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MEASUREMENT OF COLOR APPEARANCE WITH COLOR CATEGORY RATING METHOD UNDER ORGANIC LIGHT EMITTING DIODE

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ABSTRACT

Organic light emitting diode (OLED) illumination has several unique features: thin, plane emission, and high-efficiency. Here we evaluated the color appearance of the Munsell color chips under OLED light with a novel color category rating method. A subject stayed in a booth whose illumination source was variable and observed a color chip placed on a gray background. The illuminance on the color chip surface was about 450 lx. The subject described the order of the colors perceived in the color chip using up to three colors out of 11 basic color terms (red, blue, green, yellow, purple, pink, orange, brown, black, gray and white), and also rated the weight of each of the selected colors by dividing a total of 10 points between all perceived colors. For example, a subject may describe the color appearance of a chip as purple 7, blue 2 and gray 1. The results were compared with those obtained under ordinary D_{65} fluorescent lights. Our results showed that under the OLED light the rate of “orange” increased while that of “purple” and “yellow” decreased.

INTRODUCTION

Organic light emitting diode (OLED) light is expected to become a next-generation illuminant along with LED light. However, OLED light has a greatly different spectral distribution from current illuminants: there are few shorter wavelength components and it contains neither ultraviolet nor infrared rays. This makes it especially suitable for illuminating pieces of art since there would be little chance of damage from synchrotron radiation. However, the altered spectral distribution may affect color appearance.

Current fluorescent lighting is generally kept low in museums to avoid damage to the exhibits. Typical illuminance adopted at the museum is 50-150 lx, while the suggested illuminances for an office and for a living room are 750 lx and 500 lx, respectively. Under the photopic conditions, mostly the cones are functioning and color appearance can be generally predicted by measuring the chromaticity of an object. However, when the illuminance gets lower, color appearance cannot be predicted by merely measuring its chromaticity.

When people observe color, they can describe not only the detail of its attributes such as hue and saturation, but also classify roughly which category of the color name it belongs to. This is known as categorical color perception. Research on categorical color perception often involves experiments in which subjects choose one color term from eleven color terms (red, blue, green, yellow, purple, pink, orange, brown, black, gray and white), known as basic color terms, to describe the color [1].

Categorical color perception under OLED light has been investigated [2]. It is reported that most OSA color papers observed under OLED were classified to the same category as those under D_{65}. However, one major drawback to this experimental paradigm is the inability of a subject to report a perceived small color difference between chips of the same category. For example, although one can clearly call two shades of purple differently such as lilac and plum, it is not discriminable in this categorical color naming method. To address this shortcoming, we devised a new rating system based on categorical color naming that will provide a more detailed analysis than traditional categorical color naming method. In this study, we used this novel rating system to estimate the color appearance of Muncell color chips under high illuminance OLED light and compared it with the responses under a fluorescent light.

METHODS

We first compared the correlated color temperature and color rendering index (Ra) of the OLED light and D_{65} fluorescent light. The correlated color temperature of the OLED light was 4900 K and the color rendering index (Ra) was 81.0. The fluorescent light was similar, with a correlated color temperature and a color rendering index (Ra) were 5200 K and 84.0 respectively. Observation illuminance was 500 lx.
The spectral distribution of the illuminants used in the experiment is shown in Figure 1.

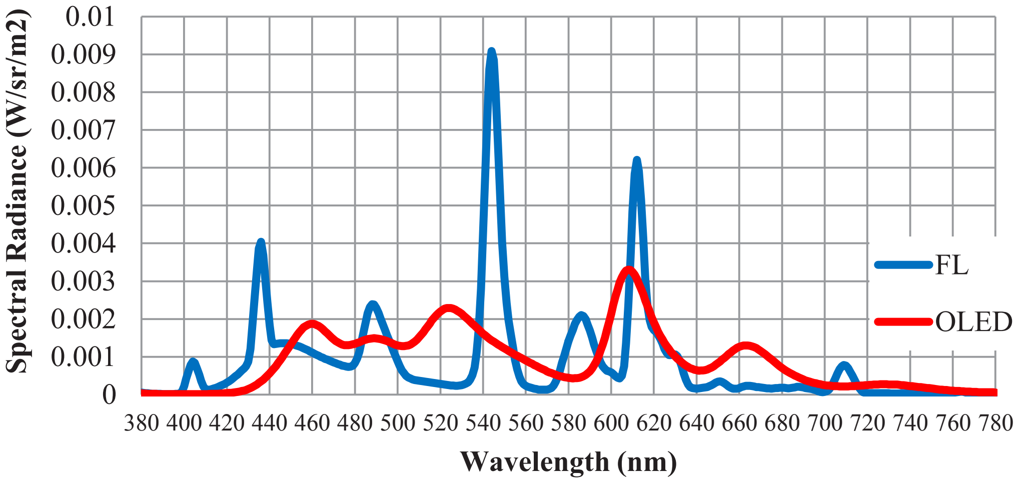

Figure 1. Spectral distributions of the illuminations

For the experiment, each subject stayed in a booth whose illumination source was variable and observed a color chip placed on a gray background. Before starting the experiment, a subject sat in the booth for 5 minutes to adapt to the illumination. Then, the subjects started a session consisted of responding to 146 Munsell color chips. The subject described the color perceived in the chip using up to three words from a set of 11 basic color terms (red, blue, green, yellow, purple, pink, orange, brown, black, gray and white), and also rated the weight of each of the selected colors by dividing a total of 10 points between all perceived colors (**category rating**). For example, a subject may describe the color appearance of a chip as purple 7, blue 2 and gray 1. The subject was also asked to choose the focal color, which appears to represent its color name, of each of 8 chromatic categories by picking up one color chip from 146 Munsell color chips for each of the category (**focal color selection**).

Four male subjects participated in the experiment. They had color normal vision, which was tested with Ishihara Plates. All the subjects conducted 2 sessions of the category rating experiment for each illuminant, and 1 session of the focal color selection experiment.

RESULTS AND DISCUSSION

Category rating

In order to analyze if the perceived color component changes, we calculated the average points for all the categories by averaging the points obtained from all the subjects. Figure 2 shows the average point of each color of all the subjects. Error bars indicate the standard deviation across subjects. The vertical axis shows all the subjects' average point, and the horizontal axis lists each color. Responses under the OLED light and the fluorescent light are shown in blue and red, respectively. All the subjects showed the similar tendency. When the results from both lights were compared, the fluorescent light had higher scores for green, purple, and white. Red, orange, gray and black were higher under the OLED light. Blue, yellow, pink and brown did not show any difference. However, no statistical significance was found for all 11 categories.

The spectral distribution in Figure 1 shows that the fluorescent light has high spectral radiance at the shorter wavelengths of 400-440 nm, the middle wavelength of 540-550 nm, and the longer wavelength of 610-620 nm. These high spectral radiances has narrow peaks of approximately 10 nm width. OLED light, on the other hand, has broader peaks at several ranges: 510-530 nm, 590-620 nm and 650-680 nm. There are also wide ranges of wavelengths, such as between 450-550 nm whose radiances are rather flat and mild.

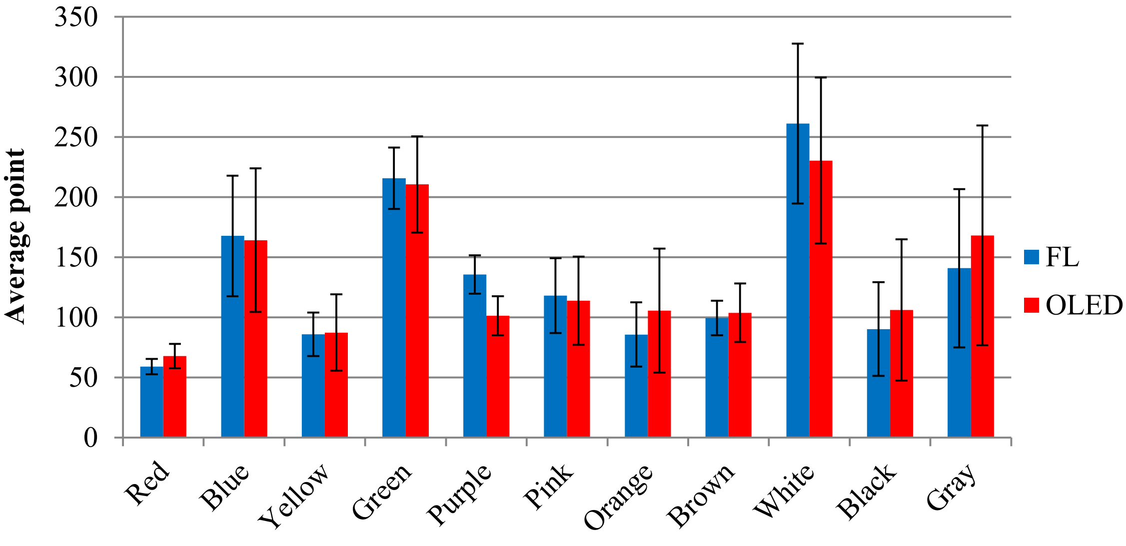

Figure 2. The average point of each color of all subjects

The differences in the response might be related with the difference in the spectral distribution of the light sources. The response of the purple obtained from the fluorescent light can be mainly caused by the spectral components of 400-440 nm, the green for 540-550 nm. The responses of red and orange for OLED were superior to those for fluorescent light as OLED has the higher spectral intensities in 590-620 and 650-680 nm.

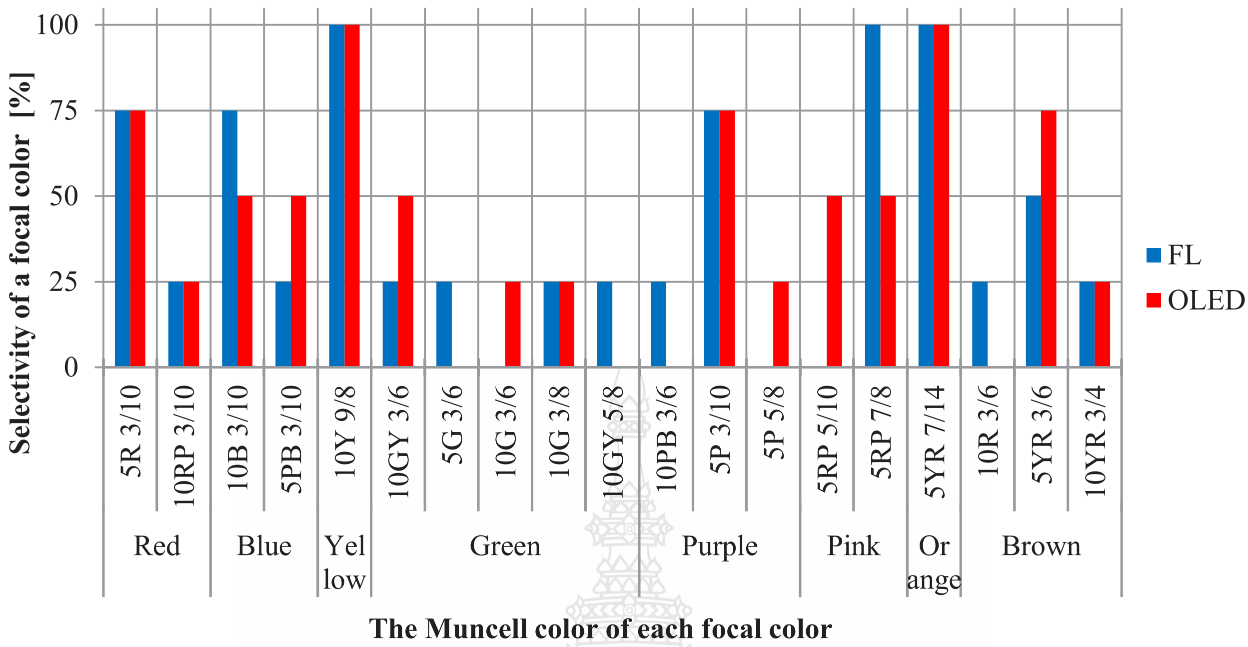

Figure 3. The Munsell color selected as the focal color and selectivity

Focal color selection

The Munsell colors selected as the focal color and its selected percentage are shown in Figure 3. Yellow and orange were very consistent with both lights. Purple and red are also consistent, as the selected percentage are 75% for both lights.

Blue and pink were consistent under the fluorescent light, while they were not so consistent under OLED light. Brown, on the other hand, was consistent under the OLED light but not under the fluorescent light. Green had a wide variety of choice as the focal color regardless of the lighting condition, and we could not determine which Munsell color chip represents green best.

We hypothesize that two very consistent colors, yellow and orange, were selected by their relatively higher chroma compared with other color chips. This hypothesis can be applied also to red, blue and purple. We need, however, further experiments to verify this hypothesis.

SUMMARY AND FUTURE WORK

We find that switching to OLED from a fluorescent light would likely increase the color appearance of red, orange, black and gray and decrease the color appearance of green, purple and white. Focal colors of red, yellow were very stable under both lights.

With our method, we are able to record small changes in appearance of the color. We would like to conduct the same experiment in lower illuminance condition to explore how the color appearance of the colors is affected by iluminance level.

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