color difference with the original image data. On the other hand it has lower complexity and is computationally much better as compared to PCA based algorithm, especially for spectral images with large size. With the increase of image size, complexity of PCA increases rapidly and hence needs more time and memory to process.

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A system for analyzing color information with the multi-spectral image and its application

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ABSTRACT

It has become easier to take a multi-spectral image of ordinary scene by newly developed multi-spectral cameras. We have constructed a system which can analyze chromaticity data from spectral data taken by a hyperspectral camera. We verified the accuracy of the data which taken by the hyperspectral camera. Although the accuracy would need to be improved, we were able to obtain chromaticity data useful for color analyses. We compared those color information and spectral distribution to analyze and simulate the color appearance of color deficiency for traffic signals with new LED and old type lamps. Using new XYZ tristimulus values derived from the cone fundamentals of CIE170-2 of red, green and yellow traffic lamps were calculated from the multi-spectral images. We also simulated the different degrees of color deficiency by shifting L or M cone spectral sensitivity. The simulated chromaticity coordinates of dichromat and anomalous trichromat are different from normal color vision for both old and new traffic signal in the case of red and blue signals. It was shown that our system can contribute to study and analyze various environments including color universal design using multi-spectral images and their data.

1. INTRODUCTION

With the development of multi-spectral cameras, it has become easier to take a multi-spectral image. This means that the information from a multi-spectral camera would be a strong tool to obtain and analyze the color information of various scenes. However, it is complicated to extract color information from raw spectral distribution data in a multi-spectral image since a precise color calibration and the calculations of colorimetric values such as chromaticity coordinates are required.

Recently, a portable hyperspectral camera has been developed, and it has become easier to take multi-spectral image data in various outside environments. With multi-spectral image data, we can do lots of things such as analyzing color statistics of natural scene, applying for color appearance models. In this paper, we will introduce a method how to transform a multi-spectral image to the CIE tristimulus values X, Y and Z. Meanwhile, it also can be simulated the color appearance of anomalous trichromat. As we all know, the CIE tristimulus values also can be convert to the CIE (x, y) chromaticity coordinates. With the CIE (x, y) chromaticity diagram, we can analyze the color between normal color vision and anomalous trichromat. This simulation model will be helpful for color universal design.

2. METHOD

We have constructed a system which can analyze color data from spectral data taken by a newly developed hyperspectral camera (NH-7, EBA Japan). The multi-spectral image data contains 1280 by 1024 pixels. Each pixel have the data of a spectral power distribution from 350 nm to 1100 nm. We used the range of visible spctrum between 380 nm and 780 nm.

First, uniformity and the shape of spectral distributions in an image due to the sensitivity of each sensor in the camera were calibrated based on a uniform reference xenon light through an integrating sphere. Then the CIE XYZ were calculated using the obtained precise spectral distributions and the color matching functions. It is also possible to transfer to the other chromaticity values such as the CIELAB and LMS cone stimulus values. With this system, we can analyze color statistics (e.g. average color and color distribution) of an image.

2.1 Model with CIE 1931 color matching function and further

The CIE1931 XYZ was calculated using the obtained precise spectral distributions and the CIE 1931 color-matching functions by following equations.

$$X = \int_{380}^{780} I(\lambda)\, \bar{x}(\lambda) \mathrm{d}\lambda \tag{1}$$

$$Y = \int_{380}^{780} I(\lambda)\, \bar{y}(\lambda) \mathrm{d}\lambda \tag{2}$$

$$Z = \int_{380}^{780} I(\lambda)\, \bar{z}(\lambda) \mathrm{d}\lambda \tag{3}$$

Where $I(\lambda)$ is a spectral power distribution obtatined from calibrated data, and $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$ are the CIE1931 color matching functions. With the above Eqs. (1), (2) and (3) , the spectral power distribution can be transform to the CIE tristimulus values X, Y and Z.

$$x = \frac{X}{X+Y+Z} \tag{4}$$

$$y = \frac{Y}{X+Y+Z} \tag{5}$$

With Eqs.(4) and (5), the CIE tristimulus values can be turn to the CIE1931 xy chromaticity coordinates. This method use the color matching function to convert the spectral power distribution to xy chromaticity.

We verified the accuracy of this method using a hyperspectral camera (NH-7). We took the spectral data of a color checker in a booth illuminated by fluorescent lamps simulating D65. Then we calculated the CIE1931 (x, y) chromaticity data of some color in the color checker with the spectral data. Meanwhile, we also meansured the CIE1931 (x, y) chromaticity data of same color as above in the color checker with a spectroradiometer (PR-680, Photo Research).

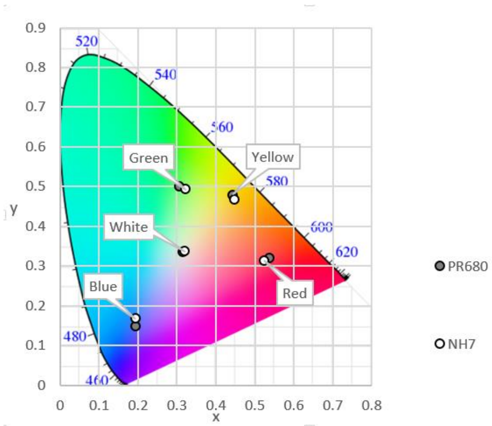

Figure 1: CIE1931 xy chromaticity diagram of 5 colors in color checker

Figure 1 shows the data of 5 colors which contains white, blue, green, yellow and red. Comparing the 2 sets of (x, y) chromaticity data, white shows good consistency. Other colors show small differencies. The data which taken by the multi-spectral camera (NH7) would be sufficient for general use, but we may need to improve the accuracy of the system further.

The advantage of our system is that we can obtain the chromaticity values of varoius color spaces, even which cannot calculate without spectral distribution of stimuli or can not convert each other based on their chromaticity values, by replacing the part of the color matching function. For example, the new color maching function to be proposed by CIE (http://www.cvrl.org/) which transformed from the CIE (2006) LMS functions (CIE 170-1:2006) requires a spectral distribution of stimuli for its calculation. We use this color maching function for the calculation of the simulation model of anomalous trichromat in the next section.

2.2 Simulation Model of color appearance for anomalous trichromat

As an example of application, we compared those color information and spectral distribution to analyze and simulate the color appearance of normal color vision, dichromat and anomalous trichromat. In the this method, we use the spectral image data and the second stage of color vision model data to simulate the color appearance of the anomalous trichromat. To develop our simulation, we make three assumptions (Yaguchi, 2013). First, we assume that anomalous trichromats posses green-shifted or red-shifted photopigments instead of one of the normal L or M-photopigments. The degree of anomalousness is presented by amount of shift. Secondly, luminance and the red/green, yellow/blue opponent color channels are defined by the linear combination of L, M, and S cone stimulus values based on the CIE cone fundamentals (CIE, 2006). Final assumption is that the equal energy white look white for all observers including anomalous trichromats.

As a result, the spectral sensitivity functions of the luminance channel, the red/green- and the yellow/blue-opponent color channels are derived with Eqs. (6), (7) and (8), where L_{EEW} and M_{EEW} are stimulus values of the equal energy white for normal trichromats, and L'_{EEW} and M'_{EEW} are those for anomalous trichromats.

$$\bar{y}'(\lambda) = 0.6899\left(\frac{L_{EEW}}{L'_{EEW}}\right)\overline{l'}(\lambda) + 0.3483\left(\frac{M_{EEW}}{M'_{EEW}}\right)\overline{m'}(\lambda) \quad (6)$$

$$\overline{r/g'}(\lambda) = 0.8344\left(\frac{L_{EEW}}{L'_{EEW}}\right)\overline{l'}(\lambda) - 1.0260\left(\frac{M_{EEW}}{M'_{EEW}}\right)\overline{m'}(\lambda) \quad (7)$$

$$\overline{y/b'}(\lambda) = 0.8344\left(\frac{L_{EEW}}{L'_{EEW}}\right)\overline{l'}(\lambda) - 1.0260\left(\frac{M_{EEW}}{M'_{EEW}}\right)\overline{m'}(\lambda) - \overline{s'}(\lambda) \quad (8)$$

Where $\overline{l'}(\lambda)$, $\overline{m'}(\lambda)$ and $\overline{s'}(\lambda)$ are the spectral sensitivity functions of L-, M-, and S-cone, respectively for the anomalous trichromat. The luminance, Y' and the stimulus values of red/green- and the yellow/blue-opponent colour channels, $C'_{r/g}$ and $C'_{y/b}$ for the anomalous trichromats are calculated with Eqs. (9), (10) and (11).

$$Y' = \int P(\lambda)\overline{y'}(\lambda)d\lambda \quad (9)$$

$$C'_{r/g} = \int P(\lambda)\overline{r/g'}(\lambda)d\lambda \quad (10)$$

$$C'_{y/b} = \int P(\lambda)\overline{y/b'}(\lambda)d\lambda \quad (11)$$

In the above equations, $P(\lambda)$ is the spectral radiance of the stimulus.

In order to simulate the appearance of the image for anomalous trichromats for color normal observers, the luminance and the stimulus values of the opponent color channels should be converted to the XYZ tristimulus values for normal observers. Using new XYZ tristimulus values derived from the cone fundamentals of CIE170-212, notified with X_F, Y_F, Z_F called the fundamental tristimus values are transformed from the luminance and the stimulus values of the opponent-color channels with Eqs. (12), (13) and (14).

$$X_F = Y' + 1.6541C'_{r/g} - 0.3675C'_{y/b} \quad (12)$$

$$Y_F = Y' \quad (13)$$

$$Z_F = Y' - 1.9349C'_{y/b} \quad (14)$$

Finally, we can use Eqs.(4), (5), transfer equation from X_F, Y_F, Z_F to (x_F, y_F) chromaticity.

3. MEASUREMENT

First, we used the hyperspectral camera (NH-7) to take multi-spectral image data of LED signal lamps and old type signal lamps placed in a street nearby the campus of Chiba University. After calibration we obtained their spectral power distributions. Using simulation model of color appearance for anomalous trichromatic as we mentioned in the method part, we can convert the data from spectral power distribution to the (x_F, y_F) chromaticity coordinates.

4. RESULTS AND DISCUSSION

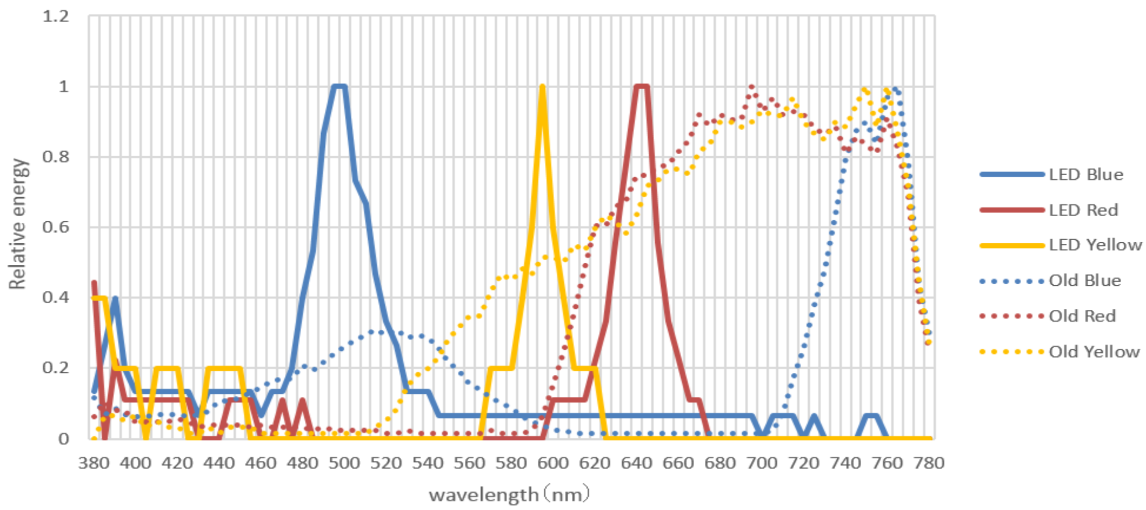

Figure 2: relative energy of LED/old signal lamp

Figure 2 show the reslut of the relative energy of LED/old signal lamp.

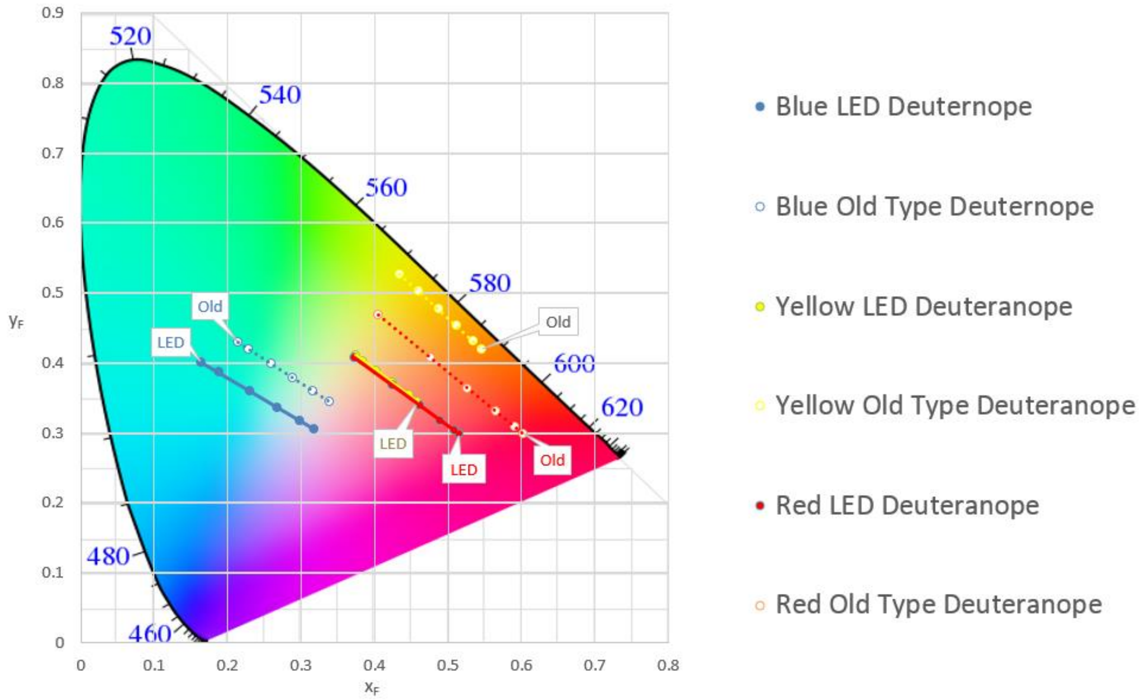

Figure 3: color simulation of Deuternope

Figure 3 shows the simulated color appearnce of deuteranope on the (x_F, y_F) chromaticity diagram. In this diagram, the point with a label is the start point which indicates the (x_F, y_F) chromaticity coordinates of normal color vision. End point is the chromaticity coordinates of the simulated color appeance of deuteranope. Points between start point and end point present deuteranope (M-100/300/500/700). "M-100/300/500/700" means that the strength of deficiency where the peak sensitivity of M-cone shits 100/300/500/700 cm^{-1} in wavenumber towards red. The locus of the red signal of LED lamp and the yellow signal of LED lamp overlap each other. It implys that deuteranope could confuse red and yellow signal of LED lamp.

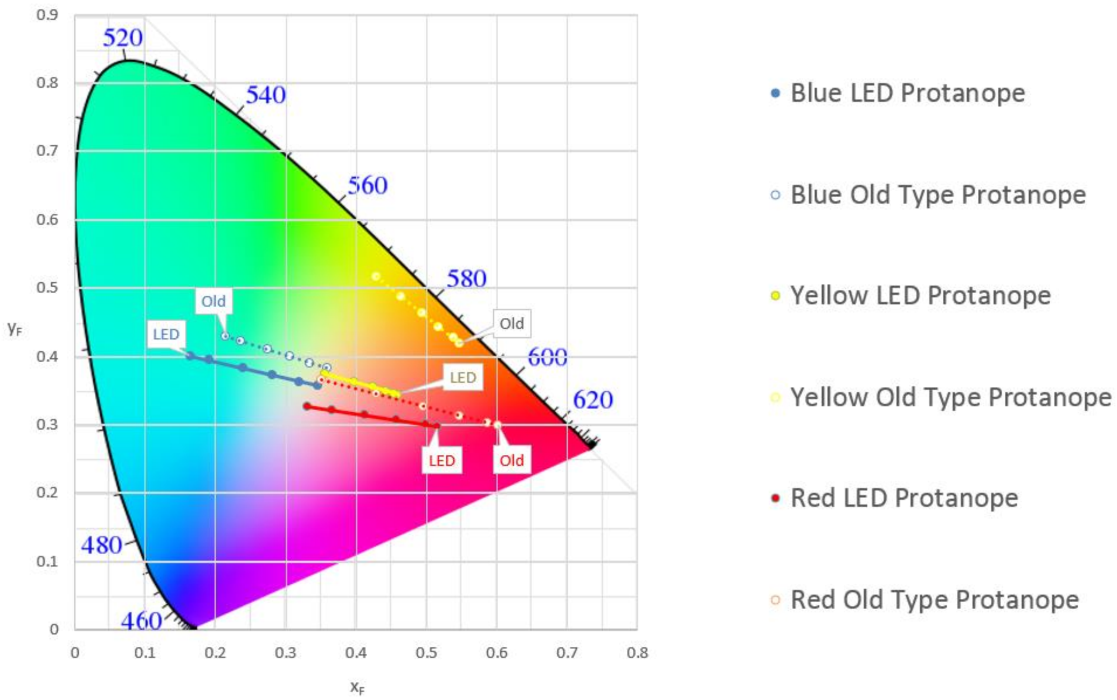

Figure 4: color simulation of Deuternope

Figure 4 shows a (x_F, y_F) chromaticity diagram of the simulated color appearance of protanope. In this diagram, the point with a label is the start point which means the (x_F, y_F) chromaticity of normal color vision. End point the simulated color appeance of protanope. Points between start point and end point present protanope (L-100/ L-300/ L-500/ L-700). "L-100/300/500/700" means the strength of deficiency where the peak sensitivity of L-cone shits 100/300/500/700 cm^{-1} in wavenumber towards green. The simulated color appeance of protanope for all signals, except for that of the old type/LED yellow signal, close each other. It implys that protanope could see the blue, red signal of LED signal lamp as similar color, and the blue and red of old signal lamp as similar color.

4. CONCLUSIONS

We constructed a system which can analyze color data from spectral data taken by a multi-spectral camera. First, uniformity of intensities and the shape of spectral distributions in an image were calibrated based on a uniform reference light. Then the CIE1931 XYZ was calculated using the obtained precise spectral distributions and the color-matching function. Although the accuracy would need to be improved, we were able to obtain chromaticity data useful for color analyses. We compared those color information and spectral distribution to analyze and simulate the color appearance of normal color vision, dichromat and anomalous trichromat based on a simulation model of color appearance for anomalous trichromat. With this model and the multi-spectral image data, we simulated the color appeance of LED and old signal lamp for the deuteranope and protanope. Our simulation suggests that anomalous trichromat could confuse some colors of traffic signal lamps. Since the multi-spectral data contains wavelength information, we can simulate other color appearance of various scenes and images not only for the abnormal color vision but also for a color vision with any individual color matching function.

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CIE 170-2: Fundamental Chromaticity Diagram with Physiological Axes - Part 2 (to be published, http://cvrl.ioo.ucl.ac.uk)

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Quality comparison of multispectral imaging systems based on real experimental data

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ABSTRACT

In this paper, we evaluate and compare the quality of three fast and practical multispectral imaging systems we proposed along with a conventional filter wheel based system. The four systems being compared are a single shot 6-band stereo camera based system, two (a 6-band and a 9-band) RGB camera and LED illumination based systems, and a 6-band filter wheel based system, for which we used a commercial SpectroCam UV-VIS system from PixelTeQ. The systems are evaluated and compared based on spectral as well as colorimetric accuracies produced by the prototype systems. Mean metric values are most commonly used to compare different multispectral imaging systems. In this paper, we propose a cumulative distribution function based measure for a more effective and consistent comparison of the systems. We believe that the quality comparison framework and the methodology provided in this paper would be useful in identifying a most appropriate technique or system for a given application.

1. INTRODUCTION

Multispectral imaging (MSI) acquires images of a scene in a limited number of narrow or somewhat wider spectral bands. The spectral reflectances of the scene are then obtained from the sensor responses using a spectral estimation method. MSI provides a simpler, faster, and cheaper solution to spectral imaging compared to hyperspectral imaging. Many different types of multispectral imaging techniques and systems have been proposed in the literature. In a conventional filter-based multispectral imaging system, either a set of traditional optical filters in a filter wheel (Martinez 1991), or a tunable filter (Hardeberg et al. 2002, Nascimento et al. 2002) in front of a monochrome camera is employed, and images of a scene are acquired with each of these filters in a sequence. Use of RGB cameras increases the acquisition speed by a factor of three (Valero et al. 2007, Yamaguchi et al. 2008). Filter array based multispectral imaging (FAMSI) (Brauers and Aach 2006, Miao and Qi 2006, Lapray et al. 2014), which is based on the extension of filter array from 3-bands in the Bayer pattern to *n* bands provides a single-shot solution, however, at the cost of spatial details because of a demosaicing step it requires for bands separation. Another promising technique of multispectral imaging is based on multiplexed LED illumination (LEDMSI) (Park et al. 2007, Parmar et al. 2012, Shrestha et al. 2012).

Even though many different multispectral imaging systems have been proposed in the literature before, the existing state of the art multispectral imaging systems were still mostly slow, complex, and expensive. Because of this their acceptance and use has been limited. We proposed several fast, practical, and inexpensive solutions such as a single-shot 6-band stereo camera based (StereoMSI) system (Shrestha et al. 2011), a single-shot filter array based (FAMSI) system (Shrestha and Hardeberg 2013), and fast LED illumination based (LEDMSI) systems using RGB cameras (RGB-LEDMSI) (Shrestha and Hardeberg 2013).

In order to identify a suitable system to be used for a given application, it is important to evaluate and compare the performance and quality of different systems. In Shrestha and Hardeberg (2014), we evaluated and compared the three major different types of fast and practical multispectral imaging techniques: StereoMSI, FAMSI, and LEDMSI systems, along with a conventional filter wheel (FWMSI) and a liquid crystal tunable filter (LCTFMSI) based systems as well as a trichromatic color camera, both qualitatively and quantitatively, using simulated systems. Quantitative evaluation was done based on spectral and colorimetric accuracies from spectral reflectance images estimated from the multi-band images acquired with the systems. In this paper, we validate the evaluation and comparison of different MSI systems through real-world experimentation using prototype systems. The systems are evaluated and compared both spectrally and colorimetrically using the root mean square (RMS) and CIE ΔE^*_{ab} metrics respectively. For a more effective and consistent comparison of the systems, we propose a new cumulative distribution function (CDF) based measure.

In Section 2, we describe the four multispectral imaging systems used in the experiments. Section 3 presents the new 95%CDF measure. We then present experimental results in Section 4 and discuss the results in Section 5. We finally conclude the paper in Section 6.

2. MULTISPECTRAL IMAGING SYSTEMS USED

We built the three prototype systems: a StereoMSI, a 6-band RGB-LEDMSI, and a 9-band RGB-LEDMSI. For a FWMSI system, we used a commercial system. The four systems and their setups are briefly described here.

- **6-band StereoMSI system**: This is a single-shot MSI system built with a Fujifilm FinePix REAL 3D W1 stereo camera, and a pair of optimal filters placed in front of the two lenses of the camera. The two filters used are XF2021 and XF2030, selected from a set of 265 filters from Omega Optical Inc. The system acquires a 6-band image of a scene in a single-shot. More details of the system can found in Shrestha et al. (2011).
- **6-band RGB-LEDMSI system**: This system is built with a Nikon D600 RGB camera, and six LEDs from JUST Normlicht (2014)'s LED ColorControl light booth. This is considered as a constrained LEDMSI case where the number of LEDs is limited to six. A 6-band image is acquired in two exposures (or shots) under two different LED combinations. Each LED combination consists of three different LEDs whose peak wavelengths lie in the three different regions (red, green, and blue) of the camera sensitivities. For the details on the spectral sensitivities of the Nikon D600 camera, the six LEDs and their spectral power distributions (SPDs) we refer to the paper Shrestha and Hardeberg (2014). Optimal LED combinations for each exposure is selected using the LED selection method we proposed in Shrestha and Hardeberg (2013). The method picked 1-3-5 and 2-4-6 as the two optimal LED combinations for the two exposures.
- **9-band RGB-LEDMSI system**: This system is also built with the same Nikon D600 camera as in the 6-band system, but using nine optimal LEDs selected from the 22 LEDs available in an iQ-LED module from Image Engineering (2014). A 9-band image is acquired in three exposures under three different LED combinations. In this case, the LED selection method picked 1-6-11, 2-8-14, and 4-7-10 as the three optimal LED

combinations for the three exposures. SPDs of the LEDs can be found in Shrestha and Hardeberg (2014).

- **6-band FWMSI system**: A commercial SpectroCam UV-VIS system from PixelTeQ (2014), with six filters in its filter wheel is used for this. The six filters used are the band pass filters with *peakwavelength*(nm)_FWHM (Full Width Half Maximum) of 425_100, 475_100, 505_50, 550_100, 615_100 and 650_100. For an improved signal-to-noise ratio (SNR), we used appropriate integration times with different filters that result in higher camera signals but without any saturated pixel. We set the exposure times to 15, 10, 30, 15, 15, and 20 milliseconds for the six filters respectively. The gain value was set to one. For the spectral sensitivity of the SpectroCam UV-VIS camera and the spectral transmittances of the six filters used, we again refer to the paper Shrestha and Hardeberg (2014).

3. CDF BASED MEASURE FOR MSI SYSTEMS COMPARISON

There are many different types of quality metrics proposed to evaluate the performance and quality of a multispectral imaging system. The root mean square (RMS) error and CIE ΔE^*_{ab} are widely used spectral and colorimetric metrics respectively. Mean of these metric values are usually used to compare two MSI systems. In this paper, we propose a cumulative distribution function (CDF) based measure as an alternative, for a more effective and consistent comparison results.

CDF describes the probability that a real-valued random variable x with a given probability distribution will be found to have a value less than or equal to a (Everitt 2006), and it is expressed as $\mathrm{CDF}(x,a) = \mathrm{P}(x \le a)$, where $\mathrm{P}(x \le a)$ denotes the probability of x to be less than or equal to a. In our context, we can assume any estimation error such as RMS and ΔE^*_{ab} in each pixel of a scene as a random variable. CDF can be plotted with an evaluation metric value along the *x*-axis and the CDF (or percentage count) along the *y*-axis as illustrated in Figure 1.

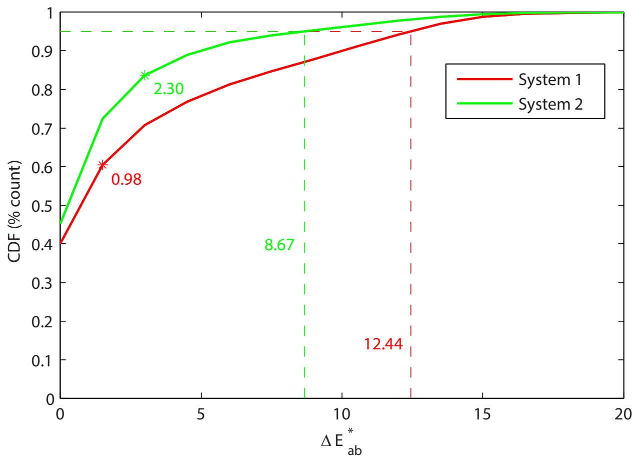


Figure 1: 95%CDF vs. mean metric values

In the illustration, two systems have mean ΔE^*_{ab} values of 0.978 and 2.295, indicating that System 1 is better than System 2. However, if we look at the CDF curves, we see that 95% of pixels produce ΔE^*_{ab} of 12.44 or less with the System 1, while the same number of pixels produces ΔE^*_{ab} of 8.67 or less with the System 2. In this aspect, the latter is much better than the former. Since CDF measure is more practical than the mean values, we propose this as a new measure for the comparison of any two MSI systems. By setting a CDF percentage count required to τ%, we can determine the corresponding metric value from the CDF, which we call it as τ%CDF. Since 95% is considered as a reasonably good value in statistics, we use 95%CDF in our experiments.

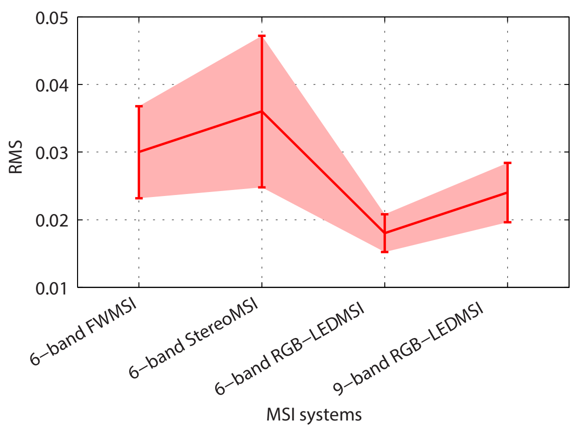
4. EXPERIMENTAL RESULTS

Multi-band images of a Macbeth ColorChecker DC (MCCDC) and a classic (MCC) are acquired with all the four systems. Spectral reflectances of the 24 MCC patches are estimated from the multi-band images, using Wiener spectral estimation method (Haneishi et al. 2000). For this, sixty-two patches from the MCCDC, selected based on the significant target selection method proposed by Hardeberg et al. (1998) are used for calibrating the system. Based on the estimated spectral reflectances from the four systems, they are evaluated and compared using both the mean and 95%CDF values corresponding to the spectral (RMS) and colorimetric (ΔE^*_{ab}) metrics.

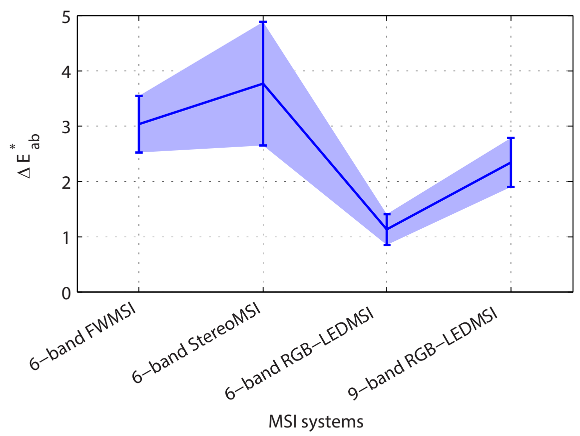
Statistics of spectral and colorimetric estimation errors is given in Table 1. Figure 2 shows standard error plots with the bounds of the 95% confidence intervals, which shows statistical significance of the RMS and ΔE^*_{ab} estimations. Histograms and CDF plots for the RMS and ΔE^*_{ab} errors are given in Figure 3. From the table and the CDF plots, we see that the 6-band RGB-LEDMSI performs the best both spectrally and colorimetrically, with 95%CDF for RMS and ΔE^*_{ab} values of 0.03 and 1.95 respectively. The 9-band RGB-LEDMSI comes next, then the 6-band FWMSI system, and lastly the StereoMSI system. The error plots show the similar performance trends both in terms of the spectral and colorimetric estimations.

Table 1. Statistics of the spectral and color estimation errors produced by the four MSI systems.

MSI System	RMS				ΔE^*_{ab}			
	Max.	Mean	Std.	95% CDF	Max.	Mean	Std.	95% CDF
6-band FWMSI	0.067	0.030	0.017	0.059	6.100	3.041	1.280	5.400
6-band StereoMSI	0.112	0.036	0.028	0.080	9.609	3.769	2.796	7.900
6-band RGB-LEDMSI (JUST LED)	0.037	0.018	0.007	0.029	3.021	1.130	0.691	1.950
9-band RGB-LEDMSI (iQ-LED)	0.064	0.024	0.011	0.035	5.607	2.344	1.108	3.900



(a) RMS

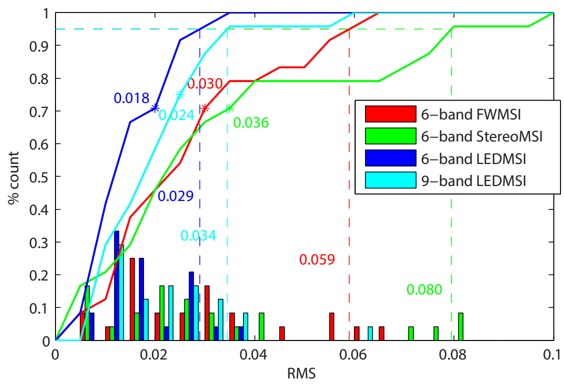


(b) ΔE^*_{ab}

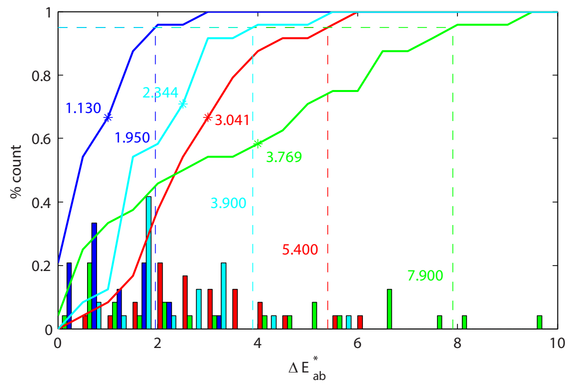
Figure 2: Standard error plots for the four prototype MSI systems.

5. DISCUSSION

Standard error plots showed that the performance of the single-shot 6-band StereoMSI system is comparable to the traditional 6-band FWMSI system, indicating its feasibility. It is to be noted here that the stereo camera used had a minimum control on the internal processing in the imaging workflow, such as white balancing, demosaicing, etc. We can anticipate significantly improved results from a fully controllable camera.



(a) RMS



(b) ΔE^*_{ab}

Figure 3: Histograms and CDFs produced by the four MSI systems for the MCC target. Mean values are shown and marked with ''. 95%CDF lines (vertical dotted) and values are also shown.*

The 6-band RGB-LEDMSI has shown to perform better than the other three systems both spectrally and colorimetrically. The decreased performance of the 9-band RGB-LEDMSI system indicates that just increasing the number of LEDs (or bands) does not always lead to an improved performance. This is in line with the conclusion of our paper Shrestha and Hardeberg (2014), where we studied various factors influencing the performance of a LEDMSI system. Influence of noise increases with the increase in the number of bands. Moreover, increase in the number of bands does not always lead to capturing of significantly new information; and in such case, we cannot anticipate a better performance. This depends on the choice of LEDs. If we had a freedom of choosing from a large number of LEDs, and in the ideal case, with equal intensities uniformly spreading along the spectrum, we can anticipate some improvement in the results. Looking at the effective channel sensitivities of the two LEDMSI systems, we find much overlaps in the channels in the 9-band RGB-LEDMSI systems; while in the case of the 6-band RGB-LEDMSI system, the channels were reasonably well separated. Because of this, even though having three more bands, the 9-band system may not capture much new information, but suffers from more noise influence. Moreover, the illumination levels of the JUST LEDs were quite high, while that of the iQ-LED modules were weak and we had to increase integration times by increasing the camera shutter speed. This seemed to introduce more noise in the camera responses, and this might have had an effect on the performance of the system. By addressing these issues, performance of the 9-band RGB-LEDMSI system could probably be improved.

6. CONCLUSION

The proposed 95%CDF measure has shown to be an effective and consistent alternative to the most commonly used mean metric values for comparing any two multispectral imaging systems. The experimental results from the quality evaluation and comparison of the four MSI systems showed that the 6-band RGB-LEDMSI system performed the best producing the lowest 95%CDF values for both the RMS and ΔE^*_{ab}. StereoMSI provides a single-shot solution with the quality comparable to a classic 6-band FWMSI system. Increasing the number of bands does not always produce better results, but requires dealing with the other influencing factors such as noise, parameter selection etc. appropriately.

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LED-based gonio-hyperspectral system for the analysis of automotive paintings

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ABSTRACT

The potential of goniochromatic pigments is being widely exploited in several industries. One clear example is the automotive sector. In order to evaluate specific colorimetric features of these pigments, commercial gonio-spectrometers have been recently developed such as the BYK-mac®, the X-Rite MA98® and the Datacolor FX10®. With the same purpose, gonio-spectral imaging systems can be very useful as they provide spectral information with high spatial resolution from a large area overcoming some of the limitations of the commercial systems currently used. A novel gonio-hyperspectral imaging system based on light-emitting diodes (LEDs) is presented in this work. The proposed device is composed by two motorized rotation stages, two digital cameras and a LED-based light source that includes a linear actuator. The imaging set includes a visible CCD camera with enhanced sensitivity in the ultraviolet region of the spectrum and an InGaAs camera covering the near-infrared range. The light source consists of 29 different kinds of LEDs from 365nm to 1300nm. White LEDs were also incorporated to analyse texture descriptors used in the automotive sector. The geometries shared by the BYK-mac® and the X-Rite MA98® were evaluated (45ºx:-60º, 45ºx:-30º, 45ºx:-20º, 45ºx:0º, 45ºx:30º and 45ºx:65º) to compare their results with those obtained with the proposed system in terms of CIE L*a*b* coordinates. As a first approach, three samples of real automotive paintings were analised: one solid, one metallic and one pearlescent. The results of this study show the usefulness of the developed system in the assessment of colorimetric features of coatings containing goniochromatic pigments with a high spatial resolution.

1. INTRODUCTION

In the last decades, the automotive sector is widely using goniochromatic or effect pigments for any kind of car painting. The result is that, nowadays, 80% of the automotive finishes are effect coatings. These kind of pigments are divided in two categories: metallic pigments, which mainly show variations in lightness; and pearlescent pigments, which exhibit hue and chroma shifts as a function of the illumination and/or observation angle (Maile 2005; Pfaff 2008).

Commercial gonio-spectrophotometers have been recently launched to cover the need of characterising these particular coatings such as the BYK-mac®, the X-Rite MA98® and the Datacolor FX10®. Even though these devices offer very accurate colorimetric information, they only evaluate integrated information from a relatively small area over the sample. This fact can be considered a limitation, especially when dealing with materials that change their appearance all over the sample depending on how they are illuminated and observed. To overcome this, we propose a LED-based gonio-hyperspectral imaging system that guarantees the colorimetric evaluation of the appearance and the spatial distribution of it along an extended area pixel by pixel. As a first step, the goal of this work is to demonstrate that the developed system allows obtaining similar colorimetric results to those provided by commercial gonio-spectrometers when analysing a central area of the acquired image.

2. METHOD

2.1 Setup

The proposed LED-based gonio-hyperspectral imaging system consists of two motorized rotation stages, two digital cameras and a light source based on LEDs (Figure 1). One of the rotation stages (8MR151-30; STANDA, Lithuania) controls the angle of illumination by rotating the sample with respect to the light source while the other stage (8MR191-30-28; STANDA, Lithuania) controls the observation angle by moving the arm that supports the cameras. The system includes two monochromatic cameras, one visible CCD camera (CM-140GE-UV; JAI, Japan) with enhanced sensitivity in the ultraviolet range of the spectrum (200nm – 1000nm) and an InGaAs camera (C10633-13; HAMAMATSU, Japan) that covers the near-infrared range (900nm – 1700nm). The resolution of the visible camera is 1392x1040 pixels while that of the near-infrared camera is of 320x256 pixels. The illumination set includes 29 different groups of LEDs, a linear actuator (ZLW-0630-02-B-60-L-1000; IGUS, Germany) that holds the LED board and allows changing from one spectral channel to the next one and a collimating lens. The light source is constituted by 28 different spectral channels with peak wavelengths from 365nm to 1300nm (370, 395, 410, 448, 470, 490, 505, 530, 568, 590, 617, 627, 655, 670, 690, 700, 720, 735, 750, 770, 810, 850, 870, 940, 970, 1020, 1050 and 1300 nm). Moreover, the light source also incorporates white LEDs which are intended for the evaluation of texture descriptors such as sparkle, graininess and mottling. They are also used in the automotive industry to describe appearance of coatings besides colorimetric features.

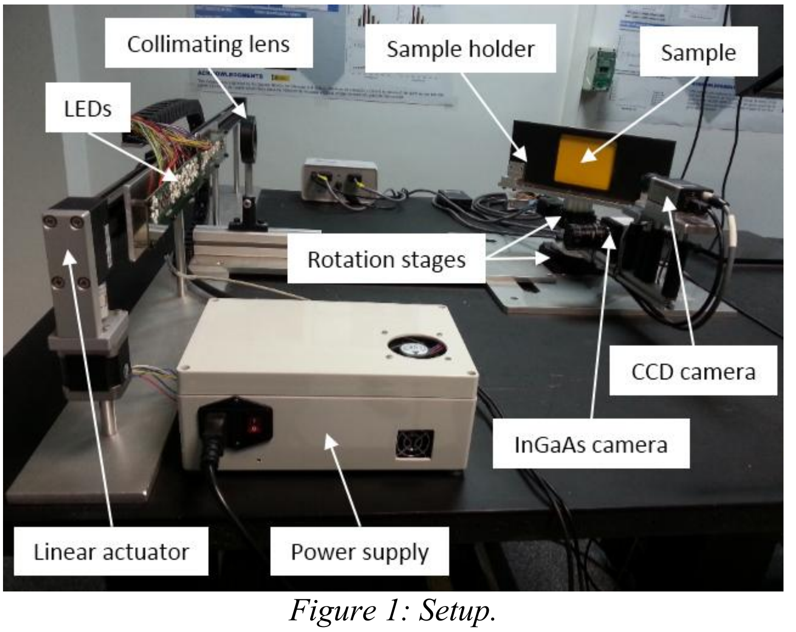


Figure 1: Setup.

2.2 Experimental Procedure

Three different samples were analyzed: one solid, one metallic and one pearlescent plates. Each one was measured at six different geometries: 45ºx:-60º, 45ºx:-30º, 45ºx:-20º, 45ºx:0º, 45ºx:30º and 45ºx:65º (Figure 2). The illumination direction was fixed at 45º from the normal direction of the sample while the observation arm was situated at six different positions with respect to the normal (-60º, -30º, -20º, 0º, 30º, 65º). These geometries were chosen because they are the angular positions that the BYK-mac® and the X-Rite MA98® share, thus allowing for a more accurate comparison of the results.

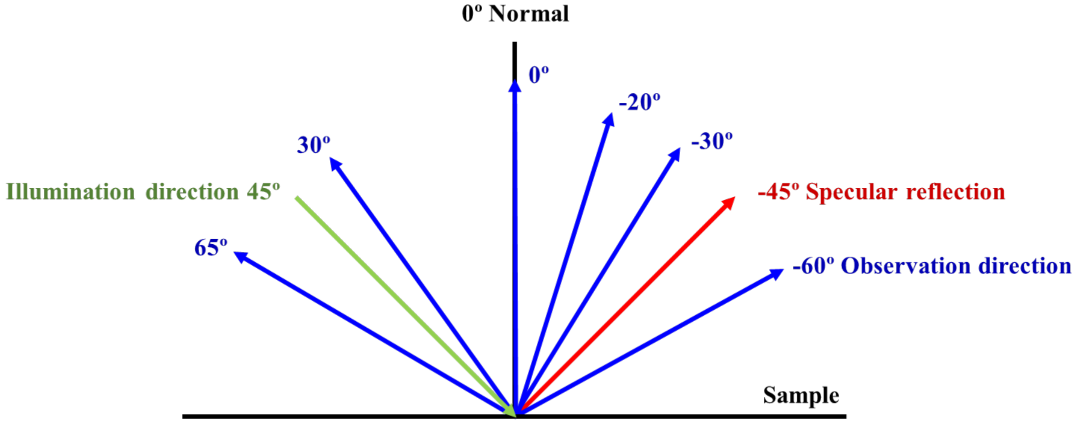


Figure 2: Measurement geometries (45ºx:-60º, 45ºx:-30º, 45ºx:-20º, 45ºx:0º, 45ºx:30º and 45ºx:65º).

2.3 Image and Colour Analysis

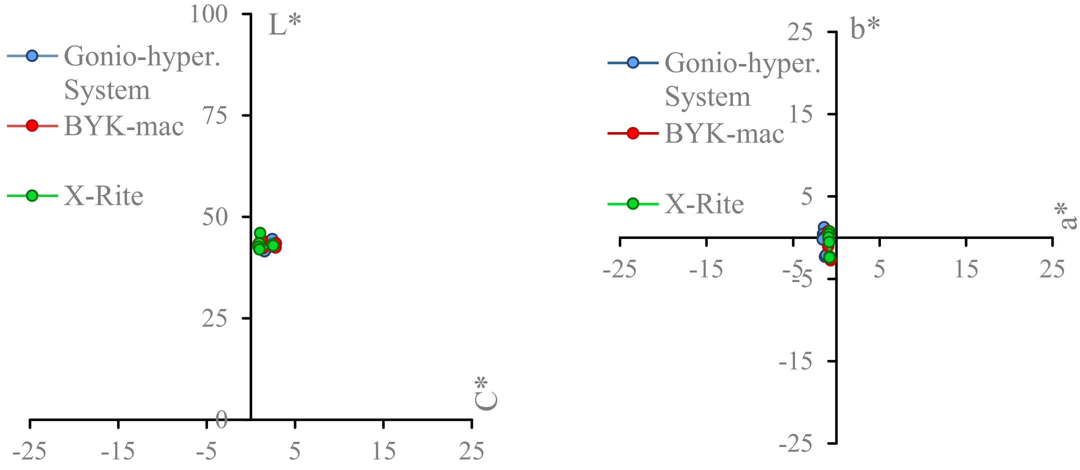
At each geometry and for each spectral channel, 10 images were captured and lately averaged to reduce noise. In addition, the following formula was applied to obtain the reflectance of each pixel of the image at a certain wavelength:

$$r(i,j) = c \cdot \frac{DL_I(i.j) - DL_{DC}(i.j)}{DL_W(i.j) - DL_{DC}(i.j)}, \qquad (1)$$

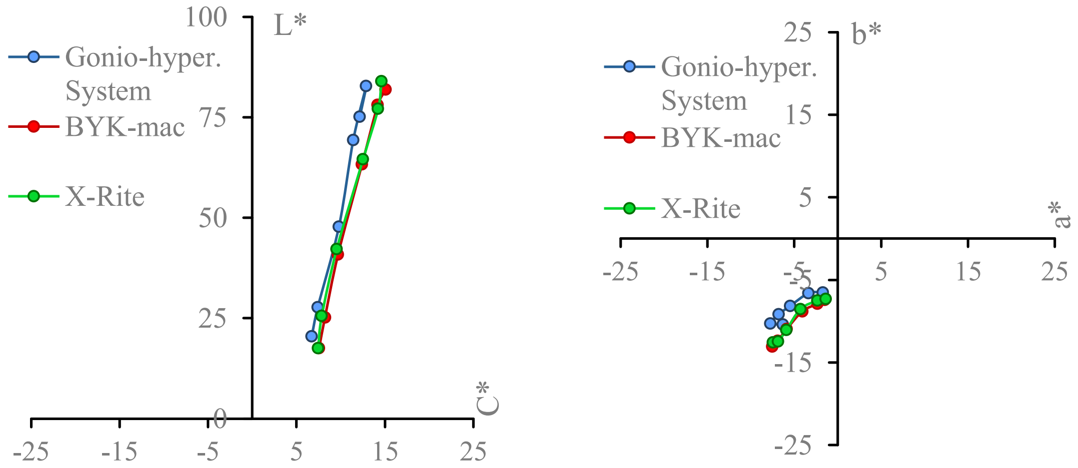
where $r(i,j)$ is the reflectance corresponding to a pixel, $DL_I(i,j)$, $DL_W(i,j)$ and $DL_{DC}(i,j)$ are the digital levels of the raw image, the reference white and the dark current, respectively, and c is the reflectance value of the calibrated reference white (BN-R98-SQ10C; GIGAHERTZ OPTIK, Germany).

Secondly, the tristimulus values XYZ CIE-1964 were computed based on the reflectance spectra from 400nm to 700nm (Nassau 1997). Posteriorly, the CIE L*a*b* coordinates were calculated for the illuminant D65 (Nassau 1997) and compared with those provided by the commercial gonio-spectrometers BYK-mac® and X-Rite MA98® in terms of colour differences (ΔE, CIELAB1976).

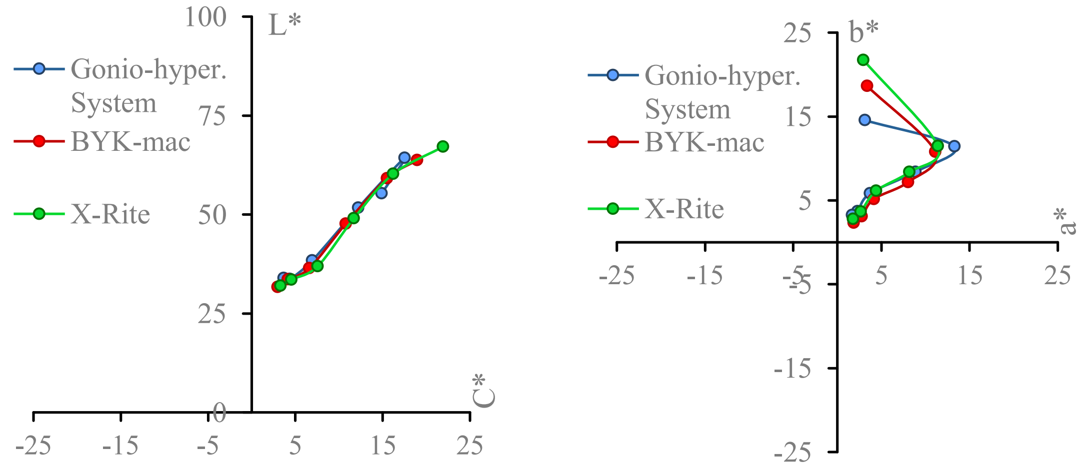
3. RESULTS AND DISCUSSION



(a)



(b)



(c)

Figure 3: CIELAB diagrams of the solid (a), metallic (b) and pearlescent sample (c) for the three devices tested.

Figure 3 shows the colorimetric behavior of three samples (solid, metallic and pearlescent) measured with the BYK-mac®, the X-Rite MA98® and the proposed system. As expected, the solid sample (Figure 3 (a)) exhibited very small variations in L^*, a^*, b^* and C^* ($C^* = \sqrt{(a^*)^2 + (b^*)^2}$) since solid pigments have similar appearance at any direction. Nevertheless, metallic (Figure 3(b)) and pearlescent (Figure 3(c)) samples did behave different as a function of the observation angle. On one hand, the metallic sample experienced the largest changes in L^* parameter, while for C^*, a^* and b^* the variation was very small. The pearlescent sample was characterised by greater shifts in C^*, a^* and b^* parameters rather than in L^*. The three samples showed similar colorimetric performance for the three devices tested.

Table 1 contains the color differences between the CIE L*a*b* parameters obtained with the system and those measured with the BYK-mac® and the X-Rite MA98® gonio-spectrophotometers. The lowest color differences were found for the solid sample with differences of less than four units and rather constant along the different geometries. In the case of the metallic and pearlescent samples, the colour difference values varied depending on the measurement geometry. The highest values were found in those positions closer to the specular reflection (45ºx:-60º, 45ºx:-30º and 45ºx:-20º), reaching values up to 13 ΔE units. In spite of this, at the geometries further to the specular reflection (45ºx:0º, 45ºx:30º and 45ºx:65º) colour differences notably decreased becoming in some cases very small.

Table 1. CIELAB color differences (ΔE, CIE1976) when comparing the gonio-hyperspectral imaging system and the commercial devices for the solid (S), metallic (M) and pearlescent (P) samples.

Sample	ΔE	45ºx:-60º	45ºx:-30º	45ºx:-20º	45ºx:0º	45ºx:30º	45ºx:65º
S	BYK-mac	2.36	0.98	1.28	1.28	0.89	2.14
	X-Rite	3.85	0.98	1.18	0.92	0.58	1.64
M	BYK-mac	7.45	5.18	6.41	7.07	2.97	3.09
	X-Rite	9.24	6.08	5.24	5.65	2.54	3.09
P	BYK-mac	9.34	5.61	4.32	2.11	0.79	2.44
	X-Rite	13.82	4.44	2.78	1.66	0.40	2.00

4. CONCLUSIONS

A LED-based gonio-hyperspectral imaging system for the analysis of automotive paintings has been presented. This system showed a good colorimetric performance similar to that of the BYK-mac® and the X-Rite MA98® commercial gonio-spectrophotometers, in particular for solid pigments. Future work will be focused on diminishing the differences that the system exhibited in comparison with the commercial devices when dealing with goniochromatic pigments. However, preliminary results are already promising. In addition, texture descriptors will be also developed.

ACKNOWLEDGEMENTS

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Multispectral image estimation from RGB image based on digital watermarking

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ABSTRACT

In this paper, we propose a method of embedding the spectral information in an RGB image by the digital watermarking. The proposed method divides the multispectral image into two components before embedding: RGB image and residual. The RGB image is extracted from the multispectral image by using the XYZ color matching functions and a color conversion matrix. The original multispectral image is estimated from the RGB image by Wiener estimation, and the difference between the original and the estimated multispectral image is referred to as the residual. In our method, the estimated spectral residual data are compressed by JPEG2000 and embedded in the lower bit planes of the RGB image. The experimental results show that the proposed method leads to more than 10 dB gain relative to conventional methods in the peak signal-to-noise ratio comparison of recovered multispectral image while there are almost no significant perceptual differences in the watermarked RGB image. The experimental results show that the proposed method can improve the quality of the recovered multispectral image at the expense of a slight degradation in RGB image quality.

1. INTRODUCTION

Multispectral images (MSIs) have been studied for many fields such as remote sensing and medical applications. MSIs have been used for not only analysis applications, but also the color reproduction of RGB images under a different illumination (Yamaguchi et al. 2008). Converting MSI into RGB image is needed to display MSIs, therefore RGB format is essential for the field of computer graphics. Additionally, most of widely used formats in computer graphics are based on RGB. However, converting MSI to RGB image cuts spectral information except for visible components. In the color reproduction of RGB images, estimating of object spectrum is required and has been studied in some literature (Haneishi et al. 2000, Stigell et al. 2007, and Murakami et al. 2013). Converting MSI into RGB image will be required in some systems because the low-dimensional image such as RGB images can be utilized easily in the current imaging system, but it is difficult to recover the original spectra once it is converted.

The conventional spectral reconstruction methods can be separated into two types: estimate/reconstruct spectrum with additional data (Keusen 1996, Yu et al 2006, Shinoda et al. 2011, and Murakami et al. 2013), or without additional data (Haneishi et al. 2000 and Stigell et al. 2007). A high-dimensional signal can be estimated from a low-dimensional one more accurately if additional data is available, but the whole data structure becomes less compatibility with conventional sRGB systems. An efficient spectral estimation method while maintaining the conventional data structure such as a sRGB image has not yet been proposed.

We propose a new spectral estimation method using a digital watermarking by embedding additional spectral information into an RGB image. The RGB image is calculated from an original MSI, and then the original MSI is estimated from only the RGB image in the embedding side. The residual of the estimation is compressed and embedded into the lower bit planes of the RGB image. This watermarked image can be used as an RGB image without any knowledge about spectrum. If reconstruction of the spectrum is required in an application, the compressed residual data is extracted from the lower bit planes of the RGB image, and then the estimated MSI from RGB image can be corrected by the extracted residual data.

This paper is organized as follows. Our compression method is presented in Section 2. The results are given in Section 3. In Section 4, we conclude this paper.

2. RGB DIGITAL WATERMARKING FOR MSI ESTIMATION

The embedding and reconstructing flow of the proposed method is shown in Figures 1 and 2. In the embedding side, an original MSI is converted to an RGB image, then the lower bit planes of the RGB image are used for digital watermarking. At first, the RGB image is calculated from the original MSI by using the CIE XYZ color matching functions under the standard illuminant D65, and sRGB color space. Let $\boldsymbol{f}$ be a spectrum (MSI is regarded as a spectral reflectance in this paper), and $\boldsymbol{g}$ be RGB values. $\boldsymbol{g}$ is calculated as

$$\boldsymbol{g} = \boldsymbol{CTEf} = \boldsymbol{Hf}\,, \tag{1}$$

where $\boldsymbol{C}$ is the XYZ-to-RGB color transform matrix of sRGB, $\boldsymbol{T}$ is the CIE XYZ color matching functions, and $\boldsymbol{E}$ is the standard illuminant. The spatial position (x, y) is ignored in this paper because each pixel is processed independently. The lower n-bit planes of the obtained RGB image are then filled with zero at this stage for digital watermarking, and the truncated RGB image is defined as $\boldsymbol{g}'$. An MSI is estimated from the obtained RGB by using Wiener estimation. The Wiener estimation from $\boldsymbol{g}'$ to $\boldsymbol{f}'$ is defined as

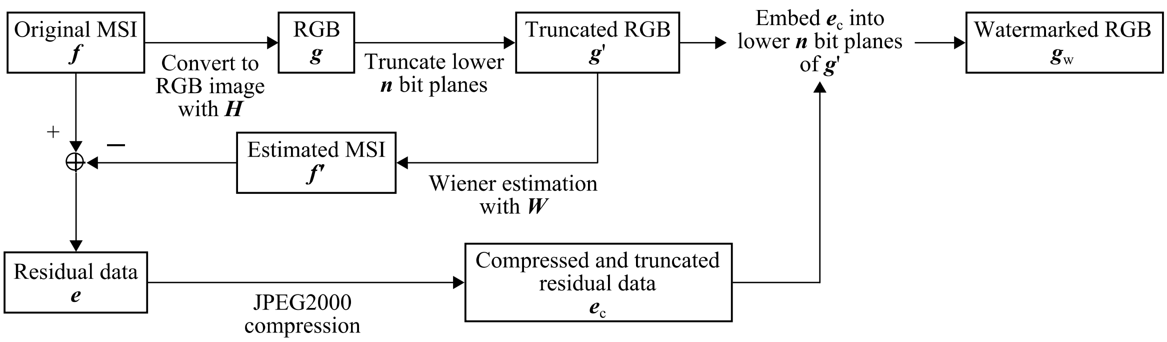

Figure 1: Proposed embedding process.

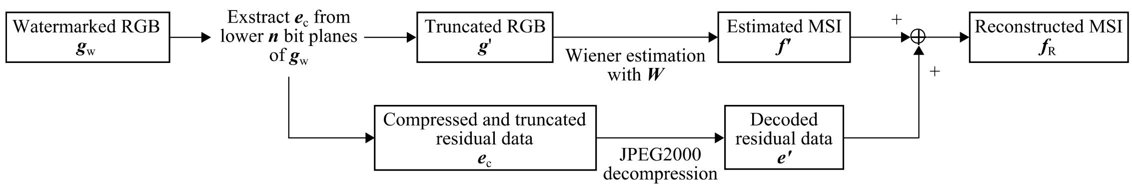

Figure 2: Proposed reconstructing process.

$$f' = Wg' \tag{2}$$

$$W = R_f H^T (H R_f H^T)^{-1}, \tag{3}$$

where W is a Wiener estimation matrix, and R_f is the autocorrelation matrix of f.

A residual spectral data can be obtained as

$$e = f - f'. \tag{4}$$

The obtained residual data is compressed by JPEG2000 with multi-component transform (JPEG2000-MCT) lossy mode with Karhunen-Loeve transform (KLT), and the truncated lossy code-stream is defined as e'. Here, if M is the total number of pixels of the RGB image, the compressed residual data is truncated into $M \times n$ bits before embedding. The compressed residual data is embedded into the lower n-bit planes of g'.

The reconstructing process is an inverse process of the embedding side as shown in Figure 2. The compressed residual data is extracted from the watermarked RGB image and is decoded by JPEG2000-MCT. The lower n-bit planes of the RGB image are filled with zero, then an MSI is estimated from the RGB image. This estimation process is completely the same as Eqs. (2) and (3). The reconstructed MSI can be obtained by adding the decoded residual data to the estimated MSI from RGB image.

The quality of the watermarked RGB image is slightly degraded because it has random bits in the lower n-bit planes, but the degradation can be suppressed as n is decreased. On the other hand, if n is increased, the reconstructed MSI quality is improved whereas the RGB image quality is decreased. The relation between the quality of RGB and MSI is thought to be trade-off. However, this is not always a completely trade-off because the estimated MSI quality from the RGB image is improved as n is decreased. The results and trade-off are discussed in Section 3.

3. RESULTS AND DISCUSSION

In this section, we show the peak signal-to-noise ratio (PSNR) of both watermarked RGB images and reconstructed MSIs. Figure 3 shows test images that consist of 512×512 pixels, 8 bits / pixel with 16 bands. The images were captured with a camera (Fukuda, 2002) equipped with 16-band filters. The residual data is encoded by using Jasper (Adams, 2015) with 9/7 real wavelet transform. The embedded information includes not only the compressed residual data but also the coefficients of the Wiener estimation matrix.

(a) (b)

Figure 3: Test images with 512×512 pixels, 12 bits / pixel, and 16 bands. (a) Dishes (b) Toys.

Table 1. Comparison of reconstructed MSI and watermarked RGB PSNRs in dB..

Embedded planes	*Dishes*		*Toys*	
n	MSI	RGB	MSI	RGB
0	33.65	Inf.	27.73	Inf.
1	44.76	51.14	47.50	51.14
2	45.52	44.13	47.72	44.03
3	45.39	37.89	46.93	37.74
4	45.63	31.85	46.42	31.63
5	46.71	25.83	47.55	25.66
6	47.62	19.37	49.14	19.56
7	48.58	14.23	49.87	14.33

Table 1 shows the PSNR of watermarked RGB images and reconstructed MSIs depending on n. We also show the PSNR of the reconstructed MSI at $n = 0$, which corresponds to using only Wiener estimation. In $n = 1$, the PSNR of MSI shows over 40 dB while maintaining over 50 dB in RGB image. The proposed method shows the greatly higher PSNR of MSI than Wiener estimation while maintaining no perceived difference in RGB images.

It is thought that the relation of the image quality between reconstructed MSI and watermarked RGB is a trade-off, but note that there is an exception. Although the PSNR of MSI is larger when n is larger, we can see the degradation of the reconstructed PSNR at $n = 3$, 4 and 5 in *Toys* image. In this case, $n = 3$ to 5 is not a reasonable choice to obtain the balanced MSI and RGB images, therefore one of the trade-off point considering both MSI and RGB images is $n = 2$ in *Toys* image. This breakpoint depends on a test image, but the proposed method can decide an appropriate n at the embedding side because we can calculate the MSI and RGB PSNRs in the embedding side.

4. CONCLUSIONS

We proposed a new spectral estimation method using a watermarked RGB image. The proposed method embeds the estimation residual information of MSI into the lower bit planes of RGB image. The quality relation between MSI and RGB images is trade-off depending on the amount of the embedding residual data, but the perceived difference of the watermarked RGB image is not significant while maintaining higher MSI quality than Wiener estimation. Additionally, the proposed method can adjust the quality of MSI and RGB by changing the embedding amount. The future work is to give a compression tolerance to the watermarked RGB.

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Image Correction for a Multispectral Imaging System Using Interference Filters and Its Application

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ABSTRACT

The present paper proposes a calibration method of a multispectral camera system using interference filters. A spectral image processing is effective to acquire an inherent information of an object in a general way. However, filter registration error often occurs when the interference filter is used. Therefore, a calibration method is presented for correcting observed images. The method is based on the phase analysis of images in Fourier domain. We use the phase correlation method for cariblating the registration error. Moreover, we describe a method for digital archiving of art paintings based the present imaging system.

1. INTRODUCTION

A multispectral imaging system can improve color accuracy in the captured images, compared with a general RGB camera system. Also the system makes it possible to estimate important surface properties such as spectral reflectance at each pixel point of an object surface. Therefore, a variety of multispectral camera/imaging systems have been proposed for the purpose of estimating spectral information such as spectral radiance in a scene and surface-spectral reflectance of an object. Some typical systems are constructed by using one or two additional color filters to a trichromatic digital camera (F.H. Imai, et al. 1999), combining a monochrome camera and color filters with different spectral bands (S. Tominaga, et al. 2007), using narrow band interference filters (S. Nishi, et al. 2011), or using a liquid-crystal tunable (LCT) filter. However, these imaging systems have several problems such as the stability of filtration, the accuracy of spectral estimation, and the time consumption for filter change. Therefore, these systems have advantages and disadvantages.

The present multispectral camera system is decomposed into two parts of a filtration system of an automatic filter changer and eight interference filters and a monochrome CCD camera system. This imaging system has an advantage of narrow band filtering, therefore it is excellent in the stability and the accuracy of spectral estimation. However, filter registration errors often occurr because it is difficult to optically align the filters with different indices of diffraction. These registration errors are called a longitudinal aberration and transverse aberration. Some calibration techniques for registration error have been proposed so far (J. Brauers, et al. 2008) (A. Mansouri, et al. 2005). In this research, we examine the calibration method that targets the transverse aberration. In addition, there is another factor to make calibration processing difficult. An image acquired by a multiband imaging system are different from the one acquired by a RGB camera. Namely, the pixel value is obviously different in each band images even if it takes a picture of the same scene. Therefore, it is difficult to correct a registration error between images using a general correlation technique.

In this paper we proposed a calibration method for the registration error caused by the interference filters. This method is easily applied to the digital archiving. In the following, we first describe an imaging system. Second a calibration method is presented for correcting observed images with the filter registration error. Third, we describe a method for digital archiving of art paintings based the present imaging system. Multispectral images of an oil painting are acquired using the imaging system, and the properties of the painting surfaces are estimated from the observed images. Moreover realistic images of the painting are rendered under arbitrary conditions of viewing and illumination. Finally, the feasibility of the proposed system is shown in experiments using real painting objects.

2. SPECTRAL IMAGING SYSTEM

Figure 1 shows the present imaging system. Our multiband camera system is composed of a monochrome CCD camera (Toshiba Teli CS3920), a C mount lens, an automatic filter changer, and eight interference filters whose central wavelengths are 420, 450, 490, 530, 570, 610, 650, and 670 nm. The full width at half maximum of filtration is about 10 nm. Figure 2 shows the composite spectral sensitivity functions for eight sensors. The CCD outputs are band-pass signals in the visible wavelength range, and they are finally integrated. The interference filter utilizes the interference effect of light occurred by a dielectric material and a metal thin film. It has the property that the spectral transmission characteristics depend on the index of refraction and the incidence angle. Moreover, note that the inner metal thin films are not always parallel to the incidence plane and the output plane. It can be considered that the registration error occurs in the acquired images for these reasons. Therefore, calibration is necessary to correct the registration error.

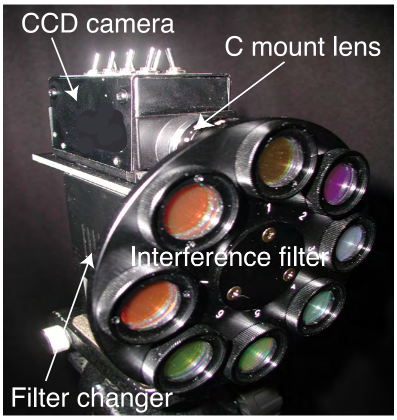


Figure 1: Imaging system.

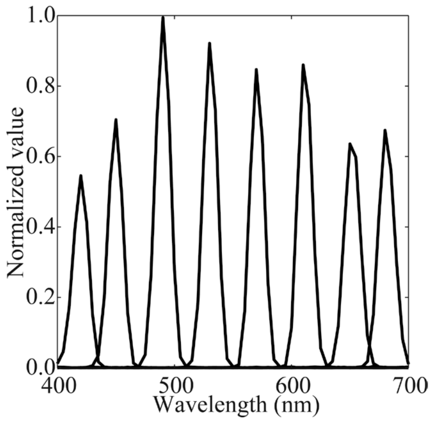


Figure 2: Spectral sensitivities of the imaging system.

3. CALIBRATION METHOD

The registration error is found when the spectral images captured with different wavelengths are aligned and superimposed. For instance, suppose that we take a picture of an object in a scene. The object images projected onto a focal plane are slightly shifted by passing through the filters. The alignment and focusing do only once with an arbitrary filter channel for the convenience of the experiment, and the adjustments are not done at all afterwards. Therefore, one of eight images is selected as a reference image and the remaining seven images are corrected as target images.

It is well known that an image acquired by a multiband imaging system is different from the one acquired by a RGB camera. That is to say, the pixel value is obviously different in each band images even if it takes a picture of the same scene. Therefore, it is difficult to correct a registration error between images using a general correlation technique. Therefore, we propose novel correlation method using phase images of each multiband image. A phase image is an image that normalizes an amplitude spectrum of an image by one. A phase correlation method (C. D. Kuglin, et al. 1975) is a technique for calculating the correlation by using the phase image. As previously mentioned, the amplitude spectrum of a spectral image is different in each acquisition band. Therefore, the proposal method can expect to correct without influence of the different amplitude spectrum in each image.

Here, let both $f(n_1, n_2)$ and $g(n_1, n_2)$ be $N_1 \times N_2$ images. Let $F(k_1, k_2)$ and $G(k_1, k_2)$ be the 2D discrete Fourier transforms of the image $f(n_1, n_2)$ and $g(n_1, n_2)$ respectively. Therefore, $F(k_1, k_2)$ and $G(k_1, k_2)$ are defined as

$$F\left(k_1,k_2\right) = \sum_{n_1,n_2} f\left(n_1,n_2\right) W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2} = A_F\left(k_1,k_2\right)\exp\left[j\theta_F\left(k_1,k_2\right)\right], \tag{1}$$

$$G\left(k_1,k_2\right) = \sum_{n_1,n_2} g\left(n_1,n_2\right) W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2} = A_G\left(k_1,k_2\right)\exp\left[j\theta_G\left(k_1,k_2\right)\right], \tag{2}$$

where k_1 and k_2 are the discrete Fourier index, and $W_{N1} = \exp[-j(2\pi / N_1)]$, $W_{N2} = \exp[-j(2\pi / N_2)]$. $A_F(k_1, k_2)$ and $A_G(k_1, k_2)$ are amplitude components, and $\theta_F(k_1, k_2)$ and $\theta_G(k_1, k_2)$ are phase components. The phase image of image $f(n_1, n_2)$ is defined as

$$f_p\left(n_1,n_2\right) = FT^{-1}\left[\frac{F\left(k_1,k_2\right)}{\left|F\left(k_1,k_2\right)\right|}\right], \tag{3}$$

where $f_p(n_1, n_2)$ is the phase image, and FT^{-1} is the 2D inverse discrete Fourier transforms. The cross spectrum $C(k_1, k_2)$ between $F(k_1, k_2)$ and $G(k_1, k_2)$ is defined as

$$C\left(k_1,k_2\right) = F\left(k_1,k_2\right)\overline{G\left(k_1,k_2\right)} = A_F\left(k_1,k_2\right)A_G\left(k_1,k_2\right)\exp\left[j\theta\left(k_1,k_2\right)\right], \tag{4}$$

where $\overline{G(k_1,k_2)}$ represents the complex conjugate of $G(k_1, k_2)$, and $\theta(k_1, k_2) = \theta_F(k_1, k_2) - \theta_G(k_1, k_2)$, it represents the phase difference spectrum. Therefore, the cross correlation using the phase image is defined as

$$C\left(k_1,k_2\right) = \frac{F\left(k_1,k_2\right)\overline{G\left(k_1,k_2\right)}}{\left|F\left(k_1,k_2\right)\right|\left|\overline{G\left(k_1,k_2\right)}\right|} = \exp\left[j\theta\left(k_1,k_2\right)\right]. \tag{5}$$

The amplitude of correlation peak shows the similarity of two spectral images, and the axis of correlation peak shows the relative registration error of two spectral images.

In order to improve the correlation accuracy in this paper, first, the captured image is divided into small regions. Then, the reference image and the target image are performed displacement detection by phase correlation method, and then, the registration error of these images are calibrated. In some band images, a region where image data is blank occurs at this time. Therefore, the image that contains a blank area is extracted from the acquired spectral images, and then, these images are calibrated again by the proposed method. Finally, the blank area is complemented by the above process. In this paper, we divide into the regions with a fixed size. However, it is also possible to vary the region adaptively depending on the degree of texture density of the acquired spectral images.

4. DIGITAL ARCHIVING OF ART PAINTINGS

We apply the proposed method to digital archiving of art paintings based the present imaging system. In this paper, it is intended for digital archive of oil paintings. We have to estimate the surface properties of oil paintings. Specifically, it is necessary to estimate the spectral reflectance of the painting surfaces, the surface shape and the light reflection model parameters (S. Tominaga, et al. 2008).

Surface reflection of oil paintings include specular reflection or gloss. Therefore the camera output for the painting surface is composed of the diffused reflection and the specular reflection. As the reflection properties, the surface-normal vector and the surface-spectral reflectance are estimated from the diffuse reflection component. The reflection model parameters are estimated from the specular component.

The surface-normal vector at each pixel point is computed by using a photometric stereo method. For estimating the surface-spectral reflectance the camera output is described as a model.

$$\rho_k = \sum_i S(\lambda_i) E(\lambda_i) R_k(\lambda_i) + n_k, \ (k = 1, 2, 3, \ldots, 8), \tag{6}$$

where $S(\lambda_i)$ is the spectral reflectance, $E(\lambda_i)$ is the spectral distribution of illumination, $R_k(\lambda_i)$ is the spectral sensitivities of the k-th sensor, and n_k is the noise. Let $\boldsymbol{\rho}$ be an eight-dimensional column vector representing all spectral camera outputs, and $\mathbf{s}$ be a n-dimensional vector representing the spectral reflectance $S(\lambda_i)$. Moreover, let $\mathbf{H}$ ($\equiv[h_{kj}]$) be a $8 \times n$ matrix with the element $h_{kj} = E(\lambda_i)R_k(\lambda_i)$. Then the above imaging relationships are summarized in the matrix form $\boldsymbol{\rho} = \mathbf{Hs} + \mathbf{n}$. When the signal component $\mathbf{s}$ and the noise component $\mathbf{n}$ are uncorrelated, a solution method minimizing the estimation error on $\mathbf{s}$ is given as the Wiener estimator

$$\hat{\mathbf{s}} = \mathbf{R}_{ss}\mathbf{H}^{\mathrm{t}}\left[\mathbf{H}\mathbf{R}_{ss}\mathbf{H}^{\mathrm{t}} + \sigma^2\mathbf{I}\right]^{-1}\rho, \tag{7}$$

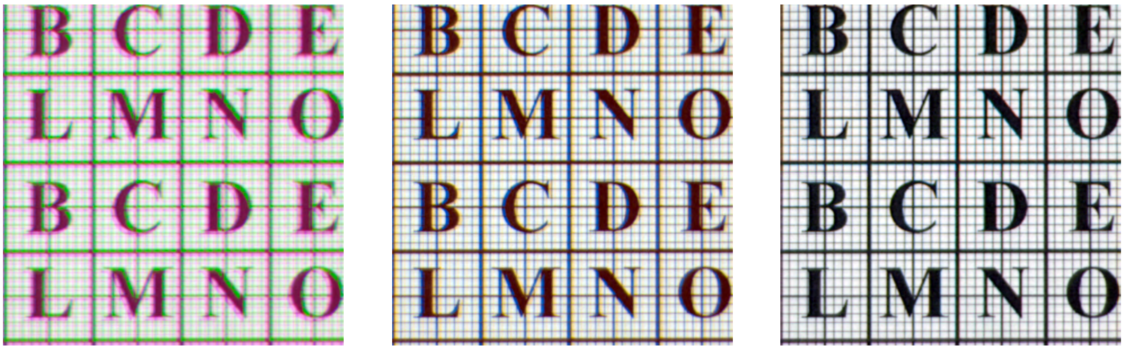
where $\mathbf{R}_{ss}$ is an $n \times n$ matrix representing a correlation among surface spectral reflectances. We assume white noise with a correlation matrix $\sigma^2\mathbf{I}$.

A reflection model is needed for rendering realistic images of oil paintings. In our previous study (S. Nishi, et al. 2007), we found that surface reflection of most oil paintings can be described by the Cook-Torrance model. The model parameters of this mathematical model are estimated from the specular reflection component of the observed images.

Image rendering is then performed based on all estimates on the surface reflection, which are the surface-normal vectors, the surface-spectral reflectances, and the reflection model parameters.

5. EXPERIMENTAL RESULTS

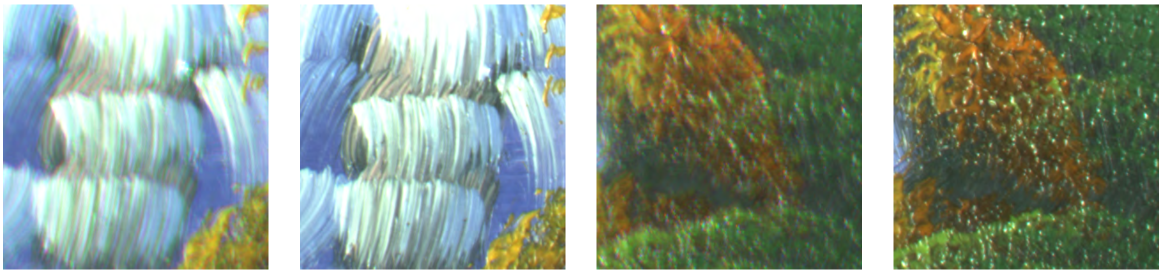
First, we experimented to verify the validity of the proposal calibration method. Figure 3 shows the calibration result. In figure 3(a), we can see the registration error occurred in the



(a) *(b)* *(c)*

Figure 3: Calibration results.
(a)Before calibraion, (b)Calibration without division, (c)Calibraion with divison.

synthesized eight band images. This phenomenon is called chromatic aberration, which is one of the factors that the reproduced image is degraded. Figure 3(b) is the calibration result by the phase correlation method without division. The registration error is improved as compared with the results in Fig 3 (a). However, pale yellow or blue has appeared, it can be seen that the calibration is incomplete. Figure 3(c) shows the calibration result by proposed method. Color in Figure 3(b) disappears, the original achromatic appearance is reproduced. Therefore, the proposed method has been verified to be useful as a calibration method. Next, we acquired the multispectral images of an oil painting by the present imaging system and performed the proposed calibration method. By the method described in chapter 4, image rendering was carried out using the estimated surface properties of oil painting. Figure 4 shows the result of image rendering of part of oil paintings.



(a)Before calibration *(b)After calibration* *(c)Before calibration* *(d)After calibration*

Figure 4: Calibration result of part of oil paintings.

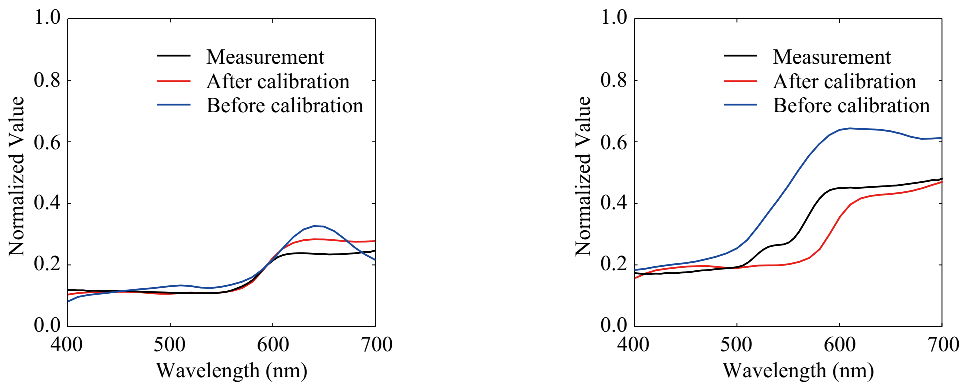


Figure 5: Estimation results for surface spectral reflectances of oil paintings.

Our proposed method is clearly beneficial by comparing with before calibration and after calibration. Figure 5 shows the estimation results for the surface spectral reflectance of part of oil painting. It can be confirmed that the estimation accuracy of surface spectral reflectance is excellent in comparison with the before calibration result.

6. CONCLUSION

This paper has proposed a method for the calibration of the registration error caused by the interference filters. The calibration method was based on the correlation technique using the phase images of acquired spectral image. In order to improve the correlation accuracy, the captured image was divided into small regions. Then, the reference image and the target image were performed displacement detection by phase correlation method, and then, the registration error of these images were calibrated. Therefore the calibration processing was able to perform with high accuracy. Furthermore, the calibration processing was capable of calculating fast for the correlation calculation in the frequency domain. Moreover, we applied this multiband camera system for the digital archive of art paintings. We have described a method for digital archiving of art paintings based the present imaging system. The availability of the proposed calibration method was shown by the experimental results.

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Development of Multi-bands 3D Projector

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ABSTRACT

Recently, devices that can display a three dimensional image is becoming inexpensive. We can enjoy a three dimensional image at home. On the other hand, a reproduction of more accurate color information and high-definition images are required in various fields. However, an accurate color reproduction is difficult because of the insufficient color gamut by RGB primary colors. There are some studies concerning to multi-primary color display devices, but the researching cost takes an expensive. Therefore, if it is possible to construct a simple system using a general 3D projectors and optical filters, it is considered that the 3D image with expanded the color gamut can be displayed. This paper proposes a method for expanding the color gamut of a 3D image by projection of the multi-primary color more than RGB 3 bands using two 3D projectors with different spectral characteristics. First, the optimal spectral transmission characteristics of notch filters is determined by a filter simulation based on the RGB characteristics of the projector. Second, the filters with the determined spectral transmission characteristics is produced, and the spectral characteristics of the projectors are changed by attaching the filter in front of the two projectors's lens. Furthermore, the experimental results are shown that the proposed system can expand the color gamut.

1. INTRODUCTION

Stereoscopic image technology is improved every day. Many people has experienced actual 3D image. On the other hand, a demand for color reproduction of images is increasing by the development of image and video communication system. It is possible to display a color image in some naturally by using the display device such as a projector. However, representation of all color range that can be human perception is difficult. Therefore, the spectral image is attracting attention in order to reproduce high-definition image recording spectral information. It is considered that the spectral information can reproduce a more accurate image by input to the display device. Furthermore, it is important to consider the color gamut problems of the display device for projecting onto a screen.

This paper focuses on approaches of using two projectors that are most attention in the color gamut extension. There are various existing studies with respect to the color gamut expansion using two projectors. The general projector can project RGB 3-bands color, so 6 bands color projection is made possible by two projectors with different optical filters. The color gamut of the image projected from the projector is known to expand by appropriately increasing the number of bands.

2. METHOD

This paper proposes a method of expanding the color gamut of a 3D image by projection of the multi-primary colors more than the RGB three bands. The proposed method is applied a color gamut expansion technique in the video presentation device using the two 3D projectors with different spectral characteristics. The optimal spectral characteristic of filters is simulated based on the spectral characteristic of 3D projector in order to realize the multi-primary color projection. Projecting images are generated from the spectral images.

2.1 Multi-band projector system

This section shows the outline of the color gamut expansion method of 3D image by multi-band projection. Figure 1 shows the proposed multiband 3D projection system. In particular, each projector is equipped with a filter that has different spectral transmission characteristics in front of the projector. The projected images from each projector are overlaied on the screen. RGB spectral characteristics changes to 6 bands information by using the filters. The desired color is reproduced by 6 bands information. Moreover the proposed system can display 3D images according to project synchronized right or left 6 band images in turn.

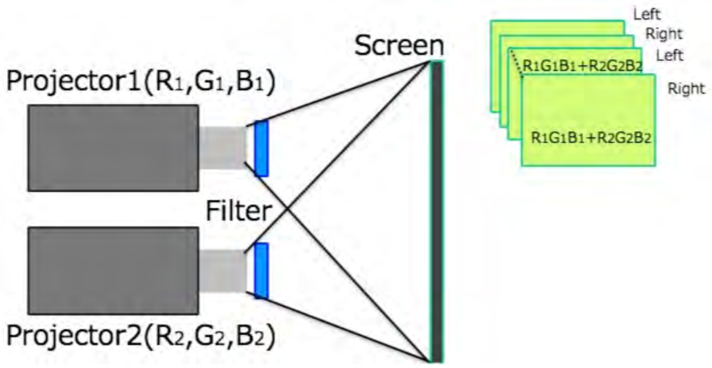


Figure 1: Proposed multiband 3D Projection System.

2.2 Filter simulation

First, the RGB spectral characteristics of 3D projector used in this study is measured. Measurement is performed in a dark room by using only the projected light from the projector. In the measurement, R (255,0,0), G (0,255,0), and B (0,0,255) are respectively projected on the screen. Each RGB spectral distribution are obtained using a spectral radiometer.

The optimal spectral transmission characteristics of each filter is simulated based on RGB spectral distribution of the projector, and the use of notch filter is supposed in this study. The filter characteristic is determined so that the color gamut becomes maximum when it is plotted on xy chromaticity diagram. The simulation performs between 380~780nm, and all wavelength is used in the range. The decision flow of the optimal spectral characteristics of filters is shown in Figure 2.

Filter simulation is calculated while changing the wavelength range which the transmittance becomes 0% in the each filter. Figure 3 shows the decided spectral characteristics of each filter and the spectral characteristics of the projector changed by the each filter. Red, green, and blue lines indicate the changed RGB spectral characteristics of the projector respectevely.

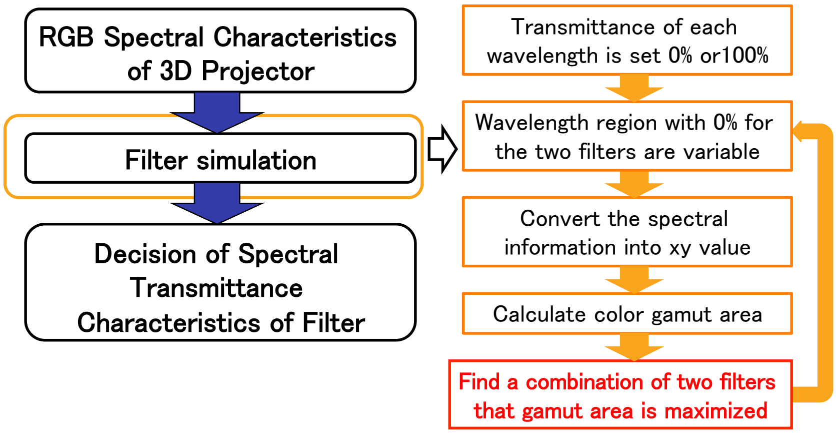


Figure 2: Flow of filter simulation.

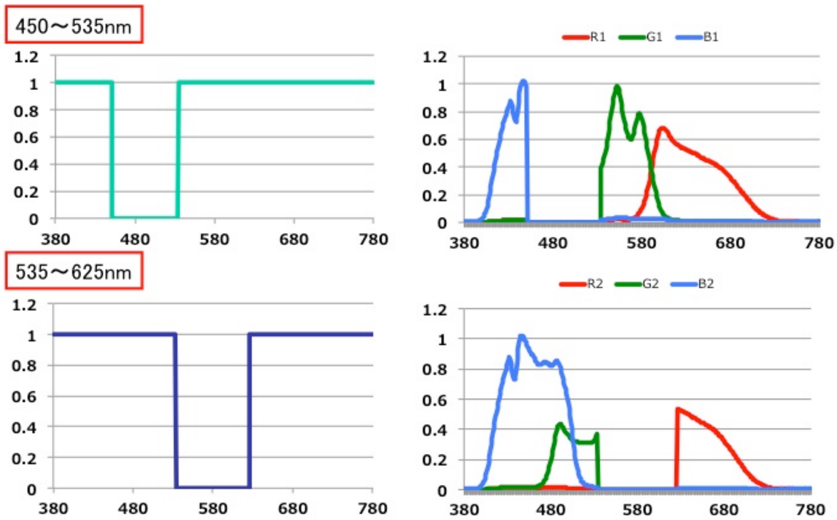


Figure 3: Simulation results.

3. EXPERIMENT AND DISCUSSION

This section shows the experimental results. The experimental system uses two VIEWSONIC PJD6253 as 3D projector. The resolution of projector is 1024 × 760 pixels. In addition, the spectral radiometer that measure spectral distribution is TOPCON SR3. Figure 4 shows the used projector and Figure 5 shows the produced filter experimentally based on the simulation result.

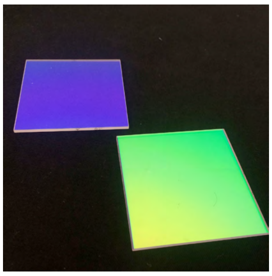
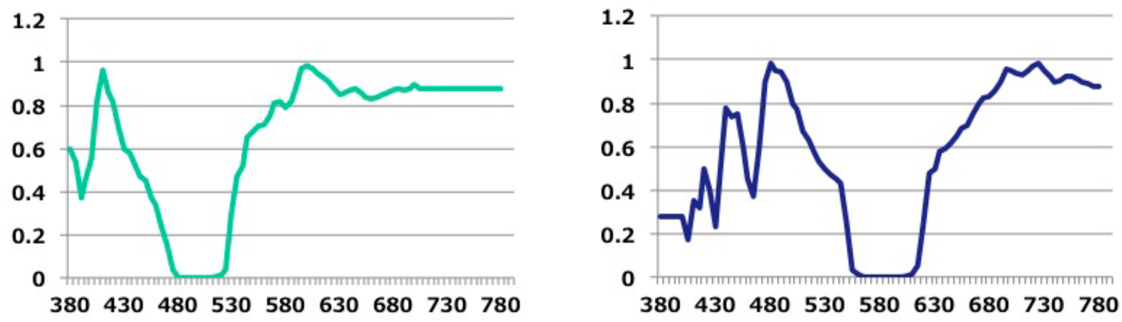


Figure 4: 3D projector. *Figure 5: Produced Filter.*

Figure 6 shows the spectral characteristics of two produced filters based on the decided spectral characteristics of filters by the simulation. It is possible to present the 6 bands information according to change RGB spectral characteristics by putting these filters in front of the projector's lens.



(a) Characteristics of the filter 1. *(b) Characteristics of the filter 2.*

Figure 6: Characteristics of the produced filters.

Table 1 and table 2 show xy values of the used projector's RGB and the proposed 6 bands projector with the produced filters based on simulation respectively. Figure 7 shows the color gamut of the used projector and the extended color gamut of the proposed system with the use of the produced filters. In figure 7, black line triangle indicates the color gamut of the projector's RGB, and red line hexagon indicates the color gamut of the prposed 6 bands projector. These measurement results show the proposed method can expand color gamut with the use of two 3D projectors and notch filter with different spectral transmission characteristics. The color gamut is covered extensively for red, green and blue regions. However, the extension of green region is not enough, because it is considered two filter of spectral characteristics affect the green area.

Using the prototype system an image is projected on a screen. This study uses a spectral image as a input image, not a normal RGB color image. Figure 8 shows the scene that project an image using the projectors put the produced filters. Lower projector is put filter 1 that cut the short wavelength, and upper projector is put filter 2 that cut middle wavelength. The projected image on the screen is shown in figure 9. This image shows that the target color image is reproduced by superimposing the two projected images.

Table 1. xy values of projector's RGB.

	x	y
R	0.625	0.344
G	0.345	0.565
B	0.147	0.085

Table 2. *xy value of RGB with filter.*

	x	y
R1	0.651	0.346
G1	0.423	0.569
B1	0.169	0.036
R2	0.697	0.288
G2	0.129	0.571
B2	0.131	0.091

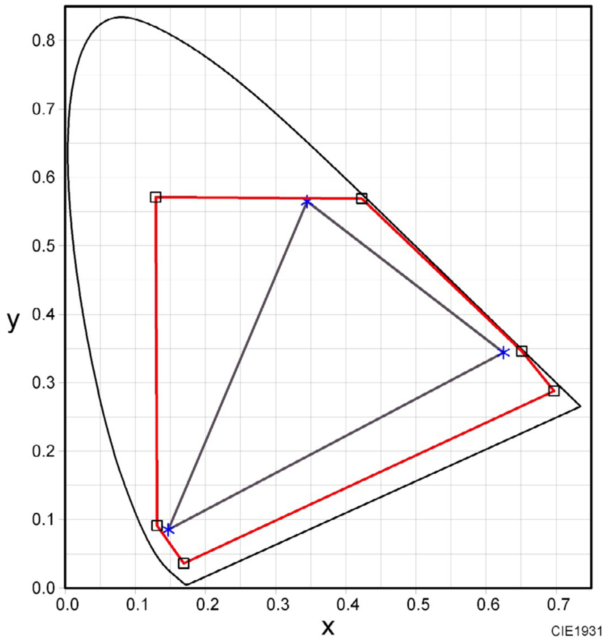


Figure 7: Extension of Color gamut using filters.

Figure 8: Two projectors put each filter.

Figure 9: Superimposed image.

4. CONCLUSIONS

This paper proposed a new method of expanding the color gamut of a 3D display system by the multiband projection using two 3D projectorsa and optical filters. The characteristics of the filter attached to the projector were simulated in order to realize multi-band projection. The optimal filter was decided based on the result of filter simulation, and the extent of color gamut was confirmed by plotting on the xy chromaticity diagram. Also, images created by processing spectral images were input to the projectors put each filter, and projected on the screen. The experimental results showed that the projected images had extend color gamut.

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Perceived Quality of Printed Images on Fluorescing Substrates under Various Illuminations

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ABSTRACT

We design a quality assessment workflow to measure the perceived quality of prints across illuminants, while accounting for the fluorescence of the substrate as well as the ink UV absorption. Given an input multispectral image, we simulate the output of a CMYKRGB printer by means of a spectral gamut mapping and an extended cellular Yule-Nielsen modified Spectral Neugebaeur model allows us to account for both paper fluorescence and ink UV absorption. We demonstrate the relevance of considering these effects as they lead to substantial changes in the perceived image difference across illuminants. These findings are of particular interest for soft- and hard-proofing applications in spectral printing workflows.

1. INTRODUCTION

In printing, colorimetric workflows ensure that the print looks as good as possible under one specific illuminant (typically daylight), but without accounting for the fact that colours, and therefore colour differences, may change drastically from one illuminant to another (Le Moan, 2014). This effect is referred to as metamerism: two objects may seem to have the same colour under one light, but not under another. There are several applications that require having some control over the quality of a print under various viewing conditions, and for which colorimetric workflows are therefore not appropriate. Furniture catalogues or paint swatch books are among these applications as it is important that customers have a good idea of the colour of a piece of furniture or a particular pigment under the light of their living room for example. Only in a spectral workflow is one able to have such control, by using the pixels' spectral reflectance factor, rather than e.g. RGB or CIELAB values. Controlling quality in such workflows is however challenging due to the potentially large number of viewing conditions that need to be considered (e.g. all kinds of domestic lights) and because distances between pixels (such as the Euclidean distance) carry very little meaning in terms of perception, when computed in the "reflectance domain" (as opposed to the "colour domain").

There is a variety of so-called image-difference metrics in the literature, that aim at predicting the perceived difference between an original image and its reproduction (e.g. a simulated print), using features such as structure, contrast, detail visibility, etc… However, most of these metrics work with three-dimensional colour spaces optimised for one illuminant only. Recently, Le Moan and Urban (2014) proposed a scheme to extend one of these metrics, called CID, for spectral workflows by using a set of representative illuminants and combining the CID scores between the renderings obtained for each of them. The resulting multi-illuminant metric is referred to as Spectral Image Difference (SID) and it has been reported to significantly outperform traditional spectral difference metrics such as the root-mean square error (RMSE) when compared to subjective data. Although SID can be applied to control quality within a spectral printing workflow, it fails to consider paper fluorescence and its impact on the perceived quality of the print. It is well known however that fluorescing whitening agents (FWA) are used to make papers appear whiter (Coppel, 2012). These dyes absorb UV radiation and re-emit light in the blue region of the electromagnetic spectrum. In this study, we design a quality assessment workflow to investigate the influence of paper fluorescence on perceived image quality. Given an input multispectral image, we simulate the output of a CMYKRGB printer by means of a spectral gamut mapping (Urban, 2011) and an extended cellular Yule-Nielsen modified Spectral Neugebaeur model allows us to account for both paper fluorescence and ink UV absorption. We demonstrate the relevance of considering these effects as they lead to substantial changes in the perceived image difference across illuminants. These findings are of particular interest for soft- and hard-proofing applications in spectral printing workflows.

2. QUALITY ASSESSMENT WORKFLOW

2.1 Spectral separation and gamut mapping

Urban and Berns (2011) introduced a spectral gamut mapping strategy, based on a sequence of colorimetric mappings within paramer-mismatch gamuts. For example, given two illuminants γ_1 and γ_2 and given that γ_1 should be prioritized over γ_2, the spectral mapping aims at minimizing the colour difference under γ_2 while keeping the difference under γ_1 unnoticeable (i.e. lower than JND – Just Noticeable Difference). We used this approach and considered a cellular Neugebauer spectral model calibrated for an HP-Z3200 printer in the 7-channel CMYKRGB mode with an almost non-fluorescing EFI offset proof 9200 semimatt 200 g/m^2 paper. Note that, as in Urban and Berns' study, only 4-ink combinations including K were considered (e.g. CMYK, CKRG or MYKB), since it was observed that 5-, 6- or 7-ink combinations do not contribute much to the spectral variability of the printouts and are therefore of limited interest in the present study (in other words, most of the spectral gamut can be described with 4-ink combinations only).

2.2 Fluorescing substrate

When fluorescence is present, the reflectance factor is no longer independent of the illumination and must be estimated for each illuminant. For a halftone print on a fluorescing substrate, the incident light is first partly absorbed by the ink dots before it changes wavelength due to the fluorescence process, and is finally partly absorbed at that longer wavelength by the ink dots. Assuming opacity in the excitation wavelength band and introducing an equivalent scalar transmittance t_j' of the Neugebaur Primaries (NP) in the excitation band, Hersch (2014) proposed an extension of the spectral Yule-Nielsen modified Neugebauer model (Wyble, 2000) expressing the total reflectance factor R^{tot} from measurement of the substrate and NPs in one illumination without excitation radiation and in one illumination with excitation radiation:

$$R^{\text{tot}}(\lambda) = \left[R_{\text{p}}^{\text{tot}}(\lambda) - R_{\text{p}}^{*}(\lambda)\right]\left[\sum_{j=1}^{N} a_j t_j'\right]\left[\sum_{j=1}^{N} a_j t_{\text{j}}(\lambda)^{\frac{1}{n}}\right]^{n} + R^{*}(\lambda)\,, \tag{1}$$

where $R_{\text{p}}^{\text{tot}}$ is the reflectance factor of the substrate in an illumination including the excitation wavelengths, R_{p}^{*} is the reflectance factor of the substrate in an illumination without fluorescence excitation, $t_{\text{j}}(\lambda)$ is the transmittance of NP j at emission wavelength λ, R^{*} is the reflectance factor of the printed substrate without fluorescence excitation, and $N = 2^4$ (four inks) is the number of NPs. The Yule-Nielsen model is applied with factor n to account for the lateral light propagation within the substrate (optical dot gain).

Equation (1) states that the reflectance factor of a halftone is the sum of the reflectance of the halftone without excitation radiation (R^*) and of the paper substrate's fluorescent component attenuated by the weighted t_j' in the excitation band and the weighted t_j in the emission band of the FWA. The apparent transmittances in the excitation band t_j' are obtained by spectrally fitting Eq. (1) with *N*=1 to the measured reflectance of fulltone individual NP ($a_j = 1$) with (R_j^{tot}) and without (R_j^*) fluorescence excitation. Two i1 spectrophotometers (X-rite Inc.), with and without UV cut-off filter were used to determine t_j' and $t_\mathrm{j} = \left(R_j^*/R_\mathrm{s}^*\right)^{1/2}$ of the inks when printed on a fluorescing substrate whose fluorescent component was measured in the same way. We propose here to determine the paper's fluorescent component in different illuminations from the Donaldson matrix $D(\lambda_1, \lambda_2)$, which gives the bispectral reflectance from all excitation wavelengths λ_1 to all emission wavelength λ_2. From this matrix we computed the fluorescent component of the reflectance factor of the paper according to (Zwinkels, 1999),

$$R_\mathrm{p}^{\mathrm{tot}}(\lambda_2|E) - R_\mathrm{p}^*(\lambda_2) = \frac{1}{E(\lambda_2)} \sum_{\lambda_1<\lambda_2} D(\lambda_1, \lambda_2) E(\lambda_1), \quad (2)$$

where *E* is the spectral power distribution (SPD) of the illuminant. Note that, in practice, FWA tend to decrease $R_\mathrm{p}^*(\lambda_2)$ in the 400-420nm band (Coppel, 2011) but this effect is neglected in this study. It is also worth noting that the fluorescent component depends on this SPD in the emission band of the FWA. This means that two illuminants that have the same SPD in the excitation band do not necesseraly lead to the same fluorescent component (Coppel, 2013). The Donaldson matrix of a typical paper sample with 18 kg/T FWA measured with a bi-spectrophotometer (Coppel, 2011) was used here.

Once the ink surface coverages are determined by the spectral separation and gamut mapping for the non-fluorescence case, Eq. (1) is used to simulate the printed spectral images with fluorescence under illuminants CIED65 and CIEA. Figure 1 shows the relectance factor of the unprinted and fulltone patches in the different illuminants.

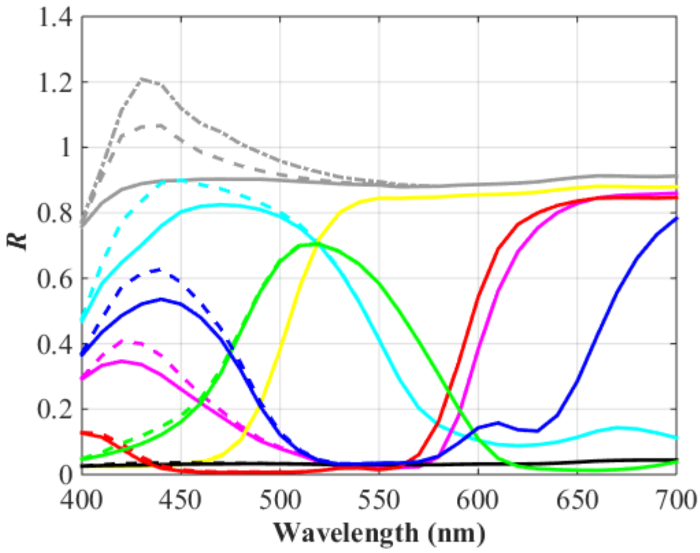

Figure 1. Measured reflectance factors R of the process inks and paper without fluorescence (solid) and simulated R with fluorescence in illuminant CIEA (dash) and CIED65 (dash-dot, only bare paper). The inks are represented by their respective colours. Note that light tones and ink combinations with only cyan, blue and magenta are the most subject to colour shifts due to fluorescence.

3. SPECTRAL IMAGE DIFFERENCE

In order to evaluate the perceived quality of the simulated prints, we used the Spectral Image Difference metric (Le Moan, 2014), with only the two illuminants under consideration. This metric evaluates the perceived image difference under each illuminant and computes the weighted mean value as the final score. Note that it uses a chromatic adaptation transform in order to account for the ability of our visual system to adjust to various viewing conditions. The resulting score was shown to correlate with human judgement to a great extent. For this particular study, we used the most recent implementation of the CID metric - on which SID is based - referred to as MSiCID (*Multi-Scale improved* CID) (Le Moan, 2015). Incidentally, we renamed the SID metric as iSID (*improved* SID). We define it as follows:

$$\mathrm{iSID}(\mathbf{I}_1;\mathbf{I}_2) = \alpha\mathrm{MSiCID}\big(\mathbf{i}_{1,D65};\mathbf{i}_{2,D65}\big) + \beta\mathrm{MSiCID}\big(\mathbf{i}_{1,A};\mathbf{i}_{2,A}\big), \tag{3}$$

where $\mathbf{I}_1$ and $\mathbf{I}_2$ are two spectral images, $\mathbf{i}_{x,\gamma}$ is the rendering of $\mathbf{I}_x$ for illuminant γ and α and β are weighting coefficients. We considered that CIED65 should be prioritized over CIEA as daylight is still the most used reference illuminant in many printing applications. Consequently, we used the following coefficients: $\alpha = 0.75$ and $\beta = 0.25$.

3. RESULTS

We used the 16 natural scenes from the two Foster hyperspectral image databases (Nascimento, 2002). They depict natural scenes (vegetation, urban areas…) and contain between 30 and 32 spectral channels, sampling the visible range of wavelength from 400 to 720nm. However, in order to fit the characteristics of our printer model (see Section 2.2), all images were modified to be in the range 400-700nm. For images whose spectral ranges starts at 410nm, the band at 400nm was assumed to be equal to the one at 410nm.

Table 1 gives the mean, standard deviation and maximum iSID scores obtained when comparing the simulated prints with and without fluorescence. Note that iSID scores range from 0 (no difference) to 1 (largest measurable difference). Figure 2 shows an example of images rendered for CIED65, with and without considering the fluorescence phenomenon. Figure 3 shows the DE2000 pixel-wise colour-difference maps for CIED65 and CIEA for one of the 16 spectral images considered in this study, for illustrative purposes. What we believe is particularly noteworthy here is that not considering fluorescence will likely result in a perceivable difference in the final print, up to 0.122 iSID units on the data tested, which is considerably high.

Table 1. Obtained iSID scores on each scene of the Foster database, between simulated prints with and without fluorescence and ink UV absorption (respectively $\mathbf{I}_{\mathrm{fluo}}$ *and* $\mathbf{I}_{\mathrm{no\_fluo}}$*).*

	$\mathrm{iSID}\big(\mathbf{I}_{\mathrm{fluo}};\mathbf{I}_{\mathrm{no\_fluo}}\big)$
Average	**0.057**
Standard deviation	**0.034**
Maximum	**0.122**

Figure 2. Simulated prints, without (left) and with (right) considering fluorescence and ink UV absorption, for CIED65. Note how these phenomena change particularly the colour of the flower petals, which consist mainly of magenta ink.

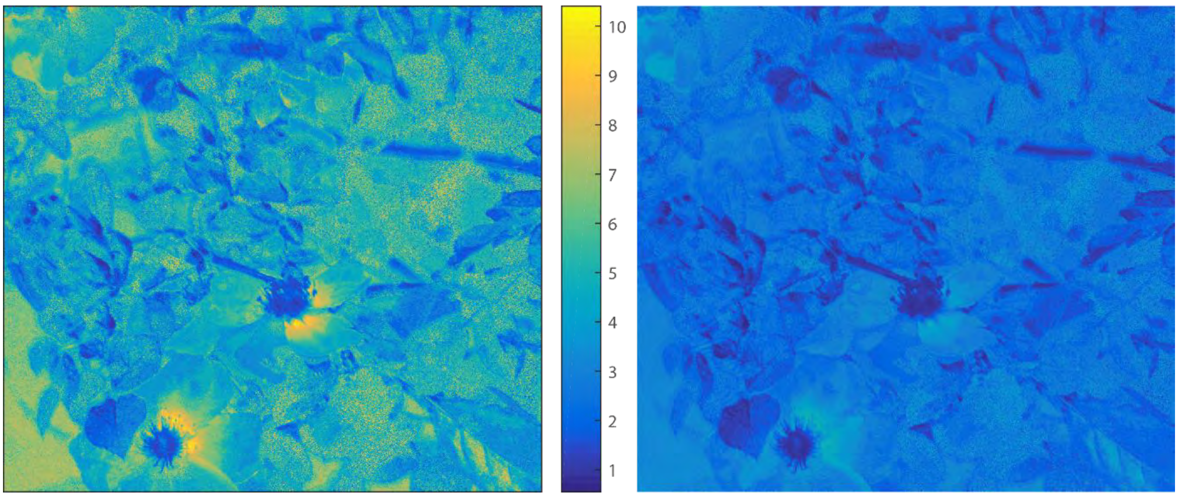

Figure 3. DE2000 colour-difference maps for CIED65 (left) and CIEA (right). Note that daylight, which contains more energy in the UV wavelengths and therefore engenders more fluorescence, yields colorimetric errors larger than 10 DE2000 for this particular image

4. CONCLUSIONS

We designed a quality assessment workflow to measure the perceived quality of prints across illuminants, while accounting for the fluorescence of the substrate as well as the ink UV absorption. Given an input multispectral image, we simulated the output of a CMYKRGB printer by means of a spectral gamut mapping and an extended cellular Yule-Nielsen modified Spectral Neugebaeur model allowed us to account for both paper fluorescence and ink UV absorption. We demonstrated the relevance of considering these effects as they lead to substantial changes in the perceived image difference across illuminants.

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To Predict Reality in Virtual Environments: Exploring the reliability of colour and light appearance in 3D-models

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ABSTRACT

To predict how the not yet built environment is going to appear regarding light and colour is a crucial problem for architects and designers. 3D-visualization is an established design tool and used for representations of project proposals, often with the aim to make good-looking images that sell the design. In order for software such as 3Ds Max to become usable planning tools of light and colour in buildings, the visualization must be trusted to show the correct appearance in accordance with the physical preconditions of reality. This paper discusses the problems of translating reality to its digital counterpart. In previous studies from 2004-2006, a reference room was compared to different simulations. The result showed significant differences in colour and light appearance between the reference room and the virtual rooms. Since then, the technology within colour rendering has moved forward. New comparisons with the reference room were performed in 3Ds Max Design 2015, in order to explore the trustworthiness of colour and light representations today. The rendering techniques Mental ray and Vray were evaluated. Preliminary results show strong improvements regarding colour variations and shadows. However, there are still incorrectly reproduced contrast effects and interreflections between angled surfaces.

1. INTRODUCTION

This paper discusses the problems of translating reality to its digital counterpart. 3D-visualization is an established design tool for architects and designers. In many cases, the aim with the visualizations is to make good-looking images to sell the design. In order for software, such as 3Ds Max, to become usable planning tools of light and colour in buildings, the visualization must be trusted to show the correct appearance in accordance with the physical preconditions of reality. The complex interaction between light and objects makes the problem of lighting scenes central within computer graphics. There are few studies on colour appearance within real compared to virtual environments (Stahre and Billger, 2006, Billger et al, 2004). A method for comparing real environments with digital images was introduced by Meyer et al (1986). This method was built upon measurements of radiant energy flux densities in a simplified physical environment; *i.e.* the Cornell Box, compared to a simulation where radiosity was used. In order for the comparison to be as accurate as possible, both the image and the box were viewed simultaneously through a camera. Another study where simulations were compared to a real scene was carried out by McNamara et al (2005). The study aimed to determine how much computation is enough in order to create a trustworthy image, based on the human visual system rather than on physical correctness. For this the ray tracing based software Radiance was used. Objects were viewed in a real scene, *i.e.* a lighting booth, and compared to rendered images. Scenes were viewed monocularly in order to eliminate depth cues. Mania et al (2003) aimed for photo-realistic simulations and made great efforts to control colour and lights. In their study, the focus lay on mnemonic recall of individual objects in a room. Colour appearance was not visually assessed or discussed, though the study involved the translation of colours from reality to Virtual Reality (VR) in different viewing conditions. In order to achieve a more 'naturalistic' awareness state, the realism in the simulations was sometimes forgone. In recent years, interesting software development has been undertaken in photorealistic rendering (Pharr and Humphreys, 2010; Billeter, 2012; Maxwell Renderer, 2015).

In a previous study (Billger et al, 2004; Stahre et al, 2005; Stahre and Billger, 2006), interactive spatial 3D-models were compared to a full scale reference room. Important in this study was that the rooms were studied interactively from *within*. Various problems were discovered in 3Ds Max related to the rendering of light and colour in the models. Compared to reality, the virtual rooms showed incorrect reflections between surfaces; too simple chromatic information on light sources; too achromatic shadows; too few contrast effects; and too few colour variations. Since then, the technology within colour rendering and computer graphics has moved forward. In this study, we want to investigate if the stated problems are solved with today's software technology, focusing on 3Ds Max and its built-in renderer Mental Ray; as well as the external renderer VRay. The aim with this study is to identify problems and test solutions for simulating trustworthy visual appearance, focusing on colour and light, in digital modeling. The results persented here are based only on rendered views of the room.

2. METHOD

In the earlier studies carried out 2004-2006, a 25 m^2 multi-coloured reference room was compared with corresponding digital models (Fig 1A, B). The models were made in Lightscape and in 3Ds Max[1]. The 3Ds Max-model was exported to VR in order for the rooms to be interactively evaluated from within. 56 observers evaluated the different rooms using various evaluation techniques. Initially, studies were conducted in the reference room, and in Lightscape/3Ds Max. To compare the model and the reference room, the results of the visual assessments (verbal description, magnitude estimation and colour matching with the colour reference box) were analyzed. These results lead to adjustments of the digital models. In order to compare colours with their digital counterparts, a process was developed to translate real colours to digital values. Since the translation was complex, it was important to find an acceptable level of correctness. A basic prerequisite for correct colour appearance in the digital models was that the computer was calibrated. Most important however was that the *relationship* between differently coloured surfaces was as correct as possible compared to reality. If so, small displacements between colours on different displays were acceptable; as well as small translocations of the colour scale, since they were results from the adaptation to the surrounding light, and the light from the computer. For documentation and reference, physical measurements of the spectral composition were conducted for the room surfaces both in the reference room and in the models. Three different illuminations were used: incandescent light; fluorescent 827 (2700K); and fluorescent 830 (3000K). In order to get the simulation of the 6 fluorescent luminaries (2 ceiling armatures and 4 wall washers) as correct as possible, the manufacturer Fagerhult's own photometric light was used as IES-files, enabling a

[1] Halfway through the project, Lightscape was incorporated into 3Ds max, and ceased to exist as a free-standing product. The light calculation functions of Lightscape were incorporated into 3Ds max, which led to the use of this program for the continued studies.

simulation of the lighting originally used in the reference room. For the renderings, the default Scanline renderer in 3Ds Max was used, since this was at the time for the studies the only renderer in 3Ds max supporting photometric light using radiosity.

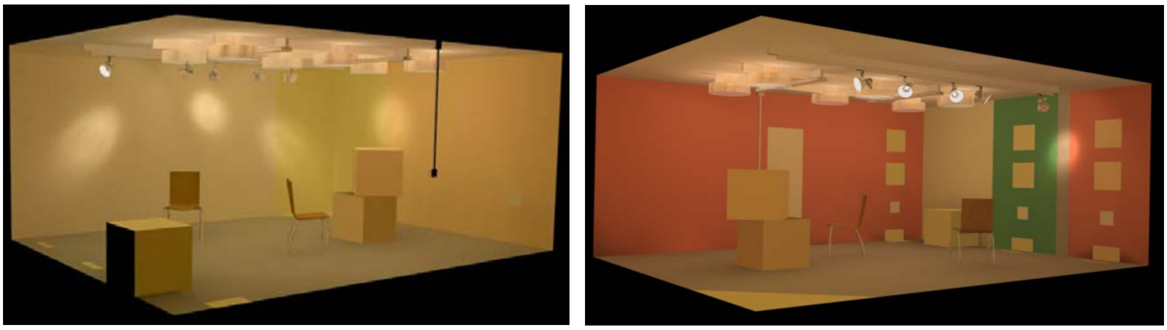

Figure 1A,B: The reference room, designed to show clear examples of how simultaneous contrast phenomena and reflections cause different appearances.

In our comparative study from 2014-2015, tests were performed in 3Ds Max Design 2015 in order to explore the trustworthiness of colour and light representations, with the aim to find out if our stated problems had been solved. For this, the same 3Ds Max-models were used as in previous studies, and evaluated against the same reference room. Focus lay on the flourescent illumination 830 (3000K). The light sources were not manipulated, and no additional illumination were allowed. The models were rendered with the built-in renderer Mental Ray, since it now supports photometric light, and the now existing external renderer VRay (Visual Dynamics, 2015). The default settings of 3Ds Max were used, following the recommended settings in the tutorials. A difference to earlier recommendations, used in the previous studies, meant that all colours in the model were based on bitmap-textures, and that Gamma 2.2. was applied by default in 3Ds Max (Aversis 3D-Tutorials, 2014). The evaluation in this study consisted of visual assessments made by the research team.

3. RESULTS AND DISCUSSION

3.1. Colour and light appearance in the reference room 2004-2006

The reference room was designed to show significant effects of illumination, reflections and contrasts. Our previous studies showed that in this room differently painted surfaces perpendicular to or opposite each other became more similar by reflections, causing large colour variations on equally painted surfaces. Each uniformly painted area showed different colour variations, and contrast effects were evident between differently painted surfaces on the same level (Figure 2A). A brightness phenomenon appeared, *i.e.* the light square on the yellow wall in the darkest corner was perceived as whitest and lightest of all surfaces, although five other areas in the room were painted in the same nuance (Figure 2B). Visual assessments showed that even small differences in colour appearance could be important for the experience. The colours also showed very different appearance in the different light situations. The white fluorescent illumination (3000K) was by most observers found to be cold or neutral, and experienced as having practically no colour, though some observers found it to be slightly yellowish. The more yellow 2700K fluorescent light was by the observers perceived as slightly warmer, and having a greenish tint.

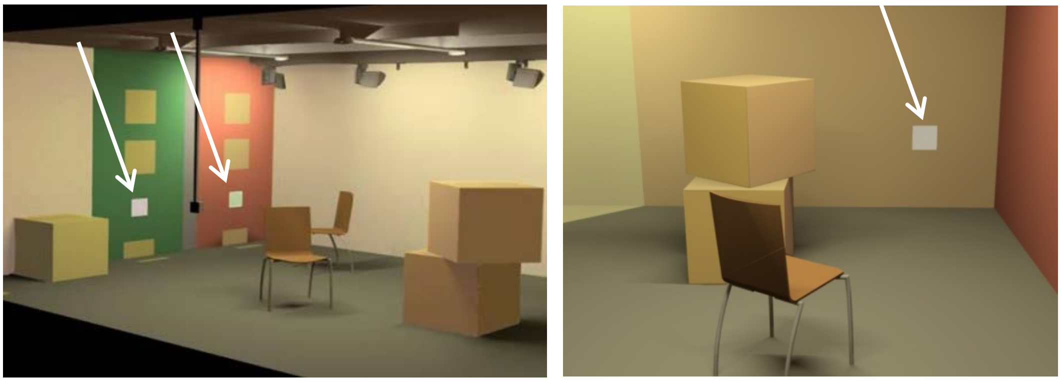

Figure 2 A: A contrast phenomenon made the greenish light square on the green background appear pinkish and the reddish light square on the red background appear greenish. B: A brightness phenomenon made the small square appear whitest and lightest. (Manipulations made to demonstrate the appearance in the reference room.)

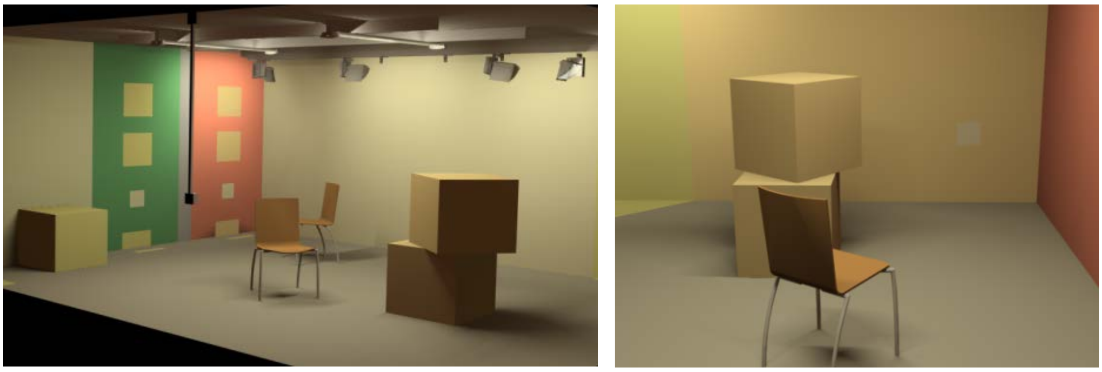

Figure 3A,B: The same views rendered with the Scanline renderer in 2004-2006.

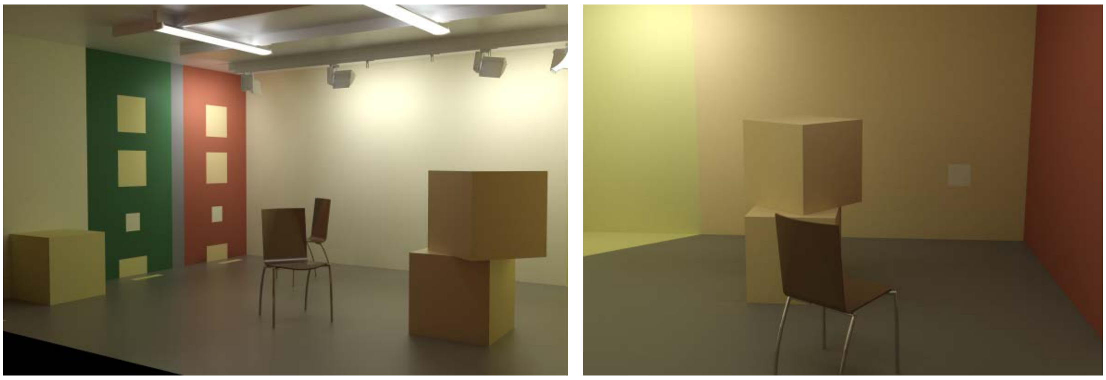

Figure 4A,B: The same views rendered with the Mental Ray renderer in 2014-2015.

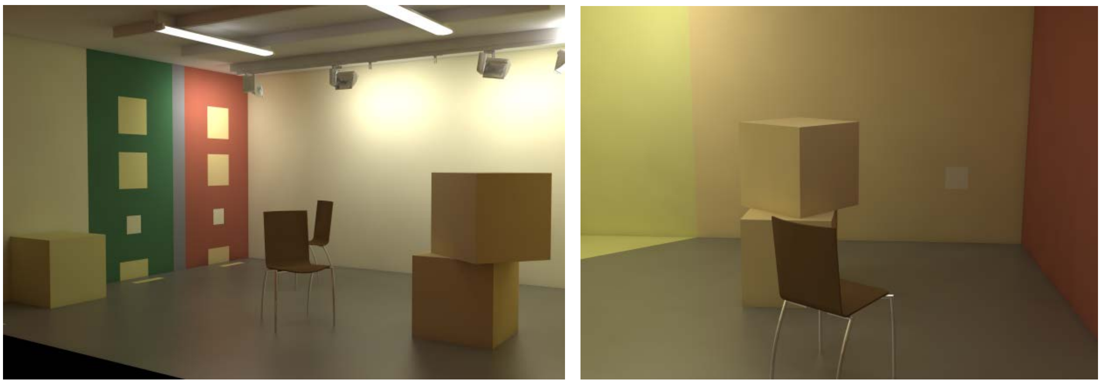

Figure 5A,B: The same views rendered with the VRay renderer in 2014-2015.

3.2. Colour and light appearance in 3Ds Max 2004-2006

In the virtual room, five significant differences in appearance compared to the reference room were pointed out, including: 1) Too few colour variations: The large colour variations on equally painted surfaces that appeared in the reference room did not show. Furthermore, the areas with the whitest nuances came out too greyish. 2) Too few contrast effects. Neither the contrast effects between differently painted surfaces on the same level (Figure 3A), nor the brightness phenomenon regarding the light square on the yellow wall (Figure 3B) appeared. 3) Incorrect reflections between surfaces perpendicular to, or opposite, each other. 4) Too simple chromatic information on light sources: The fluorescent lights 3000K and 2700K appeared identical, while they in reality caused distinctly different colour appearance. 5) Too achromatic shadows.

Moreover, problems with the parameter settings for the radiosity calculations were discovered. The recommended settings for physically correct results regarding colour bleed in 3Ds Max resulted in fewer colour variations compared to reality. Furthermore, the recommendation for colour bleed from the manufacturer of the light fixtures turned out to be too low.

3.3. Colour and light appearance in 3Ds Max 2014-2015

In both Mental Ray and Vray, preliminary results show general improvements on colour and light appearance. Concerning the stated problems from the earlier studies, the following observations were made. 1) The colour variations have visibly improved. 2) The contrast effects are still too few. No difference has been observed from previous studies. Neither the contrast effects between differently painted surfaces on the same level (Figures 4A,5A), nor the brightness phenomenon regarding the light square on the yellow wall (Figures 4B,5B) appeared to a satisfactory extent. 3) There are still incorrect reflections between surfaces: Reflections are not having enough impact on angled surfaces compared to opposite ones. For example, the short light wall appears greenish in all simulations; however in reality it is strongly affected by the red wall and appeared light beige without any green tint. 4) There is still too simple chromatic information on light sources: The lights 3000K and 2700K appeared almost the same. 5) The shadows appear close to reality, *i.e.* they are no longer achromatic. A specific difference between Mental Ray and Vray was that the light from the wallwasher spotlights created burned out areas in VRay (Figure 5A).

4. CONCLUSION

In our studies from 2004-2006, various problems related to the translation and comparison of light and colour appearance in real world settings to 3D-models were revealed. Even when the real world appearance was studied in detail, it turned out to still be difficult to simulate a trustworthy appearance in the models. In our new comparative study, results show strong improvements in 3Ds Max regarding colour variations, shadows and reflections. However, there are still incorrectly reproduced contrast effects and interreflections between angled surfaces. A conclusion drawn is that in 3Ds Max, even when the real appearance is known, the handling of various complex parameters makes the creation of an accurate colour and light appearance extremely problematic, even for expert users. Though some issues regarding the appearance by now are solved, others remain. The technology has reached the point were we by manipulations can render an almost perfect copy of a real scenario. However, it is still a problem to recreate correctness in the representation of colour and light when the real world appearance is *not* known. In order to be able to predict a future built scenario in 3Ds Max, one must have an extensive experience of both the real world appearance and various parameter settings in the software. Knowing the colour appearance of the real objects (rooms, buildings, etc) has proved to be essential in order to correctly recreate a trustworthy colour and light representation in 3Ds Max. Psychological phenomena and the way the human visual system works need to be included in the research as a complement to today's mathematical modeling of physical conditions.

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Altering Perceived Depth of Objects with Colored Lighting

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ABSTRACT

Color stereopsis is a phenomenon in which colored objects on the same plane are perceived to be on different planes or depth, and prior studies about this indicate that long–wavelength colors were often perceived to be nearer, although there are occasions wherein a reverse or even no effect was perceived. However, very little research on how lighting can affect color stereopsis exist, especially in relation to color contrast between target objects and its surround or context. This study sought to test whether lighting can alter an object's perceived depth resulting from color contrast (thereby creating a color reversal), and whether the red target object will be perceived to be nearer under different colored lighting conditions. Seven lighting conditions were used to illuminate a scaled model of a gallery, and radiance maps were created to serve as visual stimuli for the psychophysical experiment. Results show that colored lighting can affect color–depth perception due to the resulting change in color contrast between the target objects and its context, and that under different colored lighting conditions, color reversal would occur due to the color contrast.

1. INTRODUCTION

Color stereopsis, or chromostereopsis, is a phenomenon in which colored objects located on the same plane are perceived to be on different planes, therefore creating a difference in depth or spatial layout. Many studies on the topic have expressed that a long–wavelength stimulus was more often perceived to be closer than short–wavelength stimulus even when both are equidistant from the observer (Luckiesh 1918; Payne 1964; Sundet 1978). When the reverse effect was perceived, that is, the short–wavelength stimulus was perceived as nearer than long–wavelength stimulus, a color reversal is said to have occurred.

Several studies on the possible causes of this color reversal and color stereopsis in general have been conducted (Vos 1960; Winn et al 1995), but most attribute the color stereopsis effect to "optical" causes. Thompson et al (1993) drifted from this convention when they proposed that color stereopsis could be due to a combination of luminance–based and color–based depth effects, thereby suggesting a perceptual basis for the effect. This perceptual basis for the color stereopsis effect seems promising, but only a few studies cover color–based depth effects, as most focus on the influence of luminance. Dengler and Nitschke (1993) claim that the color reversal effect can be due to border contrast between the colored stimulus or target and its immediate surround rather than just the "optical" causes, while Rempel et al (2011) cited Treisman's observations that color and contrast both influence perceived depth.

However, these studies (even for studies on luminance–based effects) usually discount the illuminant in their experiments, claiming that lighting had a negligible effect on the scene. But an illuminant is known to influence color appearances, especially if the lighting is spectrally different from daylight or a cool-white illuminant. Prior studies on target–surround contrast used achromatic surround in their experiments, but should the color of the light change, the surround or context may change along with it, as will the contrast between the target and surround. This study then seeks to discover how colored lighting would affect the color stereopsis effect (wherein red was perceived nearer than blue) by manipulating the color of the illuminant, and whether color reversal would occur under different colored lighting conditions.

2. METHOD

To investigate the effect of colored lighting on color–depth perception, a psychophysical experiment was conducted to test whether the red stimuli will still be perceived to be nearer than the blue stimuli under colored lighting. Two hypotheses were developed for this study: first, that the red object was perceived to be closer even under different colored lighting conditions (at least 50% of the observed responses); and second, that the proportions of observed responses across different lighting conditions are the same.

2.1 Experiment Setup

A 1:5 scaled model of an 18 meters × 6 meters gallery was designed to be the three-dimensional environment for the study. The scaled model was composed of three bays, with its interior surfaces (walls, floor, and ceiling) lined with plain grayish brown cardboard sheets. Two of the bays had a skylight to illuminate the gallery. One of the skylights had a colored filter while the other did not. Colored cellophane sheets were used as a “filter,” to represent colored lighting.

The two cubes assigned to be the target objects were of equal dimensions (40cm × 40cm × 40cm), and were hung with a nylon string in order to appear as if they were floating in Bay C. Both cubes were spray painted with two colors, red and blue. The surfaces of the two cubes facing the observer were aligned with each other, and this same plane/surface was aligned to one edge of the skylight opening. The observer's standpoint (or in this case, the camera), was set about 12 meters away from the target objects. The blue cube was placed on the right side, while the red cube is on the left side. Figure 1 shows a cut-away view of the scene, indicating the location of the target objects, observer, and the skylights.

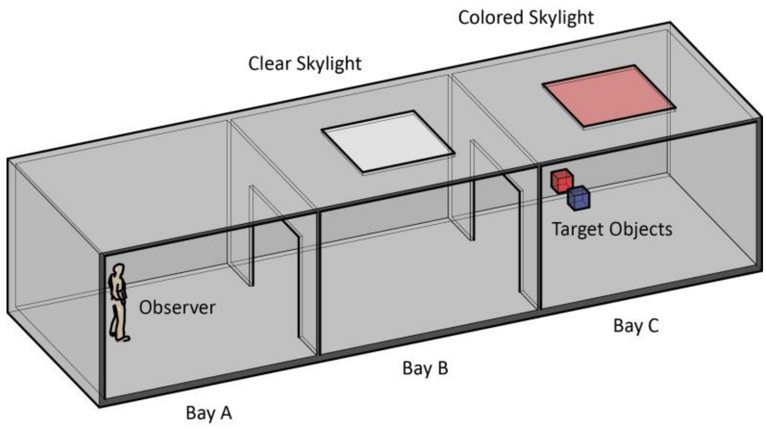

Figure 1: Cut-away view of experiment setup.

Six colored lighting were tested in this study: two variations each for the blue, red, and yellow lighting. The variations of the colored lighting were created through the layering of the cellophane sheets. The first, and lighter variation, used one layer of cellophane sheet, and the second, darker variation used four layers. The colored cellophane sheets covered the skylight opening in Bay C. A seventh test condition (neutral or uncolored) was included to serve as the control or baseline image. In this condition, there were no colored cellophane sheets over the skylight opening in Bay C. Using a room's fluorescent lamp as the light source for the scaled model, the light entering Bay C became colored due to the cellophane sheets.

2.2 Visual Stimuli

Instead of using physical objects as stimuli, which is a commonly employed color stereopsis experiments, we opted to create the visual stimuli through high-dynamic range (HDR) photography. Through radiance maps (the most common way of generating HDR content), issues about color constancy during changes in colored lighting can be minimized. A radiance map is produced by combining several low-dynamic range images to create a single HDR image.

Low-dynamic range images of the scene were captured using a tripod-mounted Canon 5D Mark III, with a 50mm prime lens attached to it. The camera was manually set to focus on the target objects. For each lighting condition, ten images of the scene were captured; each image was set to have one of the following shutter speeds: 1/15, 1/8 , 1/4, 1/2, 1, 2, 4, 8, 15, and 30 seconds. The captured images were then combined using Photosphere (Ward 2010) to create the radiance maps.

Since the typical display device cannot natively display HDR images, the radiance maps had to be tone mapped to properly display them on a typical display device. The Photoreceptor tone mapping operator was selected for this study as an example of one of the many tone mapping operators available (Reinhard and Devlin 2005). Figure 2 shows a compilation of the tone mapped HDR images of the seven colored lighting conditions.

Figure 2: Tone mapped HDR images of the scenes with colored lighting (L–R: Neutral, Blue 1, Blue 4, Red 1, Red 4, Yellow 1, Yellow 4).

2.3 Experimental Procedure

The tone mapped images were used as visual stimuli for a psychophysical experiment wherein observers were presented with one image of the colored lighting condition at a time, and they were asked to choose which of the target objects in the scene did they perceive to be nearer.

Ten trichromat observers (one of which is one of the authors) with normal or corrected-to-normal vision participated in the psychophysical experiment. The experiment was held in a completely dark environment. There was no lighting in the room except from the backlit laptop monitors (one used for presenting the visual stimuli, and another—which faced away from the observer—for recording the observers' responses). The visual stimuli were shown to observers using a 13" Intel Core i5–4258U 2.40Ghz MacBook Pro with Retina display, Intel Iris 1024 MB graphics, 2560 × 1600 resolution, and 60Hz refresh rate. The color settings of the monitor remained at default (Apple RGB color profile), and display brightness was at 75%.

Using the method of constant stimuli, each of the seven lighting conditions was shown ten times (for a total of 70 trials per observer) to the observers in block randomization. A black image was shown for about two seconds between each lighting condition to prevent the subject from total adaptation to the scene. Observers were tasked to verbally respond (forced choice) which of the two target objects in the scene appeared to be nearer based on the target objects' color. The responses of the observers were then recorded in a spreadsheet on a second laptop (display brightness was at the lowest level to decrease the amount of light in the room).

3. RESULTS AND DISCUSSIONS

By visually comparing the tone mapped images, the hue of the target objects did not seem to change, although the value and saturation appear to have been affected. The blue target object in the Blue 1 and Blue 4 lighting conditions look lighter than the blue target in the Neutral condition, while the blue target object in other lighting conditions seems to be more saturated than in the Neutral condition. The red target object in the Red 1 and Red 4 conditions appear to be less saturated than in the Neutral condition, but in other scenes the red target's saturation did not appear to change.

As for the context color (the wall behind the target objects), its color appearance changed accordingly with the colored lighting used in the scene. When the colored lighting was blue, the original context color became blue; the same goes for the red and yellow colored lighting. The grayish cardboard surfaces are no longer achromatic, even though the target objects retained their hue. The values of the surround also differed between the variations, with the dark variation of lighting creating a darker surround than the lighter variation. This change in the hue and value of the surround then changed the color contrast between the target and the surround, creating target–surround contrasts that may be higher or lower depending on the colored lighting.

Responses for the psychophysical experiment were tallied as red being nearer or blue being nearer. Figure 3 shows a graph of the medians of responses and the inter-quartile range for all seven lighting conditions. The dotted horizontal line signifies the median value of 5, the point wherein the red and blue stimuli are perceived to be equidistant from the observer. Median values above 5 indicate that red was perceived nearer than blue, and median values below 5 indicate that blue was perceived nearer than red. From the seven lighting conditions, only the Neutral, Blue 1, and Blue 4 lighting conditions have median values above 5. With red and yellow lighting, the blue target was perceived to be nearer, signaling the occurrence of color reversal.

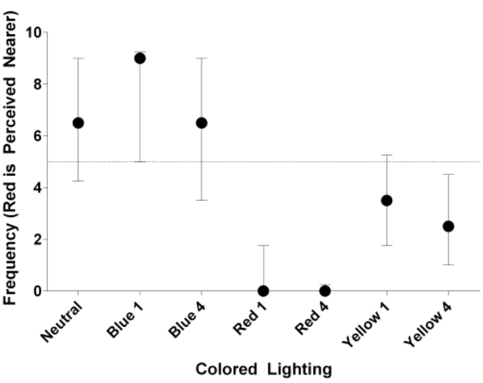

Figure 3: Median values and interquartile range in which the red stimuli was perceived nearer than the blue stimuli.

Considering that the responses for some of the lighting conditions were not normally distributed, a nonparametric analysis was selected to compare the proportions between various lighting conditions. The Friedman test was used to determine the differences in perceived depth of objects under colored lighting. Using SPSS, pairwise comparisons were then performed with a Bonferroni correction for multiple comparisons. Statistical significance was accepted at $p < 0.05$ level.

With $n = 10$ and $df = 6$, the perceived depths of the target objects were statistically significantly different under colored lighting, $\chi^2(6) = 28.326$, $p < 0.0005$. Post hoc analysis revealed statistically significant differences in perceived depth in the following pairs: Neutral lighting ($Mdn = 6.50$) and Red 1 lighting ($Mdn = 0.00$)($p = 0.033$); Red 1 lighting and Blue 1 lighting ($Mdn = 9.0$)($p = 0.011$); Red 1 lighting and Blue 4 lighting ($Mdn = 6.50$)($p = 0.013$); and, finally, Red 4 lighting ($Mdn = 0.00$) and Blue 1 lighting ($p = 0.023$); Red 4 lighting and Blue 4 lighting ($p = 0.028$). Other pairwise comparisons were not statistically significant.

The responses for when the red target object was perceived nearer under neutral or uncolored lighting were above the median value of 5. The responses for Blue 4 lighting were somewhat similar to that. The intriguing points were the results for the rest of colored lighting conditions. Our expectations for red being perceived to be nearer was at least and a little over 50%, but the responses for the other colored lighting conditions show a considerably different results, especially for the Blue 1, Red 1, and Red 4 colored lighting. For Blue 1 lighting, most observers (about 90%) perceived red to be nearer, while with Red 1 and Red 4 lighting, almost none of the observers perceived red to be nearer. Under yellow colored lighting, however, the responses were closer to the 50% proportion than the three previously mentioned colored lighting, but the responses were below the 50%, which means the observers perceived blue to be nearer instead of red.

While visual inspection of the pictorial images and statistical results have produced interesting results on the effect of colored light on depth perception, the full extent on the effect of colored lighting has yet to be explored. This study does support the perceptual basis of color stereopsis proposed by Thompson et al (1993), who believed that color could influence the perceived depth of objects.

The color stereopsis effect was also observed in this study, but only under colored lighting conditions that altered the color contrast of the target and surround. As the current study has tested only three chromatic illuminants, the point or threshold at which a positive color stereopsis effect (red in front of blue) shifts to a negative color stereopsis (color reversal) cannot be determined at this point. This study can only, at best, claim that color reversal is possible under colored lighting.

4. CONCLUSIONS

Visual inspection of the images and the results from the experiment show that colored lighting can indeed alter the color contrast between the target and its surround, thereby also altering the perceived depth of objects in a three-dimensional space. Under neutral (or uncolored) and blue lighting, red was perceived to be nearer than blue, but under red and yellow lighting, a color reversal occurs, wherein blue was perceived nearer than red.

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A Model for Estimation of Overprinted Colors on *Nishiki-e* Printings

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ABSTRACT

Nishiki-e, a type of *Ukiyo-e*, is Japanese historical multicolored woodblock printing. Some of *Nishiki-e* printing were lost over the years even though printing woodblocks were remained. For digital reproduction of lost Nishiki-e printings from remained woodblocks, accurate estimation of printed color is essential requirement. In this paper, a model for estimation of overprinted color using spectral reflectance and the order of every colorant is proposed and verified. The proposed model is based on Kubelka-Munk theory and Minato's method. Estimation of overprinted orange and green was tried. Reflectance of orange was estimated well compared with measured one. However, green was not estimated successfully. Improvement of the model in order to be applied to various overprinted color is our future work.

1. INTRODUCTION

Ukiyo-e is very famous Japanese historical visual art. Especially, multicolored woodblock printings in *Ukiyo-e* are called *Nishiki-e*. A *Nishiki-e* printing is produced by a set of printing blocks. National Museum of Japanese History, Chiba, JAPAN has thousands of *Nishiki-e* printings and hundreds of printing blocks. Some sets of printing blocks don't have printed *Nishiki-e* because they were lost over the years. It is beneficial that lost *Nishiki-e* printings can be reproduced from remained printing blocks from a viewpoint of restoration of cultural assets. However, any colorants should not be put on remained printing blocks immediately because these have great historical value and should not be damaged. Establishment of digital *Nishiki-e* reproduction technology is one of constructive approaches to satisfy both conservation and utilization of *Nishiki-e* materials.

Digital reproduction of *Nishiki-e* printings requires shape information and color information. In our previous work, painting region as shape information is available by measuring printing block of National Museum of Japanese History non-destructively (Taya 2015). This paper focuses on color information. Accurate color information is essential in order to reproduce *Nishiki-e* more realistically. *Nishiki-e* has two way of representing color. One way is to put only single colorant on paper, and the other is to put more than two colorants on paper one by one. Overprinted area and kinds of colorants used in the area can be discriminated from remained printing blocks. However, the order of overprinting of colorants is hard to know with non-destructive inspection.

In this paper, a model for estimating a spectral reflectance of an overprinted area using spectral reflectance and the order of every colorant is proposed and verified. Reflectance data obtained by measuring single colorant part of *Nishiki-e* printings are applied to the proposed model, and the estimated reflectance data are compared with measured reflectance data in the overprinted area to confirm the validity of the model. The order of overprinting also can be estimated from the result of estimation of reflectance.

2. PROPOSED MODEL

The proposed model is based on Kubelka-Munk theory (Kubelka 1948). We assume that overprinted area has a kind of layered structure of colorants.

In the case of two layered structure, inter-reflectance is occurred between the layers like the optics model shown as Figure 1. Then, reflectance of the whole layer is represented by Equation (1).

$$\begin{aligned} R_{1,2} &= R_1 + T_1^2 R_2 (1 + R_1 R_2 + R_1^2 R_2^2 + \ldots) \\ &= R_1 + \frac{T_1^2 R_2}{1 - R_1 R_2} \end{aligned} \qquad (1)$$

Overprinted color part has three layers of upper-colorant, lower-colorant and paper shown as Figure 2. However, lower-colorant may be absorbed by paper. Therefore, shown as Figure 2, the proposed model is constructed with two layers of the layer of upper-colorant and the layer consists of lower-colorant and paper.

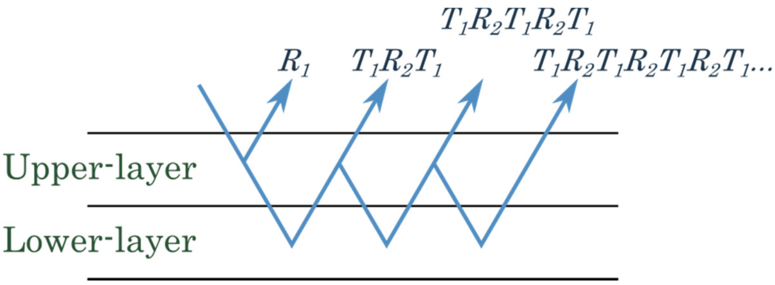

Figure 1: Optics model of two layers

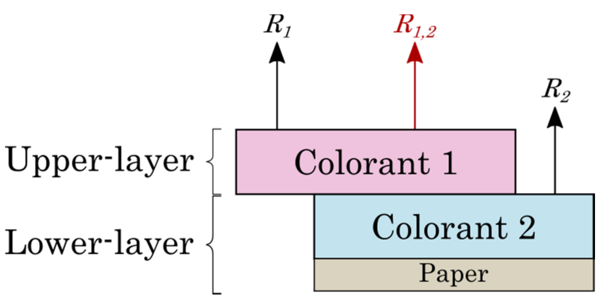

Figure 2: Layered structure of overprinted colorants

To calculate reflectance of the whole layer $R_{1,2}$, reflectance of upper-layer R_1, transmittance of upper-layer T_1 and reflectance of lower-layer R_2 are required. R_2 is measurable value from *Nishiki-e* printings, but R_1 and T_1 are immeasurable directly. They are calculated by Equations (2) and (3).

$$R_1 = \frac{1}{a + b\coth(bSD)} \tag{2}$$

$$T_1 = \frac{b}{a\sinh(bSD) + b\cosh(bSD)} \tag{3}$$

$$a = \frac{1}{2}\left(\frac{1}{R_\infty} + R_\infty\right),\ b = \frac{1}{2}\left(\frac{1}{R_\infty} - R_\infty\right)$$

In these equations, S means scattering coefficient, D means thickness and R_∞ means unique reflectance at upper-layer. Unique reflectance of layer indicates the reflectance in case that the layer has enough thickness to conceal the ground. That is, unique reflectance of layer is not influenced by the reflectance of ground at all.

Unfortunately, the unique reflectance of colorant used in *Nishiki-e* is immeasurable. There are two reasons. One is because there is not a part of colorant whose layer has enough thickness to conceal the ground. The other is because it is difficult today to generate the colorant used in those days when *Nishiki-e* printings are produced. Then, it is assumed that the method by Minato (Minato 1969) is available for colorants of *Nishiki-e*. The method estimates the unique reflectance of translucent layer from the difference of the reflectance of the layer on black ground and that on white ground. Equation (4) shows the estimation equation of the method.

$$R_\infty = \frac{-B + \sqrt{B^2 - 4A^2}}{2A} \tag{4}$$

$$A = R_w B - R_b W$$

$$B = (W - B)(1 + R_w R_b) - (R_w - R_b)(1 + WB)$$

In this equation, R_w means reflectance of layer on white ground, R_b means reflectance of layer on black ground, W means reflectance of white ground and B means reflectance of black ground. Scattering coefficient S required in Equations (2) and (3) is calculated by Equation (5).

$$S = \frac{1}{bD}\coth^{-1}\left(\frac{1 - aR_b}{bR_b}\right) \tag{5}$$

3. RESULTS AND DISCUSSION

Figure 3(a) shows the three measured points of red, yellow, and orange. Orange is overprinted by red and yellow. In Figure 3(b), the two estimated results that order is different are shown. A correlation coefficient between estimation 1 (red over yellow) and measured reflectance of overprinted colorants is 0.99, and that between estimation 2 (yellow over red) and measured one is 0.97.

Figure 3(c) shows the three measured points of blue, yellow, and green. Green is overprinted by blue and yellow. In Figure 3(d), the two estimated results that order is different are shown. A correlation coefficient between estimation 1 (blue over yellow) and measured reflectance of overprinted colorants is 0.78, and that between estimation 2 (yellow over blue) and measured one is 0.39.

In each overprinted colorants, the spectral reflectance is estimated differently by the order in which colorants overlap. Estimate results considering the order are deduced by the proposed model. About overprinted orange, estimation 1 is close to measured reflectance and the correlation coefficient of it is higher than that of estimation 2. Figure 4 is a photomicrograph of overprinted yellow. It is observed that red colorant is putted on printed yellow. The estimation is successful about the orange. However, about overprinted green, neither result is close to measured reflectance. The correlation coefficient is also the same.

4. CONCLUSIONS

A color model for estimation of overprinted color from each colorant information and its order using Kubelka-Munk theory was proposed. The estimated results were obtained from the model using the spectral reflectance of single colorants measured in *Nishiki-e* printings. The model well explains the difference of estimated spectral reflectance of overprinted colorants by the order. Estimated results of overprinted orange and green were also shown as an application of the proposed model. Reflectance of orange was estimated well compared with measured one. However, green was not estimated successfully.

In future work, improvement of the model will be required in order to be applied to various overprinted color.

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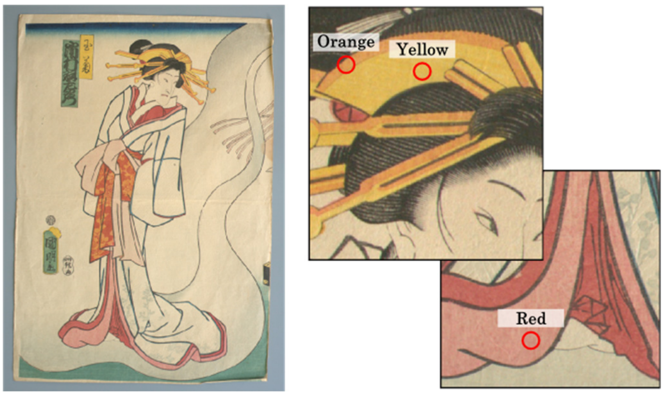
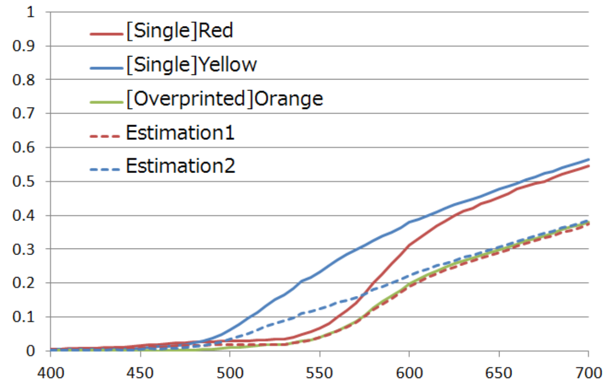
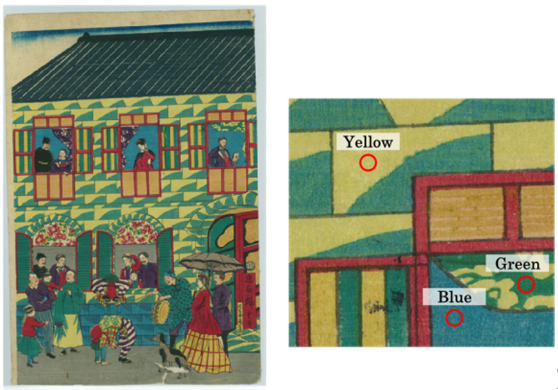


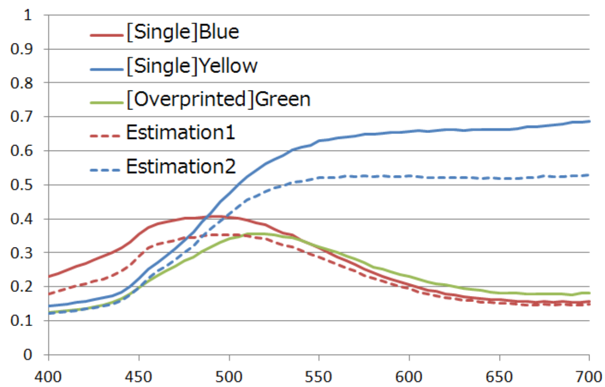
(a) Example 1: Red, Yellow, and Orange



(b) Estimated reflectance of example 1



(c) Example 2: Blue, Yellow, and Green



(d) Estimated reflectance of example 2

Figure 3: Examples of Nishiki-e Printings and these estimated results

Figure 4: photomicrographs of overprinted orange and background yellow

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Ethical Considerations on Gene Therapy for Color-Deficient People

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ABSTRACT

In 2009, a procedure for creating trichromacy in dichromatic monkeys has been proposed by Mancuso *et al*. The treatment could be used to "cure" color deficiency in human observers in the future, but to-date the method has not been adjusted and tested on humans yet. I believe that from an ethical view point the proposed method should be adjusted for humans and allowed for clinical trials, as long as the risks and harms are minimized, the treatment and its long-term benefits and risks have successfully been studied on animal trials, and as long as possible human trials follow certain international standards like for example the informed consent etc. Since color deficiency does not qualify as "real" disability, however, only somatic gene therapy as opposed to germ line therapy should be allowed, and private actors and the patients themselves should carry the main costs of development and application. From a social view point, other image improvement methods, like for example daltonization, should be prioritized for public funding in order to increase usability in general resulting in better navigation and communication for not only color-deficient people but other groups of people who have issues distinguishing color due to age, etc. as well.

1. INTRODUCTION AND BACKGROUND

The majority of people can differentiate between millions of different colors. Most scientists agree on that the perception of color leads to behavioral advantages connected to the attentional system, object recognition, and possibly detection of emotional states, as I discussed in a previous paper (Simon-Liedtke, Farup and Laeng 2015). Also, color has been used more and more in our modern world for communication in arts, navigation, traffic, and education. Color-deficient people are people that have difficulties distinguishing certain colors, however, most color-deficient people are not in fact color-*blind*. De Valois and De Valois (1993) explain that information from our eyes is processed in three distinctive pathways representing color attributes of intensity, red–green opponency and blue–yellow opponency. Most color-deficient people only have a reduced or missing perception along the red–green axis, but perceive fairly good color perception along the blue–yellow axis. In natural settings, color-deficient people might face discomfort (f.ex. collecting berries in the forest) but they are not in immediate threat of danger. It is especially in social contexts that color-deficient people are confronted with problems (Flatla and Gutwin 2012). Luckily, there are computational solutions in image processing to simulate color-deficient vision or daltonization methods that improve images for color-deficient people, as listed in a previous paper (Simon-Liedtke, Farup and Laeng 2015).

Mancuso *et al.* (2009) have proposed a procedure – aka the Mancuso-Neitz method – based on somatic gene therapy for creating trichromacy in dichromatic squirrel monkeys by injecting the missing cone pigment in the retina of dichromatic males. The procedure is implemented as somatic gene therapy, i.e. the genes are affected only in the treated cells directly (Anderson 1985), in opposite to germ line therapy, where the specific gene is modified in the genome as a whole (ebid.). Although this procedure might also be used to “cure” color deficiency in human observers, the method has not been adapted for humans to-date, and thus is not permitted for clinical trials on humans yet. Prior to approving clinical trials, there are certain international standards for these kind of clinical trials, like the Declaration of Helsinki (WMA 2013) that lists certain guidelines to ensure ethical conduct for test on humans like the right of informed consent, right to withdraw, privacy etc. On a national level, institutions and branches of government like the US Department of Health and Human Services (HHS) (1997) provide detailed guidelines about what can and cannot be done, and how it should be done, like for example that all trials have to be supervised. Therefore HHS introduces Institutional Review Boards (IRB) for monitoring trials. Furthermore, Anderson (1985) argues that the aspect of delivery, expression, and safety[1] has to be successfully fulfilled in animal studies as requirement before proceeding to clinical trials on humans. One main factor in the ethical debate about gene therapy for - people is whether this type of gene therapy would be defined either as somatic gene therapy to correct a genetic defect or as enhancement genetic engineering. In other words, whether color deficiency is defined as disability or as non-harmful anomaly. In this paper, I present arguments for and against allowing gene therapy for human observers, before I conclude with the proposition that gene therapy for color deficiency should indeed be allowed for humans under certain restrictions.

2. DISCUSSION

The ethical problem of gene therapy for color-deficient people gravitates around the two questions of if gene therapy for color deficiency should be allowed at all, and if yes, if the introduced Mancuso-Neitz therapy should be allowed for clinical trials on humans. The evaluation depends strongly on whether or not the nature of color deficiency is defined as natural variation, i.e. anomaly, or as mild disability. I argue for somatic cell gene therapy on a case-by-case analysis because it might facilitate color-deficient people to fulfill their life goals, and clinical trials have to follow certain international standards.

2.1 Is gene therapy for color deficiency ethical justifiable in general?

I argue that color-deficient people would benefit from gene therapy on a personal level but that most color-deficient people could function perfectly in society without it as well. On the one hand, banning gene therapy for color deficiency would lead to minor personal distress and discomfort for color-deficient people when navigating in social contexts, and it would manifest the exclusion of color-deficient people from certain professions like becoming a pilot, train conductor etc. Although, color-deficient people have indeed slight empirical measurable disadvantages to normal-sighted observers, I do not believe that color deficiency justifies as mild disability. Firstly, it does not lead to immediate danger or harm of the color-deficient person’s life. In opposite to other disabilities, where people would suffer a notable decrease in quality of life, and exclusion from central aspects of daily life, color-deficient people manage most important tasks without difficulties since they learned to compensate for their deficiency when growing up. Exclusion occurs only in

[1] In other words, only the targeted cells should be affected, the exogeneous gene does lead to the creation of the additional pigment, and it does not harm the cell or the whole animal.

some peripheral aspects like mentioned professions, and society as a whole can usually compensate very well for a color-deficient person who is excluded from those professions. The benefit for color-deficient level on a personal level, on the other hand, can be huge, ranking from facilitating navigation in traffic to fulfilling lifetime professions. Inclusion and self-realization of all their citizens is an important goal in many Western democracies including Norway, the USA etc. Last but not least, the Mancuso-Neitz method could lead to development of tetracromacy in trichromatic people (Jordan 2010).

In conclusion, the resulting benefit for society as a whole from curing color deficiency is not very high, and, in my opinion, would not justify heavily public funding of development of such a therapy. Moreover, I want to underline that most problems for color-deficient people occur in a society that only focus on the needs of normal-sighted, i.e. trichromatic, people. Most problems can easily be solved by implementing guidelines known from universal design and usability, i.e. making all media that use color as communication more accessible for the color-deficient and other "visually disadvantaged" interest groups, like for example the elderly, as well. For this purpose, image processing provides the possibility of daltonization, i.e. the automatic image enhancement for the color-deficient, and other image enhancement methods. Also, I argue that it is unjustified to realize the treatment as a germ line therapy, meaning to change the genetic code in the genome such as to extinguish color deficiency altogether, since the effects of changing the gene pool are firstly hard to comprehend and do not justify the means, similar to the arguments about germ line therapy by Anderson (1985) in general. However, I do believe that gene therapy for color deficiency should be allowed as somatic gene therapy, if funded privately, since the presented therapy could help many color-deficient people to increase their personal quality of life, enable democratic inclusion and help them to fulfill lifetime professions.

2.2 Is the Mancuso-Neitz color deficiency gene therapy ready for clinical trials?

General ethical aspects circulate around the question of risks and harms for the health of people and animals involved in the process of developing the final treatment, and patients of the final treatment. In order to allow the presented Mancuso-Neitz method for clinical trials, we have to guarantee the integrity of health, human rights and the dignity of people and animals involved. Harms and unnecessary danger have to be averted. The current method to-date has only been tested on squirrel monkeys, on which it does not seem to have any negative effects, but the authors have not sufficiently listed long-term consequences of the treatment for the animals. If the presented results from Mancuso *et al.* (2009) are true, the results suggest sufficient integrity according to Anderson's (1985) three requirements from animal studies. Namely, only cones have been affected, the modulated genes did create the additional and intended pigment, and no other cells were harmed. However, further studies have to be conducted on animals as well to document and investigate long-term effects. If these studies, too, test satisfactorily, the method could be allowed for human clinical trials given they comply with international standards defined by for example the HHS (1997) or the Declaration of Helsinki (WMA 2013). I argue that a new chapter for clinical trials on humans could be opened given that the long-term effect of the treatment have been studied on animals, an exact overview over benefits and risks of the treatment has been documented, and as long as the trials follow international standards like the right to informed consent, and the trials are planned and monitored according to national and international standards guaranteeing the reduction of risks for the patients. Moreover, as discussed before, I believe that the financial costs of the development should not be handled by the general public but by private actors.

3. CONCLUSIONS

In conclusion, I argue for the case of gene therapy for color-deficient on an individual level if international standards are fulfilled for the treatment, the risk is reduced to a minimum for the patient, and private actors handle the costs. Public funding should better be spent on other solutions that may help both color-deficient people and other groups with color vision that differ from the majority like for example the elderly. More precisely, the focus should be put on usability and daltonization. Concerning the Mancuso-Neitz gene therapy, I argue that clinical trials should be allowed if patients of this clinical trials are treated according to guidelines of international standards like informed consent, information about the risks etc., and the research is financed by private actors or the patient him/herself.

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Robust Cross-Domain Reflectance Estimation

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ABSTRACT

A common step in multi-spectral imaging is the estimation of spectral reflectances from camera responses. Most practical spectral reconstruction methods rely on examples to learn a transformation from camera responses to reflectances. The main problem then lies in the selection of the training samples. It is often impractical to produce the required number of samples for a given algorithm and application. Instead, samples from a different "domain" are used: a standard color chart or printed samples. We compare the performance of linear and non-linear estimation algorithms, paying particular attention to the effect of using training and test samples from different domains, in our case different printers and papers.

1. INTRODUCTION

Color measurement using camera systems requires a transformation from the camera space to standardized color spaces. A common step in multi-spectral imaging is therefore the estimation of spectral reflectances from camera responses, which then allow for the calculation of most common colorimetric properties. Most practical spectral reconstruction methods rely on examples to learn a transformation from camera responses to reflectances.

The main problem then lies in the selection of training samples. It is often impractical to produce the required number of samples for a given algorithm and application. Instead, samples from a different "domain" are used: a standard color chart, printed or painted samples, depending on the application. The word "domain" refers to any systematic differences influencing the measurement results. Different paper types, printing inks, measurement conditions or gloss levels could all be seen as separate domains.

This is problematic because spectral estimation is an underdetermined problem, where the number of camera channels is typically much lower than the number of spectral bands to be estimated. One way to improve results is to incorporate prior knowledge about the reflectance domain, either directly through regularization (Heikkinen et al. 2007) and sparse representations (Zickler et al. 2006; Zhang et al. 2012; Lansel, Parmar, and Wandell 2009), or indirectly through an adaptive learning algorithm that is capable of capturing structural properties of the training data (Bengio, Courville, and Vincent 2012; a. Mansouri, Marzani, and Gouton 2005).

In this work we use the example of print inspection: we want to estimate the reflectance spectra of colors produced by a particular printer, but for training only standard color charts or samples printed on a different printer and paper are available.

2. METHOD

2.1 Spectral Reconstruction

The estimation of spectra from camera responses can be achieved by inverting the image formation process or by learning a transformation from examples.

Examples of direct spectral reconstruction (inversion of the image formation process) are the spatial Wiener filter (Shimano 2006) and an extension that includes a deblurring component (Christoph Godau and Urban 2013). We do not consider spatial information in this work, although it is possible to extend most approaches this way. The main advantage of spatial approaches are increased robustness to noise and preservation of structure in the image (Urban, Rosen, and Berns 2009), both of which are not relevant in our study since we perform measurements on relatively large and homogeneous regions.

A large number of indirect (learning-based) methods have been proposed for spectral estimation. In principle, any multi-dimensional regression method may be used. The simplest approaches estimate a linear transformation from camera responses to spectral reflectance, for example using the Moore-Penrose pseudoinverse or an iteratively reweighted robust least squares method (Dumouchel and O'Brien 1992).

More complex approaches add regularization and non-linear components to the estimation process (Heikkinen et al. 2007). We include the log-kernel estimation method in our comparison (Eckhard et al. 2014), which performs well for spectral estimation on printed samples with a camera system very similar to the one used in our experiments.

Another common approach is the use of a more compact representation for reflectance spectra. Each spectrum can then be described with a small number of coefficients or parameters, which may reduce the effect of noise and potentially makes it easier to invert the previously underdetermined system. There are many ways to obtain such representations, both linear (A. Mansouri et al. 2008; Kohonen, Parkkinen, and Jääskeläinen 2006) piece-wise linear (Lansel 2011) and non-linear (Tenenbaum, de Silva, and Langford 2000). We performed tests using these methods, but found that the reduced representations are most useful for estimation from very low dimensional systems (such as RGB).

2.2 Experimental Set-up

We use data from the following domains (different printers and papers) for our experiments:

- **Inkjet HP (IJ_HP):** Chart printed on an HP Z3100 7-ink system (CMYKRGB) on high-gloss photo paper.
- **Inkjet Epson (IJ_EP):** Chart printed on an Epson R2880 9-ink system (CMYK+light/vivid variants) on semi- to high-gloss paper.
- **Offset A (OFS_A):** Chart printed by a commercial CMYK offset printing service in high quality on semi-gloss paper.
- **Offset B (OFS_B):** Chart printed by a commercial CMYK offset printing service in normal quality on thinner semi-gloss paper.

On each system we printed the same color chart containing more than 2000 randomly colored patches. We then measured each patch using a spectrophotometer[1] and obtained camera response data using a 12-channel multi-spectral system[2], taking the average of the central region from each patch to reduce effects of noise, and normalizing responses to the [0,1] range. From each chart we then selected 1000 patches, maximizing the spectral

[1] XRite i1iSis, http://www.xrite.com/i1isis-with-obc

[2] Chromasens TruePIXA Multi-spectral line scan camera, http://www.chromasens.de/en/multi-spectral-camera-truepixa

difference between selected colors. The spectra and camera response data is available in the supplementary materials[3].

In our experiments we use the following learning-based methods for reflectance estimation:

- **Linear: Least Squares (LSQ):** Direct linear least-squares using the Moore-Penrose Pseudo-Inverse.
- **Linear: Robust Least Squares (RLSQ):** An iteratively reweighted least squares method, giving less weight to outliers[4].
- **Non-Linear: Neural Network (NN)**: A neural network with one hidden layer of size 12 trained using backpropagation[5].
- **Non-Linear: Log-Kernel (LKL):** The logarithmic kernel method which has previously been shown to perform well using a set-up similar to ours (C Godau et al. 2013), using the suggested parameters from (Eckhard et al. 2014) [6]

Note that the main goal is not the direct comparison of the reconstruction results, but rather of the methods ability to generalize across domains. Given sufficient knowledge about an application, the results reported here could likely benefit from adjusting relevant parameters or choosing an alternative representation. In particular we compare the generalization properties of linear vs. non-linear methods.

We then used each of the 4 sets to train the algorithms and evaluated the reconstruction quality using the CIEDE2000 color difference formula (Sharma, Wu, and Dalal 2005). Due to space restrictions we only present the mean error for each result, for more details please refer to the supplementary material. To avoid using the exact same data for training and testing, we used 10-fold cross-validation when test and training set were identical (diagonals in the result matrices in Table 1).

3. RESULTS AND DISCUSSION

The error matrices for the algorithms using all 12 camera channels are shown in Table 1, where columns indicate the training set and rows the test set. All methods performed well when test and training data where from the same domain (diagonals of each matrix), with the best result for each combination of training/test domain indicated in bold. Using the median instead of the mean resulted in overall smaller numbers, but the overall trends remained the same.

The biggest errors occur for the Inkjet HP chart; in particular the non-linear methods (neural net and log-kernel) performed much worse than the linear methods in estimating the HP Inkjet's spectra. This is probably due to the glossy paper, additional inks (RGB) and larger gamut of the printer. The differences in spectral properties can lead to arbitrarily

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[3] http://www.idd.tu-darmstadt.de/re_search/colorg/color_publications/index.en.jsp

[4] Implemented using MATLAB and Statistics Toolbox Release 2014b, The MathWorks, Inc., Natick, Massachusetts, United States.

[5] Implemented using MATLAB and Neural Network Toolbox Release 2014b, The MathWorks, Inc., Natick, Massachusetts, United States.

[6] Implemented using the original code available online at http://www.ugr.es/~colorimg/suppl_docs/log_kernel.html

large errors depending on the properties of the non-linear terms, while linear methods typically perform consistently even for extrapolation. This problem actually becomes worse with a higher dimensionality.

Table 1: Error matrices for spectral reconstruction using 12 camera channels. Columns indicate the training domain, rows the test domain. Numbers show the average CIEDE2000 color differences to the spectrophotometer measurements, the best result for each training/test combination is highlighted in bold. When training and test sets are identical, we use 10-fold cross-validation.

LSQ	IJ_HP	IJ_EP	OFS_A	OFS_B
IJ_HP	**1.25**	**1.79**	2.11	**2.07**
IJ_EP	**0.89**	**0.37**	0.82	1.05
OFS_A	**0.81**	**0.58**	0.42	0.86
OFS_B	**0.98**	**0.78**	**0.78**	0.32

RLSQ	IJ_HP	IJ_EP	OFS_A	OFS_B
IJ_HP	1.98	1.82	**1.94**	2.54
IJ_EP	1.48	**0.37**	**0.62**	**1.02**
OFS_A	1.37	0.71	**0.41**	**0.81**
OFS_B	1.52	0.94	0.79	**0.31**

NN	IJ_HP	IJ_EP	OFS_A	OFS_B
IJ_HP	1.82	2.19	8.78	7.38
IJ_EP	2.30	0.29	1.33	1.33
OFS_A	2.20	0.74	0.48	1.35
OFS_B	2.00	0.97	0.78	0.36

LKL	IJ_HP	IJ_EP	OFS_A	OFS_B
IJ_HP	1.50	2.56	2.97	2.89
IJ_EP	23.70	**0.22**	1.11	1.24
OFS_A	21.33	1.05	0.43	0.88
OFS_B	20.32	0.99	0.99	**0.31**

Table 2: Error matrices for spectral reconstruction using 3 channels (RGB).

LSQ	IJ_HP	IJ_EP	OFS_A	OFS_B
IJ_HP	4.91	5.33	5.43	**4.71**
IJ_EP	**2.73**	2.07	2.50	2.33
OFS_A	**2.22**	1.93	1.78	1.81
OFS_B	**2.55**	2.39	2.29	1.69

RLSQ	IJ_HP	IJ_EP	OFS_A	OFS_B
IJ_HP	5.27	4.97	5.86	4.91
IJ_EP	4.24	1.49	2.62	2.25
OFS_A	3.74	1.94	1.86	1.79
OFS_B	3.16	1.99	2.41	1.71

NN	IJ_HP	IJ_EP	OFS_A	OFS_B
IJ_HP	2.65	**4.24**	5.53	5.42
IJ_EP	12.02	0.59	2.08	2.04
OFS_A	10.78	**1.56**	**0.68**	1.46
OFS_B	12.88	1.35	1.33	**0.46**

LKL	IJ_HP	IJ_EP	OFS_A	OFS_B
IJ_HP	**1.95**	4.52	**5.10**	5.60
IJ_EP	8.24	**0.45**	**2.00**	**1.78**
OFS_A	7.57	**1.56**	0.70	**1.44**
OFS_B	6.98	**1.34**	**1.25**	0.48

Overall, the linear estimators performed best on 12-channel data across domains. The log-kernel method performs well when training and test data are from the same distribution but performance deteriorates significantly when the data sets are different. The neural network performs does not perform particularly well in any combination, but the maximum errors are significantly lower than for the log-kernel.

In most camera systems the number of available channels is however much smaller. We therefore also tested the performance for a lower number of channels by only using 3 of the 12 available channels of our system (RGB). Surprisingly, the non-linear methods performed *better* in a number of configurations with only 3 channels than with 12. Table 2 shows the results for this scenario. While large differences between test and training sets are still a problem, both the neural net and the log-kernel significantly outperform the linear approaches, except for the problematic Inkjet HP data set. Another interesting result is that the "robust" least squares method appears to be more sensitive to domain changes than regular least squares, probably because it fits the training set more closely by giving less weight to outliers.

4. CONCLUSIONS

The non-linear methods (neural net and log-kernel) appear to be more sensitive to differences between test and training data, particularly when the dimensionality of the camera space increases (this might be an example of the *curse of dimensionality)*. For low-dimensional spaces, the advantage of a non-linear estimation is significant, but overfitting remains a problem when training and test domain differ significantly.

When the dimensionality of the camera system is sufficiently high (>6 channels in our case), a linear least squares solution provides the best results in terms of overall colorimetric error, especially across domains. Non-linear approaches provide significant benefits only when the training and test domains are similar *and* the number of camera channels is small.

It is obvious that all of these results heavily depend on the selected domains. The spectra of printed samples presumably have a low effective dimensionality (roughly proportional to the number of inks), other samples such as natural reflectances would most likely lead to different results.

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Colorama: Extra Color Sensation for the Color-Deficient with Gene Therapy and Modal Augmentation

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ABSTRACT

Color-deficient people may be confronted with disadvantages and discomfort when navigating through a society that relies heavily on color as medium of communication in their daily lives. Daltonization as automated methods to improve color images for color-deficient people has traditionally been proposed by the field of image processing. Also, Sensory Substitution Devices from vision-to-touch or vision-to-hearing have been developed for the blind, and could be adapted to the needs of the color-deficient as well. And last but not least, a gene therapy for creating trichromacy in dichromatic monkeys has been proposed that might be applicable for humans as well in the future. All three approaches can be used to facilitate the life of color-deficient people with different up- and downsides to each method. Firstly, gene therapy holds the promise of a complete cure and regain of the lost color perception, while being highly intrusive and holding still unknown costs, risks and long-term effects on the patients' health. Secondly, SSDs provide an approximate substitution of the lost color sense, at the same time as it is somewhat intrusive and cannot copy all aspects related to the attributes of colors to a full degree. Thirdly, daltonization is probably most effective and can even help other groups of people that have problems distinguishing colors like the elderly, but it cannot fully emulate lost color perception. I argue that, while all three methods can promise interesting results, daltonization should be the method in focus of public attention when evaluating all alternatives in the light of usability and accessibility.

1. INTRODUCTION

Color deficiency exists in about 8% of the male population. Color-deficient people have problems distinguishing certain colors, or do not perceive certain colors at all. Most color-deficient people have problems with colors along the red–green axis. The problems of color-deficient people are closely related to reduced usability and accessibility in daily life situations. Discomfort and problems for color-deficient people in daily life are closely connected to social settings where our society heavily relies on color-coding as can be seen on how color is used in geographic maps, advertising, communication etc. We might use so-called daltonization methods, Sensory Substitution Devices (SSDs) – most commonly realized as vision-to-touch or vision-to-hearing – or even gene therapy. To evaluate each method, it makes sense to use categories such as efficiency, costs, feasibility etc. with special focus on the improvement in the light of accessibility and usability for a lesser or greater extend of people. In this paper, I am going to present the different methods, discuss their advantages and disadvantages in order to answer the question, how each of the presented approaches might help to increase accessibility and improve usability of electronic media for color-deficient people.

2. BACKGROUND

Daltonization methods are automated methods from the field of image processing to increase image quality for color-deficient people, some of which are mentioned in a previous paper (Simon-Liedtke, Farup and Laeng 2015). Daltonization methods help to regain lost information and to facilitate differentiation of colors that are otherwise hard to distinguish for color-deficient people by increasing global and/or local color contrast. Daltonization methods can be implemented on practically any computing device and various applications like for example on computers, smart phones, printers etc., for web browsers, camera interfaces, etc., as color profiles, filters, lookup-tables etc.

Sensory Substitution Systems (SSDs) have been developed mainly for the blind to translate visual information into other senses, like for example into touch and/or hearing by "systematically converting properties of vision […] into auditory properties […] or tactile properties […] by means of a man-made device" (Ward and Wright 2014). Ward and Wright (ibid.) mention several implementations related to the two main categories of Haptic SSDs, i.e. SSDs that translate to the sense of touch, and Auditory SSDs, i.e. SSDs that are translate to the sense of hearing. Haptic SSDs are for example the TVSS and the TDU that project tactile information to the back or the tongue of the user respectively (ibid.). In terms of Auditory SSDs, devices like "seeColOr" that encodes color as orchestral instruments, "The Vibe" or "The vOICe" that convert a two-dimensional gray-scale image into a two-dimensional sound image have been mentioned by Ward and Wright (ibid.). Also, the "eyeborg" project by Harbisson and Montandon (2013) deserves to be mentioned, in which a chip that is permanently attached to the back of the head of achromats maps light frequencies to sound frequencies, making color "hearable"

Mancuso et al. (2009) proposed a somatic gene therapy to create trichromacy in dichromatic squirrel monkeys. The treatment consists of a viral injection caring an L-opsin gene into the retina of male squirrel monkeys: A specie, of which females are usually trichromats whereas and of which males are dichromats. After the treatment, male squirrel monkeys displayed a clear trichromatic behavior. To-date, however, there are no published studies about the applicability for humans and/or long-term effects on the health of the squirrel monkeys.

Universal Design is defined by The Center for Universal Design (CUD) (2008) through a quote of Ron Mace as "the design of products and environments to be usable by all people, to the greatest extend possible, without the need for adaptation or specialized design". In universal design, we take into consideration the fact that people or groups of people have different needs and possibilities, which we do have to take into account when designing an (interactive) media outlet. CUD (1998) lists therefore seven principles facilitating the implementation of a successful universal design, including equitable use, flexibility, simplicity, perceptibility, error tolerance, low physical effort, and size and space. An important aspect of universal design is the question of usability, i.e. "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO 1998). A usability evaluation should measure to which extent a color-deficient user is able to extract-correct visual information from a photography or an information graphic like maps, public transportation schedule etc. Next to the principles of universal design and usability, I include the following aspects of the discussed methods: Firstly, if there is any notable improvement for the color-deficient users, secondly, the aspect of practicality and feasibility, and, thirdly, the aspect of intuition and training.

3. DISCUSSION

Daltonization methods do not help color-deficient people to actually perceive more colors, but they help to change colors in a way that colors that are otherwise easily confused become more distinct from each other. These methods reach their limit in cases where a lot of colors are present in an image and the possibilities of rearranging color contrasts get exhausted. By contrast, most daltonization methods are efficient in terms of costs and computation. They are also easily implementable on most electronic output devices like computers, smart phones etc. for both screens and prints – after prior pre-processing. They can be realized as filters, apps, lookup-tables etc. making it easy to use for every color-deficient person that owns a smart phone, tablet or computer. Moreover, daltonization follows the usability guidelines of equitable use, flexibility, perceptibility, low physical effort, and size and space. I believe that the easy availability of daltonization methods, especially in combination with color deficiency simulation methods as listed in a previous article (Simon-Liedtke, Farup and Laeng 2015) also helps to increase awareness for color deficiency in normal-sighted people, since normal-sighted people as well can try out daltonization without huge costs or effort.

On the one hand, SSDs require a certain adaptation period before enabling simple and intuitive use, even though most participants reported to have adapted very well after the initial training phase (Ward and Wright 2014). Some implementations do not provide lesser physical effort with respect to the CUD guidelines, especially in the case that tactile information is obtained through fingers. However, other devices have been proposed that are attached to the body directly without further interaction (ibid.). Also, the physical nature of visual, haptic and acoustic stimuli may lead to obstacles. Consider for example the range of the senses: Things can be seen from very far away, whereas sound has undeniable range limitations, and touch can basically only be perceived from very nearby. This would make it difficult to translate certain visual information into other senses. Furthermore, SSDs might interfere with other stimuli. If sound is for example being used to transport color, there will be problems in conversations with others. Last but not least, SSDs are somewhat intrusive because it means that the color-deficient person has to carry around additional devices, like for example the “eyeborg” prosthetic, that might even be somewhat expensive. On the other hand, SSDs can make colors truly sensible: Harbisson, for example, reported that he actually started to hear colors (Harbisson and Montandon 2013). Ward and Wright (2014) point out that SSDs might lead to artificially acquired synesthesia, i.e. that participants start to both hear and see colors, respectively both feel and see. The argument of device costs can be limited to the degree that most modern smart phones are already capable of giving haptic or auditory feedback, a fact that might reduce costs and intrusiveness of SSDs. And last but not least, SSDs can be combined with virtually any form of sensor that measures any kind of electromagnetic radiation or fields, thus it might enable people to perceive UV- and/or NIR-radiation, electronic and/or magnetic fields etc.

Admittedly, gene therapy is a somewhat young field of research to-date, such that the full extend of the treatment, long-term risks and harms, costs etc. are not fully comprehensible. There are certain shortcomings in the documentation of aspects related to safety in the gene therapy study by Mancuso *et al.* (2009). And since no adaptation has been made for humans, there is no prediction about costs and harms for humans; let alone if the procedure is even applicable for humans. Moreover, the procedure is highly intrusive since it alters the genetic code of the participant. On the other hand, though, it is the solution that truly “cures” color deficiency leading to the only real sensation of the color dimensionality that is lost for color-deficient people. Moreover, it could be used to create tetrachromacy, i.e. the ability to perceive more colors than normal-sighted people can (Jordan *et al.* 2010)

4. CONCLUSION

Daltonization provides effective and easily implementable help of improving media outlets but it cannot create additional visual perception. SSDs show deficits concerning simplicity, physical effort, nature and range of the stimuli, integrability, compatibility and costs but provide huge advantages of SSDs related to equitable use, flexibility, perceptible information, error tolerance, size and space, and creation of a truly new sense. Thirdly, gene therapy raises question concerning safety and feasibility at the possibility of truly curing color deficiency. I, as a computer scientist, believe that daltonization to-date surely provides the best solution in daily life in the light of universal design, at the same time as the possibilities of SSDs and gene therapy should be further investigated.

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Benchmarking a Grating-Based Spectral Imaging System

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ABSTRACT

Spectral imaging system handles image signals in spectral form. Different approach can be used to generate spectral image. Early spectral camera system uses tunable liquid crystal tunable filter for capturing narrow band signals. Newer multi-filter camera system uses optimized filters with monochromatic camera to captures spectral data and then to numerically process the data into finer spectral resolution. Another example is two-filter RGB camera system that captures image with RGB CCD sensor array through specifically optimized filter pair. Numerical process is followed to reconstruct the full spectral range. Active illumination is also a new approach proposed for faster acquisition of image in spectral form. A gating-based spectral imaging system is used by the authors as well. Each method deploys different hardware device resulting in difference color reproduction perfromance. In this study the colorimetric performance for spectral imaging system is under investigation. Two different calibration procedures were performed in the grating-based spectral imaging system. The 24-color ColorChecker were used as the baseline test target to generate color difference values as the performance metrics. Results indicate that this grating-based spectral imaging system is capable to yield similar colorimetric performance than the other spectral imaging system. With tighter calibration procedure, it has the potential to generate even better colorimetric performance than the other spectral imaging system. Nevertheless, all the spectral imaging systems studied here perform better than conventional RGB camera in color reproduction accuracy.

1. INTRODUCTION

Spectral imaging system is gaining more attention not only from the technical development point of view but also for the actual application of high accuracy color reproduction. There are various approaches to configure the imaging system to acquire imaging data in spectral form. One common way is to use optimized filters to capture integrated signals and reconstruct the spectral data by known vector characteristics (Berns et al., 2005a; Imai and Berns, 2009). Another newer way utilizes active illumination, like LED or DLP projector, to generate spectrally selected signals to reconstruct the full spectral data (Tominaga and Horiuchi, 2012). The other way uses grating-type device to capture the spectral signals directly. Each approach may deploy different hardware device or different computation method, therefore results in different operation procedures and colorimetric performance. There are different operational merits, like faster to capture or easier to process for different approaches among these spectral systems. However, it is the colorimetric performance that is focused in this study.

Some of the colorimetric performance analyses of high-end RGB digital camera in museum community can be found in prior benchmarking studies (Berns et al, 2005b; Frey and Farnand, 2011). Berns' more recent study summarized the colorimetric benchmarking of museum imaging system: average color accuracy in 2005 for four museums was 12.4 $\triangle E^*_{ab}$; average performance improved to 8.9 $\triangle E^*_{ab}$ among 22 participating museums in the range between 4.25 to 17.15 in 2010 (Berns, 2012). For more recent camera back systems incorporating color management default camera profiles, the average $\triangle E^*_{ab}$ for ColorChecker are ranged from 6.6 to 9.8 (Berns, 2012). These results are based on high-end RGB (tri-chromatic) cameras.

For spectral imaging system, the RIT Dual-RGB approach included a filter slider that can sequentially place two custom color filters to capture image. When optimized to minimize average $\triangle E^*_{ab}$ for the ColoeChecker, the colorimetric accuracy was reported for average $\triangle E^*_{ab}$ at 1.1 and 0.7 in $\triangle E^*_{00}$. Other custom-made test targets were also verified (Berns, 2012). On the other hand, an active spectral illumination approach is proposed at Chiba University. A special light source which is capable of emitting arbitrary spectrum in high speed was used with three algorithms (Tominaga and Horiuchi, 2012; Fong et al., 2008). The best colorimetric accuracy for mini ColorChecker was reported for average $\triangle E^*_{ab}$ at 1.88 with maximum $\triangle E^*_{ab}$ at 3.90 when narrowband algorithm was used. These prior results provide good references in benchmarking the colorimetric performance of spectral imaging systems.

In addition a grating type device, spectrograph, is capable to disperse incoming light into spectrum. With 2-D monochrome CCDs and X-Y scan-bed, a spectral scanning system can be established. It is the objective of this study to perform the colorimetric benchmark for this spectral scanning system that is used by the authors. The results are provided for general reference as one example of spectral imaging systems.

2. METHOD

A gating-based device (spectrograph by Specim) is deployed in this research to establish a spectral imaging system for digital archive of small museum objects. A special Xeon light is used as the illumination. Two optical fibers guide the illumination to both sides of the lens to form a 45/0 geometry. The image is captured in line-by-line manner. The incoming light of every pixel on the line is dispersed by the spectrograph into a series of spectrum perpendicular to the line direction to be projected on a monochromatic 2-D CCD sensor array. The two-dimensional signals on the CCD sensor array comprise the spectral signals on every pixel of the scan line.

The light source, lens, spectrograph device and monochrome CCD camera are mounted on an X-Y scan bed as shown in Figure 1. Each scan line includes 1600 pixels and each pixel consists of 800 samplings from different wavelengths in the visible bandwidth, which are consequently interpolated into samplings from 390 nm to 730 nm in 10 nm increments. Each wavelength reading is recorded in 12-bit encoding by the monochrome CCD camera. This configuration can avoid the potential registration problem from multiple exposures. After calibrating to a known reference standard and post-processing, spectral reflectance factor for every pixel can be generated. Colorimetric accuracy can be estimated by computing the color difference between the measured spectral reflectance factors of the original test color patches and the spectral reflectance factors of the reproduced values. Both $\triangle E^*_{ab}$ and $\triangle E^*_{00}$ are generated in D65 for comparison with prior studies. Average and maximum color difference are reported.

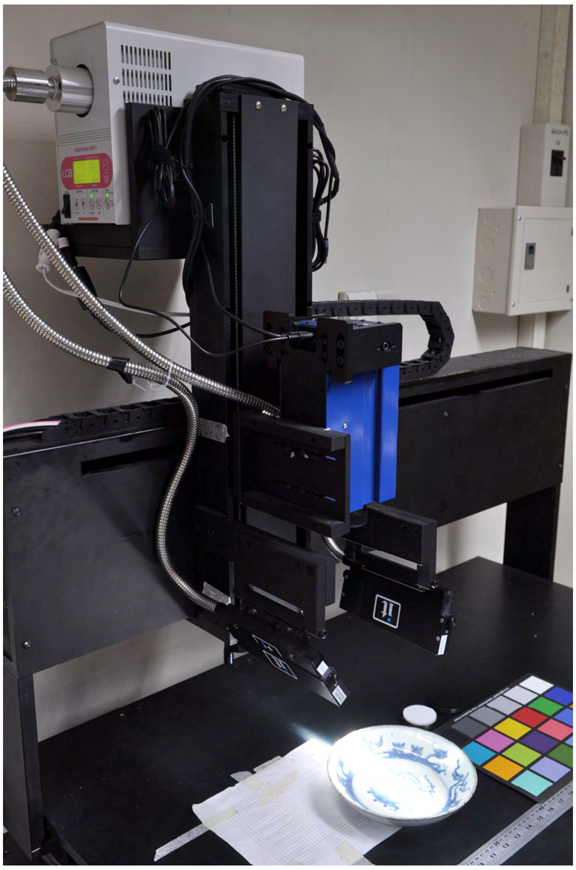

Figure 1: Spectral imaging system used in this study.

2.1 Sample Preparation

An X-rite mini ColorChecker (Passport) wae used as the testing target. The spectral reflectance factors of the 24 color patches were measured using a GretagMacbeth SpectroEye spectrophotometer. A pair of Labsphere reference target (2% and 99%) were used as calibration references as shown in Figure 2 altogether. A MATLAB program is developed to perform the calibration and to process all the spectral data.

Figure 2: Test targets and reference targets used in this study.

2.2 Experimental Procedure

This spectrograph with CCD camera generates 12-bit raw signals. After calibrating the raw signals with reference standards, spectral reflectance factor can be computed. In this study two rounds of calibration procedures are reported. The first one only uses two independent reference targets (2% and 99% Labsphere patches) in the calibration procedure. The 24 color patches in the ColorChecker Passport are used as independent test samples to verify the calibration results. After analyzing the first results, the second calibration procedure is proposed. Since the ColorChecker includes six levels of neutral color and its size is not to large, it is then feasible to just take the six neutral colors as the calibratoion references and to use the rest eighteen colors as independent test targets. It is assumed that more neutral targets can improve the reproduction accuracy within the calibration (linearization) process. This is the idea behind the second procedure.

3. RESULTS AND DISCUSSION

Two sets of color difference values are computed. The first procedure just uses a black and a white independent references to perform the calibration. The second procedure uses 6 neutral colors as reference to perform the calibration. Table 1 summarized the testing resutls in $\triangle E^*_{ab}$ units. Procedure one uses two independent reference targets, therefore the 24 color differences in the average of 2.11 $\triangle E^*_{ab}$ can be considered as the colormetric performance under this circustance, while the maximum difference is 4.40 $\triangle E^*_{ab}$. Procedure two takes the 6 neutral color patches in the ColorChekcer as the calibration (linearization) references, therefore taking the rest 18 colors to compute the average color difference reveals more independent information. It can be seen that procedure two yields better results than procedure one for the averaged 18 colors, which implies a larger range of linearization in this configuration can improve the performance. The averaged 6 colors is from the 6 neutral color patches in the ColorChecker, which is provided for cross-check.

Table 1. Summary of the results from the two procedures in $\triangle E^*_{ab}$. (noted for the small difference)*

Procedure/ $\triangle E^*_{ab}$	24 Colors (ave)	18 Colors (ave)	6 Colors (ave)	24 Colors (max)	18 Colors (max)	6 colors (max)
Black and White	2.11	2.45	1.10	4.40	4.40	2.42
Six neutral levels	0.827*	0.829*	0.821	1.81	1.81	1.10

Table 2. Summary of the results from the two procedures in $\triangle E^*_{00}$.

Procedure/ $\triangle E^*_{00}$	24 Colors (ave)	18 Colors (ave)	6 Colors (ave)	24 Colors (max)	18 Colors (max)	6 colors (max)
Black and White	1.19	1.28	0.91	1.72	1.69	1.72
Six neutral levels	0.52	0.42	0.821	1.40	0.65	1.40

The same data are computed in $\triangle E^*_{00}$ and is summaried in Table 2. As shown in Table 2, the trend is similar that procedure two yields better performance than procedure one. However, there is one exception that when finding the maximum difference, it always falls in the neutral color group in $\triangle E^*_{00}$ units for both procedures. When computed in $\triangle E^*_{ab}$ units, the maximum difference is always found not in the neutral color group. The different weightings in the two color difference formulas may cause the shift. This variation might deserve some attention in the museum community while selecting color different formula as performance metrics. Further studies might be needed though.

Another possible future work is to use just the darkest and lightest neutral color patches in the ColorChecker to perform the calibration for comparison. The other possible work is to use six independent color patches, like the Labsphere targets, as reference standards from dark to white for comparison. It is preferred though to use the ColorChecker's nutral colors for the calibration since this mini ColorChecker is so small that can be included in the scan easily. These can be good topics for future studies. Nevertheless, all these results are good benchmark values for this grating-type spectral imaing system.

4. CONCLUSIONS

There are various approaches to establish spectral imaging system. This study used grating-type spectrograph device to build a spectral scanning system. With a basic calibration procedure (reference to a black and a white patch), this system can reach an average color differnce for ColorChecker at 2.11 $\triangle E^*_{ab}$ or 1.19 $\triangle E^*_{00}$ with maximun difference at 4.40 $\triangle E^*_{ab}$ or 1.72 $\triangle E^*_{00}$. If tighter calibration (linerization) is used with the 6 neutral color patches in the ColorChecker, this system can reach an average color differnce for 18 chromatic colors in the ColorChecker at 0.83 $\triangle E^*_{ab}$ or 0.42 $\triangle E^*_{00}$ with maximun difference at 1.81 $\triangle E^*_{ab}$ or 0.65 $\triangle E^*_{00}$. These provide a benchmark reference for this grating-type spectral system. It is within a similar range for the colorimetirc performance of the other spectral imaging systems.

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Experimental Evaluation of Chromostereopsis with Varying Spectral Power Distribution of Same Color

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ABSTRACT

On the assumption that chromostereopsis is caused by chromatic aberration of the eyes, not only color but also the spectral power distribution (SPD) of observed light should affect the phenomenon. To confirm this, we displayed two color patches with different SPDs but the same chromaticity values on an LCD and compared their depth impressions. The SPD of the LCD's backlight can be changed by selecting band-pass filters attached in front of the light source. One color patch had an SPD consisting of a single peak at one wavelength, the other had one consisting of two peaks at different wavelengths. Evaluation results show that the former seems to be placed in front of the latter.

1. INTRODUCTION

Choromostereopsis has been well known for over a hundred years as a visual illusion in which color affects depth perception [Hartridge 1918; Howeard 1995]. For example a red patch next to a blue patch on a black background is often perceived as being in front of the blue one (Fig. 1). The wavelength of red light is longer than that of blue light. Therefore chromostereopsis is thought to be caused by a chromatic aberration of the eyes. There are two models for explaining chromostereosis; longitude chromatic aberration and transverse chromatic aberration. However, with the former, the effect of monocular stereoscopy is weak. In addition, it is difficult to explain by longitude chromatic aberration why a minority of observers perceive blue in front of red. For these reasons, transverse chromatic aberration is thought to be the major factor in chromostereopsis [Vos 1960; Kishto 1960; Sundet 1976; Faubert 1994] (Fig. 2). Recently, several models explaining chromostereopsis [Sundet 1972; Ye et al. 1991; Kitaoka 2006] and

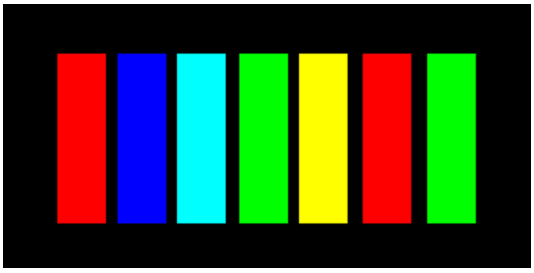

Figure 1: Color chart for confirming effect of chromostereopsis. Each colored rectangle is the same size.

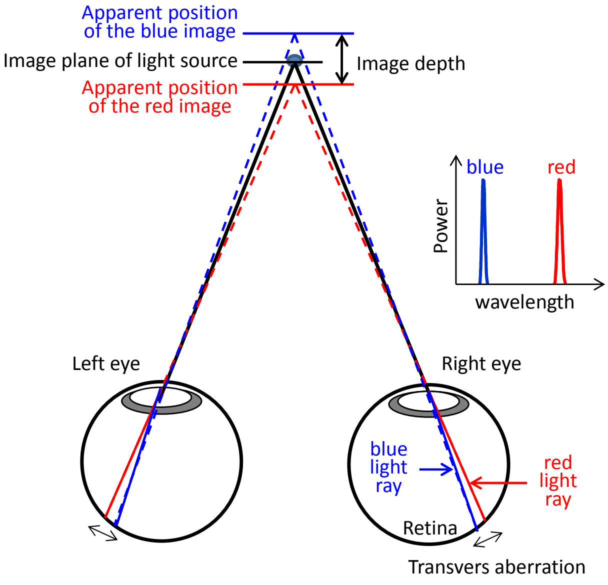

Figure 2: Transverse chromatic aberration model. Incident light ray (e.g. red and blue) is divided into two by refraction and transvers aberration occurs. This causes different apparent position of each color image.

methods for enhancing the stereoscopic effect [Steenblik 1987; Bailey et al. 1998; Ucke et al. 1998; Schemali et al. 2014] have been proposed.

Most previous research has only dealt with monochromatic light, i.e. light whose spectral power distribution (SPD) consists of a peak with a small full width at half maximum (FWHM) at the center wavelength. Some researchers have evaluated the relationship between depth perception and the FWHM and have confirmed that the effect of chromostereopsis among different colors is reduced when the FWHM is increased, especially when SPDs of each color overlap [Tsuchida et al. 2014]. However, there are cases where the chromaticity value of a color is the same but its SPD is different. Discussions concerning colors whose SPD is broad or consists of several peaks at different wavelengths with small FWHM are necessary. According to the transverse chromatic aberration model, a color with an SPD consisting of several peaks at each center wavelength causes blur on the retina. This should make the depth perception of the color patch weaker than that of a color patch with an SPD consisting of a single peak with a small FWHM at the center wavelength when their chromaticity values are the same.

To verifying this hypothesis, we compared depth perception of two color patches with different SPDs but the same chromaticity values. One color patch whose SPD consisted of a single peak at a wavelength was used as the target and its center wavelength was fixed. The other whose SPD consisted of two isolated peaks at different wavelengths was used as the reference, and the combinations of center wavelengths were changed. Target and reference color patches were displayed side by side on a liquid crystal display (LCD).

2. EXPERIMENTS

2.1 System Configuration

Our experimental system consists of an LC panel with a red-green-blue filter array, two xenon lamp systems, a metal halide lamp and band-pass filters (Fig. 3). The xenon lamp systems and the metal halide lamp are used to backlight the LCD. A band-pass filter is attached in front of the lens of the light-guide optical fiber of the metal halide lamp. Light from the metal halide lamp is used as a target color. Each lamp system consists of a xenon lamp, an ND filter, and a filter turret on which eight filters can be attached. Brightness and the filter turret can be controlled by software on a computer Light from the two xenon lamp systems is combined by light-guide optical fibers. The combination of band-pass filters and brightness of light are adjusted to match the chromaticity value to a target color. The SPD of the reference color has two peaks at different wavelengths. Target and reference color patches were displayed side by side on the LCD. The distance between each color patch was 0.5 cm. Images of color patches were 10 cm in height and 2.5 cm in width.

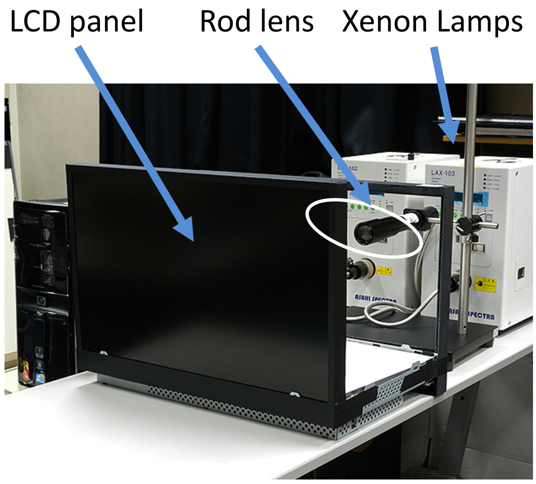

Figure 3: LCD system used in experiments. Interference filters are attached inside lamp housings.

The distance between the LCD and observers was approximately 50 cm. The experiments were conducted in a dark room.

The spectral locus on the chromaticity diagram between 520 and 630 nm is linear (see Fig. 4), and a target color can be synthesized by combining two lights whose center wavelengths are different. Then, these wavelengths were used for the experiments. Light that had passed through a band-pass filter whose center wavelength and FWHM were 570 and 30 nm, respectively, was chosen as a target color. To obtain enough brightness as target color, we chose a filter with relatively large FWHM. As a reference color, four combinations of light that had passed through the band-pass filter were chosen and their center wavelength were 520 and 610 nm, 530 and 630 nm, 540 and 610 nm, and 550 and 600 nm (note that the FWHM of the 630 nm filter was 30 nm; that of the other filter was 10 nm). There were few overlaps between SPDs of the target color and the third and fourth combinations (540 and 610 nm, and 550 and 600 nm).

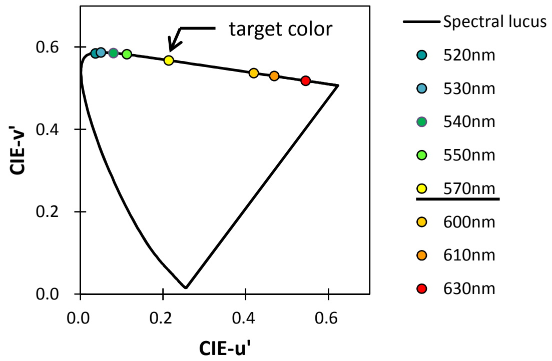

Figure 4: Chromaticity values of each color.

2.2 Results and Discussion

First, the brightness of each light from the lamps was adjusted to obtain the same chromaticity value between the target- and the reference color patches. Table 1 shows chromaticity values of each color patch, and their SPDs are shown in Fig. 5(a). Figure 5(b) is a chromaticity diagram plotting chromaticity values of each color patch. These results show that the same color with different SPDs were obtained. Note that we made one of the tristimulus values (CIE-Y) of each color the same to avoid the effect of difference in brightness.

Next, we compared the apparent depths of the target and reference color patch. The combination of lights, whose

Table 1: Measured chromaticity values of target and reference color patches.

	CIE-xyz			CIE-u'v'	
	x	y	z	u'	v'
570nm (target color)	0.475	0.523	0.002	0.228	0.565
520nm and 610nm	0.464	0.509	0.028	0.227	0.560
530nm and 630nm	0.471	0.517	0.011	0.228	0.563
540nm and 610nm	0.472	0.519	0.009	0.228	0.564
550nm and 600nm	0.469	0.528	0.003	0.224	0.565

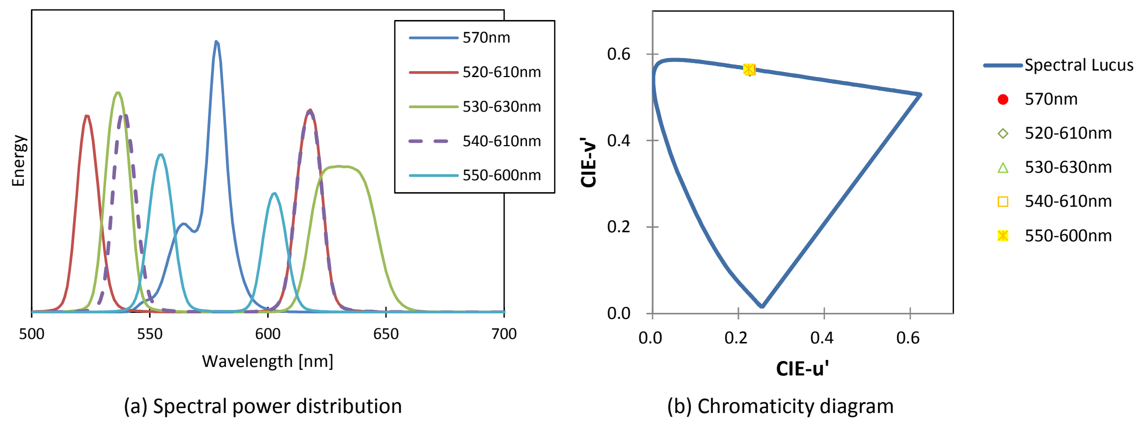

Figure 5: (a) Spectral power distribution and (b) chromaticity value of each combination.

Table 2: Standard deviations of each SPD of color patch.

	570nm (target color)	520nm and 610nm	530nm and 630nm	540nm and 610nm	550nm and 600nm
Standard deviation	8.08	46.71	45.67	39.07	23.90

center wavelengths were 520 and 610 nm, was used as the first reference color patch. In this case, the target color patch was perceived as located in front of the reference patch. The same result was also observed when center wavelengths of the reference color patch were 530 and 610 nm. However, the difference in the apparent depth between the target and reference color patches was reduced for the third and fourth reference color patches (540 and 610 nm, and 550 and 600 nm). Particulaly, the target and reference color patches seemed to be located at the same depth for the fourth reference color patch. These results infer that the apparent depths of target and reference color patches whose chromaticity values are same depends on variance of the SPD of each color patch. Table 2 shows standard deviations of each SPD.

It can be said that the experiment described above is equal to that using an eight primary color display. The displayed color could be presented using either one primary or two primaries. When the chromaticity values of displayed color patches are the same, the SPD of the color presented by one primary is narrower than that of the one presented by two primaries. The number of primaries for presenting color, distance between center wavelengths of two primaries, and the FWHM of each primary's SPD affect its apparent depth.

4. CONCLUSIONS

We experimentally showed that the spectral power distribution (SPD) of a displayed color affects depth perception. The SPD consisting of a single peak with a small full width at half maximum at a center wavelength was narrower than that consisting of two isolated peaks at each center wavelength. Even when chromaticity values of two displayed color patches were the same, the color patch with the narrower SPD seemed to be in front of the other patch. In cases where the SPD of each color overlapped, the effect caused by chromostereopsis was reduced or disappeard. We used eight monochtome colors between 520 and 630 nm in the experiments. We will conduct experiments using other colors in near future.

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HAZE AND CONVERGENCE MODELS: EXPERIMENTAL COMPARISON

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ABSTRACT

Bad environmental conditions like bad weather, such as fog and haze, and smoke-filled monitored closed areas, cause a degradation and a loss in contrast and color information in images. Unlike outdoor scenes imaged in a foggy day, an indoor artificial hazy scene can be acquired in controlled conditions, while the clear image is always available when the smoke is dispersed. This can help to investigate models of haze and evaluate dehazing algorithms. Thus, an artificial indoor scene was set up in a closed area with a mean to control the amount of haze within this scene. While a convergence model simulates correctly a small amount of haze, it fails to reproduce the same perceived hazy colors of the real image when haze density is high. This difference becomes obvious when the same dehazing method is applied to both images. Unlike simulated images, colors in real hazy images are resulted from environmental illuminants interference.

1. INTRODUCTION

Outdoor images are usually prone to degradation caused by atmospheric scattering particles. Indoor images captured and handled by monitoring sensors could be as well subject to color and contrast fadeout caused by occasional smoke emission, causing security failure. Many dehazing methods have been proposed to minimize this degradation and to recover original scene contrast [7, 12]. Although several articles have reported the shortage of color fidelity in recovered scenes [4, 9], none of the existing methods has deeply addressed this problem from a color point of view. In order to address this issue, we initiated to depict color shift between original clear image and the dehazed one of a simulated scene based on convergence model [3]. Recently, an artificial indoor hazy scene was installed to see how a real hazy scene could be faithfully represented by simulation.

The principal aim of this paper is to identify the limits that prevent a simulated hazy image formed by the convergence model to represent the same veiled object placed at a constant distance while changing fog density. Convergence model does not include the distance between the object and the camera and the effect of the fog that lies through the line of sight.

The rest of this paper is organized as follows. After briefly introducing dehazing and color convergence models and outlining the previous work in section 2, we describe in section 3 the experimental procedure of hazy images establishment. Experimental results and discussion are given in section 4, and conclusions and future works in section 5.

2. BACKGROUND AND PREVIOUS WORK

2.1 Haze and convergence models

According to D'Zmura *et al.* [1], translation and convergence in CIE xy lead to the perception of transparency. Color constancy revealed in presence of fog can be modelled by convergence model while taking into consideration shift in color and contrast. This was confirmed by asymmetric matching experiments.

Koschmieder [8] established a linear relationship between the luminance reflected by the object and the luminance reaching the observer. This linear relationship is based on the distance between the observer and the object. As Koschmieder stated, the problem of restoring true intensities and color, presents an underlying ambiguity that cannot be analytically solved unless scene depth data is available. The scene depth is equivalent to transmission.

Haze (1) and color transparency (2) are equivalently modelled:

$$I(x) = J(x)t(x) + A_{\infty}\big(1 - t(x)\big) \quad (1) \qquad b = (1 - \alpha)a + \alpha f \quad (2)$$

$I(x)$ is the perceived intensity of the hazed image, $J(x)$ is the scene radiance of the original free-haze image and $t(x)$ is the direct transmission, which represents the non scattered light emanating from the object and is attenuated by the scattering along the line of sight ($t(x) = e^{-\beta d}$, β is the scattering coefficient and d is the scene depth). The airlight corresponds to an object at an infinite distance and it is called atmospheric light A_{∞}. The airlight $A(1 - t(x))$ is the light coming from an illuminant (*i.e.* sun) and scattered by the atmospheric particles towards the camera. In the transparency model, a represents the tristimulus values of a surface; a convergence application leads to new tristimulus values b. f is the target of convergence. α represents the amount of fog covering the surface. Light that reaches the eye from the surface is the sum of the original light emanating from the surface and the light that depends on the chromatic properties of the fog.

2.2 Previous work

Dehazing aims at the inversion of haze model, the automatic evaluation of parameters influences color recovering. In order to qualify this, we initiated previous work by studying how dehazing methods fail to recover accurately original colors of simulated hazy scene. In the previous work [3], we proposed a simulation of haze based on the convergence model. Color shift evaluation was done using this model. Unlike haze model, the transmission of the surface depends only on the amount of covering fog, which is a transparent filter, and it does not depend on the distance between the surface and the camera. We assumed that the effect of this distance is equivalent to α: when alpha increases, this gives the same impression as the distance increases through the haze. According to the convergence model, the simulation consists on embedding haze in CIE XYZ image of GretagMacbeth ColorChecker. We applied the same model to RGB image in order to perform a cross validation with two different spaces basis [3]. The dehazing method Dark Channel Prior (DCP) [6] was applied to recover original image. Thus, we realized by converting color to IPT color space [2] and CIE LUV, that this method boosts the color saturation without altering hue of highly chromatic colors.

3. EXPERIMENTAL SETUP

In order to provide stable basic conditions that simplify the evaluation of dehazing processes, we proceeded by creating controlled indoor hazy scene. This scene was set up in a closed room with a large window that allows a homogenous sunlight to get in, in order to avoid directionality of artificial light. At the back of the calibrated scene, the farthest point to the camera Nikon D7100 (6.9 m), where the covering airlight is considered to have the maximal value, we placed a GretagMacbeth ColorChecker, and we changed consecutively the amount of emitted haze. The smoke machine FOGBURST 1500 was used for haze emission, and the different levels of haze by evacuating progressively the emitted haze. We used also the Konica Minolta CS-2000 spectroradiometer for transmittance measurements of the haze.

The spectra of Figure 2 depict the transmittance of the white patch of each haze level. When the haze veil dominates the image, we can easily notice that transmittance curves represent the light scattered by haze particles adding to it the daylight reflected by the patch. The manner how the transmission intensity evolves through haze levels, we can notice that the luminance of haze density is exponentially evolving. From level 6 the transmittance intensity becomes to reach back and to be closer again to the transmittance spectrum of the clear image. This leads to deduce that the airlight causes the atmosphere to behave like a secondary light source of a different type than the outdoor global illumination.

According to the definition of convergence model parameters, b is the image that is covered by a given level of haze. a is the clear image, which is considered to be the one captured without embedding haze. f represents the tristimulus value of the captured target when it is covered by an opaque haze veil. Finally, α is calculated by inverting the convergence model and choosing the value corresponding to the black patch. We assume that the darkest patch does not reflect the daylight, and that the airlight over this patch is only due to the haze veil. The camera noise is removed by subtracting the tristimulus values of the black patch in clear image from the values of the same patch covered by different haze levels. Equiluminous veil embedded in simulated images where α is constant, is unnatural, and it cannot be represented by such physical veil.

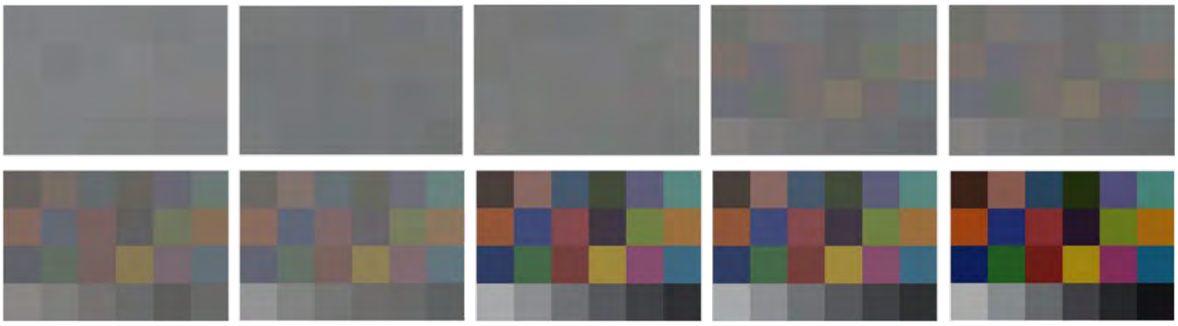

Figure 1 – Our database. The images of the GretagMacbeth ColorChecker taken under different haze levels. From left to right: Level 1; Level 2; Level 3; Level 4; Level 5; Level 6; Level 7; Level 8; Level 9; Clear image.

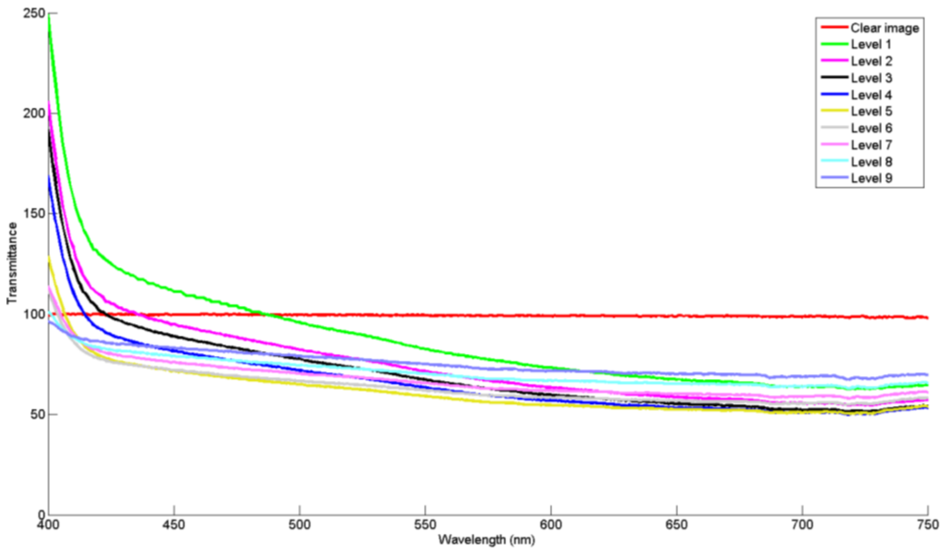

Figure 2 – Transmission curves of the white patch at different haze density levels. We notice that the short wavelength overcome the calibration. According to Rayleigh scattering [11], the strong wavelength dependence of the scattering ($\sim\lambda^{-4}$) means that shorter (blue) wavelengths are scattered more strongly than longer (red) wavelengths.

4. DISCUSSION

Haze that lies between the camera and the ColorChecker target modifies the light that emanates from it and reaches the camera. The light reflected from the target is added to the light scattered by the intervening particles. When the haze density greatly increases and the scattered light overcomes the light reflected by the target, the perceived colors components, hue and saturation, shift from their original values. This is clearly shown in Figure 3, where the simulation succeeds to represent the real scene of level 9 (with a little saturation difference related to the clear black patch) and fails for level 5. Referring to Figure 4, the distributions of points representing the red patch from level 5 to level 2 change between (a) and (b), while other points keep the same relative place between the end points (red and white) with a little shift in saturation (as shown in Figure 3 for Scene Level 9 and Simulated Level 9).

As it is defined above, the direct transmission is the light that reaches the camera without being scattered. Thus, the hue of this light is assumed to be independent of the reflected surface depth. The hue of airlight depends on the particle size distribution and tends to be gray or light blue in the case of haze and fog [11]. According to Figure 4, when the haze veil becomes great, the points placed on the chromaticity diagram of the patches, deviate from the line linking the haze veil color (white point) to the original unveiled color (red point), and they are biased toward blue/green area. Some points are also located outside the area between the red and white points. The deviation rate depends on the patch color, the airlight and the sunlight interference. When the amount of deviation in simulated scenes is smaller, all points representing a given patch at different haze levels remain between the red and white point.

When DCP is applied to Scene Level 5 (Figure 3), it accentuates the veiled colors by enhancing saturation. The recovered colors are totally different from those recovered from the Simulated Level 5, where the target and the veil are colorimetrically independent.

Figure 3 – The first line represents two different levels of scene images and the corresponding simulated images. The second line represents the recovered images by DCP of the first line images. From left to right (first line): Scene Level 9 – Simulated Level 9 – Scene Level 5 – Simulated Level 5. DCP fails to recover accurately the same colors for both images of Level 5 where haze density is high. Unlike the simulated scene, irradiance undergo illuminants interference and scattering effects.

This work confirms the previous conclusions considering that DCP saturates recovered colors. And the way it estimates the airlight and the transmission does not enables it to take into consideration the interference of different illuminants. As the retrieval of these parameters is limited to the pixels' intensities estimation, its mission remains limited to saturation enhancement, and original hues are not accurately recovered (Figure 3). On the other side, when the density of haze is small and the original hue is not altered, a simple adjustment based on convergence model could reinstate original saturation.

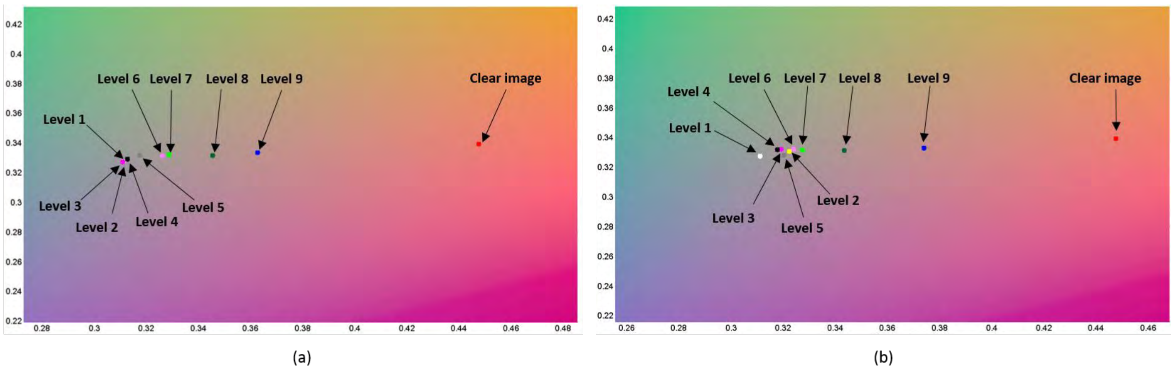

Figure 4 – The chromaticities of different haze levels placed on the chromaticity diagram of the red patch. (a) Real Scene, (b) Simulated Scene. Red: clear image – white: Level 1 – yellow: Level 2 – magenta: Level 3 – black: Level 4 - gray: Level 5 – pink: Level 6 – green: Level 7 – dark green: Level 8 – blue: Level 9. The distributions of points representing the red path from level 5 to level 2 are different between (a) an (b), while other points keep the same relative place between the end points (red and white) with a little shift in saturation.

5. CONCLUSIONS AND FUTURE WORKS

In this article we study the similarities between a simulated hazy image created by a convergence model and a real hazy scene. Physical luminous interaction modifies the perceived scene, while colors in the simulated image maintain their hue information and only their saturation component shifts between the original color (saturated), and the haze color (unsaturated). Convergence model fails to stand for hazy image when the density of haze becomes considerably high. Dehazing methods like DCP, aim just to remove the covered veil and to recover the color as it is not completely hidden, without taking into consideration the interaction of different phenomenon. Thus, a pre-processing aiming to adjust hue color, and a post-processing based on convergence model for saturation adjustments.

Future works shall focus on the validation of the color correction on dehazed images. We intend also to investigate the possibility to extend color-based image dehazing methods to multispectral-based image. Calibrated hazy images database should evidently considered as a benchmarking tool of colorimetric issues that are related to dehazing methods.

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Hyperspectral Reflectance Reconstruction Using a Filter-based Multispectral Camera

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ABSTRACT

In this study, a filter-based multispectral camera is used to extent its data from 16 band to 61 bands within visual spectra. The camera provides uncorrected achromatic image for each filter-band. We corrected its lighting uniformity, estimated multispectral tone responses using a polynomial regression by not only achromatic samples but also color samples from a ColorChecker chart, interpolate its spectral data to 5nm interval using cubic interpolation. The maximum color errors greatly reduced from 21.97 to 5.2 ΔE. PCA based method also were tested. The maximum color error was further decreased to 1.9 ΔE.

On the other hand, the spectral filters of the camera are switchable. However, if we switch the filters, the spectral images captured from different filter sets cannot align each other accurately. A deblurring process and a Scale Invariant Feature Transform (SIFT) therefore are applied to align the sub-frame of a spectral image spatially.

1. INTRODUCTION

In multispectral imaging field, three types of spectral cameras are commonly used: (1) a line-scanning hyper-spectral camera (Grahn and Geladi, 2007), (2) a filter-based multispectral camera (Hill, 1998) and (3) a trichomatic camera with known principal components of the spectral reflectances (Imai and Berns, 1999). Each of them has its own pros and cons. The line-scanning hyperspectral camera is time-consuming in its spectral image acquisition, whereas the filter-based multispectral camera cannot provide accurate hyperspectral data with its limited bands. The trichomatic camera cannot predict the spectral data in high precision when the principal components of surface reflectances are unknown.

In digital archiving, hyperspectral data is useful for image restoration. In this study, a filter-based 8 band multispectral camera was used to extent its data from 8 band to 61 bands within visual spectra. The spectral filters of the camera are switchable. The spectral accuracy can be enhanced by using two sets of narrowband filters (16 wavebands) for image acquisition. The camera provides uncorrected achromatic image for each filter-band. Therefore, we have to write software to improve the accuracy of spectral estimation. On the other hand, the filter-based camera enables of capturing each frame up to 20 fps. However, the fast moving of the color wheel results in minor motion blur. In addition, if we change the spectral filter set manually, the spectral images captured from different filter sets cannot align each other accurately. The resulted spectral images will suffer from blurring or ghosting. Spectral correction and image alignment therefore are the two challenged issues for the post processing of spectral images.

2. APPARATUS

The spectral camera used in this study was Pixelteq SpectroCam VIS-NIR. It contains a filter wheel holding 8 easily changeable filter segments, digital progressive scan CCD scientific imager and operating in Visible / Near Infrared (VIS/NIR) range. In this study, two use two sets of spectral filters, one set starts from 400nm to 680nm in 40 nm interval. The other set starts from 420nm to 700nm in 40 nm. The bandwidth of each spectral filter is about 20nm. Figure 1 shows the spectral transmittances of the 16 VIS filters measured by a spectrophotometer. The image format of the spectral image is 16bit PNG file in 1280×1024 resolution. All measurement were done under a X-rite SectralLight III light booth. This spectral camera can use Fast Mode or Index Mode. The latter allows the user to set exposure time and gain for each channel. To achieve the best image quality, we set the exposure time and the gain value solely for each channel. The criteria of the adjustment is to set exposure time first to meet 80% gray level for No. 19 white patch on a X-rite ColorChecker chart. If the exposure time is up to its limit, adjust gain value to fullfil the criteria.

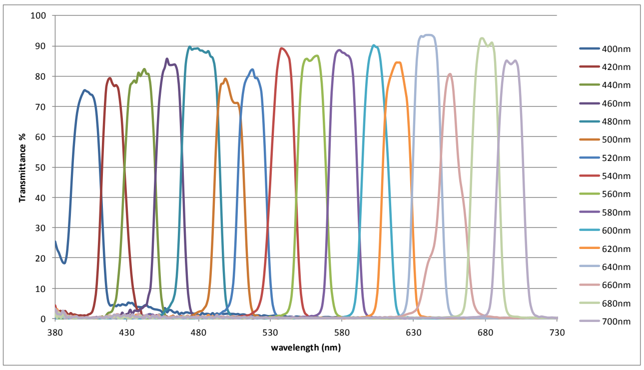


Figure 1: Spectral transmittances of 16 VIS filters.

3. SPECTRAL CORRECTION

X-rite ColorChecker was used to optimize the accuracy of reflectance reconstruction. The spectral reflectances of 24 patches on ColorChecker were measured by DataColor SF600 in its specularly excluding mode. Four commonly used light sources, A, D65 (filtered halogen), TL84 and CWF, were tested. And we found D65 shows best results on reflectance reconstruction as it provides smooth power spectra and more energy at short wavelength. The following test therefore all carried out under D65 light source. The spectral accuracy is judged by calcuating RMSE (root-mean-squared error) and color color differences (ΔE_{76}) under the four illumants. The measured and approximate spectral reflactances were compared in 400nm to 700nm range with 5nm intervals. The following steps were taken to optimize the accuracy.

2.1 Tone Correction

If we reconstruct the spectral reflectances of ColorChecker directly using the 16 band spectral images with nearest point interpolation, the mean and maximum color differences across the four light sources are 9.49 and 21.97 ΔE respectively. If only normalizes the data based on the reflectance of white patch, the maximum error can be reduced to 19.30 ΔE. The errors can be greatly reduced by black and white equalization shown as Figure 2, where the mean and maximum errors are 3.02 and 8.01ΔE respectively. The maximum errors can be further reduced to 7.42 by tone correction using first-order linear regression based on the grayscale No.19 to No.24 for each channel individually.

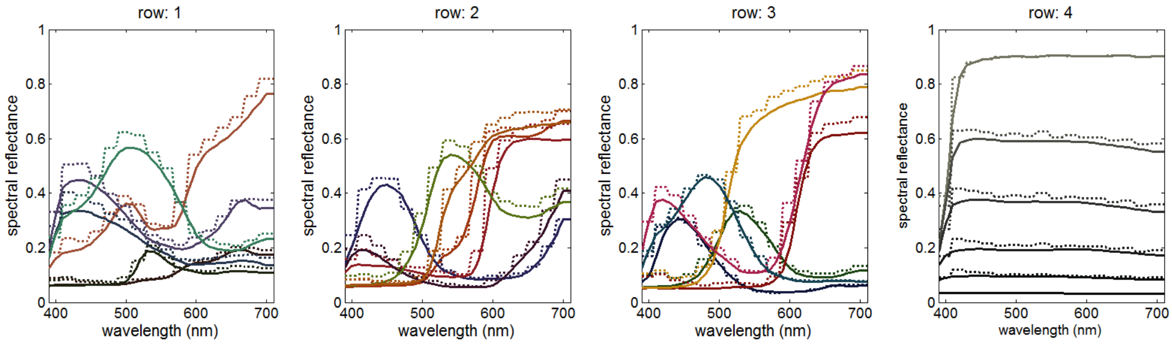


Figure 2: Spectral reconstruction of ColorChecker using black and white patches for tone correction. Solid lines: measurement. Dotted lines: approximation.

Table 1. Summary of the results from the experiment.

				mean					maximum				
band	tone	interpolate	uniform	A	D65	TL84	CWF	RMSE $*10^{-5}$	A	D65	TL84	CWF	RMSE $*10^{-5}$
16	no	nearest	no	9.15	9.50	9.67	9.63	72.59	18.05	20.75	21.78	21.97	183.49
	white	nearest	no	9.43	9.64	9.82	9.81	42.00	16.06	18.29	19.31	19.30	64.12
	black & white	nearest	no	2.74	3.00	3.15	3.19	13.03	6.76	7.82	7.96	8.01	30.07
	grayscale (1st)	nearest	no	2.59	2.72	3.18	3.01	8.78	5.77	6.29	7.42	6.74	19.54
	grayscale (1st)	linear	no	2.27	2.42	2.65	2.50	4.26	6.01	6.46	6.86	7.32	11.79
	grayscale (1st)	cubic	no	2.29	2.47	2.87	2.65	4.20	6.01	6.53	7.26	7.33	11.70
	grayscale (1st)	cubic	yes	1.60	1.89	1.89	1.85	1.75	4.69	6.42	6.08	6.28	5.21
	color (1st)	cubic	yes	1.44	1.62	1.48	1.54	**1.18**	3.91	5.16	5.10	4.94	**3.14**
	color (2nd)	cubic	yes	1.80	1.78	2.03	1.98	4.79	5.47	6.43	7.08	6.96	16.76
	PCA (n=3)	-	yes	6.16	7.98	7.71	6.28	11.64	15.00	17.81	20.17	15.41	26.52
	PCA (n=6)	-	yes	1.44	1.31	2.15	1.44	1.95	5.34	5.08	8.79	4.10	6.45
	PCA (n=9)	-	yes	0.20	0.22	0.65	0.30	**0.27**	0.86	0.97	1.95	0.90	**1.00**
8	color (1st)	cubic	yes	1.80	1.78	2.03	1.98	4.93	5.47	6.43	7.08	6.96	16.78

2.2 Spectral Interpolation and Uniformity Correction

Compared the color differences of three spectral interpolation methods – nearest, linear and cubic interpolations, the results have not significant differences. However, if we look at the RMSEs, both linear and cubic interpolations can reduce the maximum values to nearly a half. ColorChecker is a big color target. It won't recevie equal illuminance across each patches. An spectral image of X-rite WhiteBlacing chart therefore was taken in the same environment for equalizing the spatial uniformity of spectral data. After the uniformity correction, the maximum RMSE redcue from 11.70^{e}-5 to 5.21^{e}-5 where the mean and maximum color differences are 1.81 and 6.42 ΔE respectively. The best results we can achieve using a 16 band spectral image was applying first order regression not only from the grayscale but also from all 24 color patches in the spectral tone correction. The mean and maximum color differences are 1.52 and 5.16 ΔE respectively, and the approximate spectra are shown in Figure 3. However, if 2-nd order polynomial regression is applied, the maximum error increased. The reason could be that the characteristic curve of the CCD is almost linear to luminance, a non-linear tone correction is not necessary and the regression might overestimate the tone characteristics. If only 8 spectral filters are used, the mean and maximum color differences using the 1st order color regression are 1.90 and 7.08 ΔE respectively.

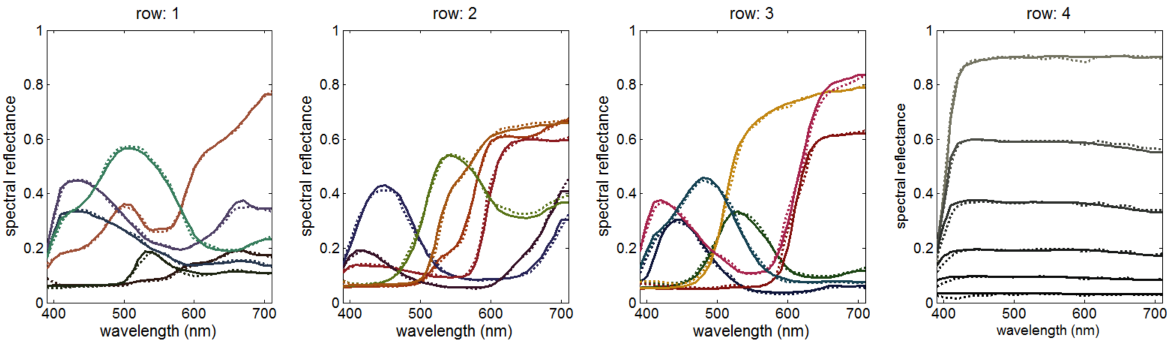


Figure 3: Spectral reconstruction of ColorChecker using color regression and uniformity correction. Solid lines: measurement. Dotted lines: approximation.

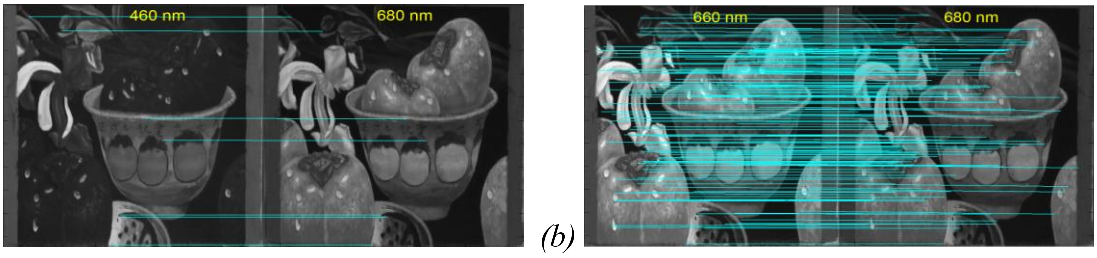
2.3 PCA-based Approach

Imai and Berns (1999) proposed a spectral estimation method for a trichomatic camera with known principal components of the spectral reflectances. A specrtral camera can be regarded as a multi-channel color camera and the results of spectral estimation should be more accuracte. We tested the method using 16, 8 and 4 narrowband filters and the results show that both 8 and 16 filters can reconstruct the spectral reflectances accurately when more than 6 basis functions are used. However, it the filters don't cover the whole spectral range or the number of basis functions is not enough, the results won't be acceptable. As the PCA-based approach only work when the PCA spectra of the target objects are known, it isn't recommended for normal spectral inspection.

3. DEBLURRING AND SUB-FRAME ALIGNMENT

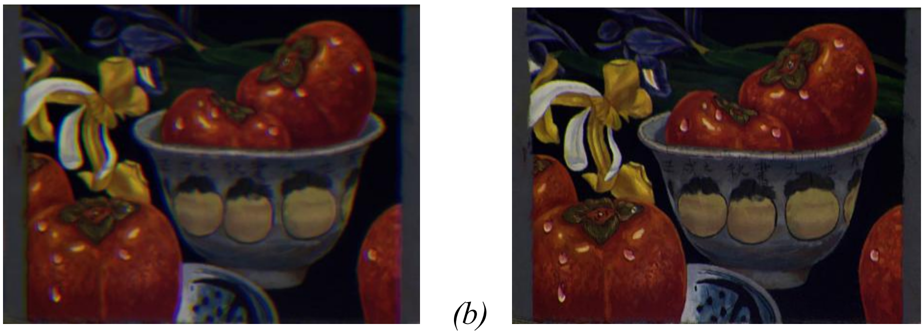
As mentioned previously, the vibration of the color wheel might cause image blur and the manual swtiching of different filter set and slight moving of the target object might also result in blurring and even ghosting. To improve the spectral image qaulity, A deburring process should be applied to each spectral frame and an image alignment process must be done to generate a ghost-free and clear spectral image. In terms of deblurring, there are many methods such as Wiener filter (Gonzalez and Woods, 2007) can be used.

In terms of sub-frame alignment, a Scale Invariant Feature Transform (SIFT) (Lowe, 2004) therefore is applied to align the spectral images spatially. If we the two spectral band to match the SIFT key-points, only few of them can be found as Figure 4a. It is not s sufficient for geometry transform of the two images. However, if we choose adjacent wavebands for matching, many SIFT key-points can be found. Once we found enough correspondent key-points, after removing unusual moving vectors, a 3 by 3 transform matrix can be derived to project one sub-frame to the other. To optimize the image quality, the sub-frame near 550 nm should not be changed spatially.



(a) *(b)*

Figure 4: The results of SIFT key-points correspondence – (a) inconsecutive wavebands and (b) successive wavebands.



(a) *(b)*

Figure 5: The results of deblurring and sub-frame alignment – (a) uncorrected and (b) uncorrected.

4. CONCLUSIONS

In this study, a filter-based multispectral camera is used to extent its data from 16 band to 61 bands within visual spectra. The camera provides uncorrected achromatic image for each filter-band. We corrected its lighting uniformity, estimated multispectral tone responses using a polynomial regression by not only achromatic samples but also color samples from a ColorChecker chart, interpolate its spectral data to 5nm interval using cubic interpolation. The maximum color errors greatly reduced from 21.97 to 5.2 ΔE. PCA based method also were tested. The maximum color error was further decreased to 1.9 ΔE.

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BYK-Gardner sets standards in color and appearance control.

Konica Minolta Inc.

Sensing Business Unit of Konica Minolta Inc. provides light and color measuring instruments based on the company's core optical technology to every corner of the world. As a pioneer in this filed, we developed the first light meter used on board a spacecraft in 1968 (Apollo 8) and the world's first portable spectrophotometer in 1982. Our products have recently become a staple in research and manufacturing environments, helping our partners to be innovative and successful in making breakthroughs with the least waste of time and effort by improving and assuring the quality of their products. This commitment to creating value for customers is the shared passion and the core principle behind the Konica Minolta brand. Color management is essential in almost all areas of manufacturing, including automotive, paint, plastic, chemicals, textiles, construction materials, medicine, cosmetics, and food. Our color control techniques are instrumental in measuring subtle color differences that human eyes cannot distinguish accurately. Konica Minolta's spectrophotometers and colorimeters are therefore widely utilized at quality control and R&D. We promise to do our best to contribute to the success of our customers by providing not only the state-of-the-art products, but the high level of customer-centric technical support and services worldwide.

Gold sponsor

EBA Japan Co.,Ltd.

EBA Japan CO.,LTD. treats spectral imaging technologies.
Our technologies clear and propose the path for your innovative future.
They can get spectroscopic information not for one pixel but for all pixels quickly.
Using the spectroscopic information map, you can convert colors to every color space coordinates and evaluate them in 3 dimensions (horizontal, vertical, spectral).
The spectral color imaging system is helpful in "Various display evaluations", "Color rendering evaluation", "Color evaluation of cultural assets" or "Evaluation of light source".
We hope that "EBA Japan Imaging" will help you with your research and offer the hints for your future prosperities.

FUJIFILM Holdings Corporation

Fujifilm Group is transcending its conventional business fields of "Imaging and Information" to transform into a company that contributes to the development of culture, science, technology and industry, as well as improving health and environmental protection across society. To help enhance the quality of life toward realizing a society in which people enjoy spiritual and material wealth, we will strive to realize our corporate philosophy through the three business fields of Imaging Solutions, Information Solutions and Document Solutions.

Suga Test Instruments Co.,Ltd.

SUGA Test Instruments Co., Ltd. is a manufacturing company specialized in optical property measuring instruments.
Since 1959, SUGA Test Instruments, has developed Colour Meters and thereafter other unique color property, and accumulated rich experiences supporting gl-obal partners in improving and assuring the quality of partners' products.
SUGA Test Instruments, manufacturers, sells and provides services globally, portable and desk top, world-class colour meters, spectrometers, and unique & bench top gloss meters, haze meters and image clarity meters.
These colour appearance analyzers allow one to access and control the colour appearance properties of products and materials.
SUGA-only is a brand that you can rely and depend upon to solve all your colour appearance needs.

Silver sponsor

DIC Corporation / DIC Graphics Corporation

DIC is a fine chemicals company with a top share in printing inks, organic pigments and PPS compounds in the global market.
DIC provides a broad range of products that respond to the needs of society and its customers, and works to bring people "Color & Comfort by Chemistry."

Japan Paint Manufacturers Association

The Japan Paint Manufacturers Association (JPMA) was established in April 1948 as a voluntary organization of paint manufacturers industry. JPMA consists of about 258 members: Regular Members who are leading paint manufacturers in Japan, plus Supporting Members who are engaged in paint-related industries.

Murakami Color Research Laboratory

NIPPON DENSHOKU INDUSTRIES CO.,LTD.

NIPPON DENSHOKU INDUSTRIES CO.,LTD., is specialist for color measuring instruments.
It's been half a century since we have started to support the color management and will broaden our view and contribute to color business society.

OPTIS Japan

Since 1989, OPTIS has led the way in light simulation software. Our unique physics based simulation tools deliver the most accurate representation of optical and lighting systems and are fully integrated into the world leading CAD platforms. OPTIS solutions can also help you understand how color and spectrum work in your products and systems.

Spectral Application Research Lab. Inc.

Spectral Application Research Laboratory Inc. (SARLI) supplies a Spectral Imaging System (all own designs) which is able to examine the mixed state of natural and artificial materials more deeply. Our system consists of camera and drive device on sample side, and also a dedicated software application is built-in.

Systems Engineering Inc.

Topcon Technohouse Corporation

Topcon Technohouse Corporation provides various types of light and color measuring instruments and contributes to the development of many industries.
Our Luminance colorimeter BM series, Spectroradiometer SR-3/UL series, and Illuminance meter IM series have been used as standard in various industry fields such as Flat panel display, Illumination, and Automotive.

Basic sponsor

Canon Inc.

Canon specializes in an extensive range of imaging products such as digital cameras, printers, office multifunction devices, and others for consumers, businesses, and professionals. With years of expertise in image-processing technologies, Canon creates high-quality, unified color look possible even for input and output devices with differing color reproduction ranges.

Integra Inc.

Primary businesses of Integra Inc. are development, marketing and sale of computer software products and related services for engineering.
Main products of the company are software packages, Hybrid Light Simulation Software, lumicept for optical and illumination simulation where accuracy and speed to simulate propagation of light has the essential importance.

KLV. CO., Ltd

KLV is known as one of the top makers of light sources, optical parts, and optical products. We have contributed to the development of optical technology in many field including medical, biological, agricultural, environmental, and food sciences for the past 30 years in Japan.

SERIC Ltd.

We are a manufacturer of artificial solar light, branded SOLAX for color evaluation. We have many sales result to deliver our products for our customers, who are car manufacturers, paint companies, digital camera makers, cosmetic companies, and so. We recommend our product for color management as the professional sunlight maker.

Coffee Break sponsor

OFFICE COLOR SCIENCE Co., Ltd

Office Color Science Co., Ltd is specialized in computer system relating to color science. We have mainly developed Computer Color Matching (CCM) system and Color Quality Control system for Metallic and Pearlescent color. We pursue the possibility of color application and create value through our technology to enrich color design of industrial products.

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