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The Effect of Neighboring Colors on Color Appearance

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Abstract

This research aimed to investigate the effect of neighboring colors on color appearance. The psychophysical experiment was carried out in a dark room by using D65 standard lighting booth. Total of 5 different neighboring color conditions were used in the experiment and those were 'Reference', 'Desaturated', 'Saturated', 'Dark', and 'Light'. Total of 20 participants were invited to each neighboring color condition. Each participant evaluated hue, colorfulness, and lightness of 22 test colors by using magnitude estimation method. Result found that colors shown with the low chroma neighboring colors look more colorful and when the neighboring colors have high lightness, colors look less colorfulness and darker.

Introduction

Color appearance is not just determined by the local light signals from each object, but instead depends on relative light signals across the visual scene [1]. That is, people don't perceive one color independently, but perceive many neighboring colors simultaneously. In that sense, neighboring color could affect color appearance.

For an example of cosmetics shop, the color make-up products are usually displayed together and the way how they displayed could affect the color perception. One surrounded with generally vivid colors might be perceived differently than the identical one surrounded with generally less colorful colors.

Previous color appearance studies presented the neighboring colors around the test color to simulate complex scene [1, 2, 3, 4]. The neighboring colors were chosen to cover the wide range of colors without considering the effect of neighboring colors on the color appearance of the test color.

In this research, the effect of neighboring colors on the color appearance was investigated by conducting psychophysical experiment using 5 different neighboring colors – 'Reference', 'Desaturated', 'Saturated', 'Dark', and 'Light'.

Experimental settings

Test pattern

Figure 1 shows the experimental environment and the test pattern which was shown to each participant.

***Figure 1**. Experimental environment and the test pattern*

As shown in Figure 1, the experiment was carried out in a dark room using D65 lighting booth having 6300K and 1090lx at the centered bottom of the booth. The test pattern consists of various color patches on gray background (Munsell N7) which fitting to the size of the booth as 61 cm (Width) x 41.5 cm (Height).

Test colors were presented in the center with the reference white. There was also a reference colorfulness given for evaluating colorfulness below test color and reference white. Twenty-four colors are selected as neighboring colors. The size of all the patches was same as 3.8x3.8cm. In the test pattern, neighboring colors occupied 13.7% of the entire background.

Test colors

Total of 22 test colors were used in the experiment. Among them, 8 colors were from the colors used to calculate CIE CRI (Color Rendering Index) [5] and 14 were from the ones for calculating CQS (Color Quality Scale) [6].

Figure 2 shows the distribution of the test colors on CIELAB a*b* color space setting reference white as (X, Y, Z) = (97.7, 100.0, 124.0).

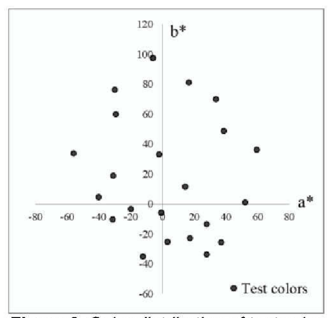

***Figure 2**. Color distribution of test colors on CIELAB color space*

Neighboring color conditions

Total of 5 different neighboring color conditions were used in this experiment and those were 'Reference', 'Desaturated', 'Saturated', 'Dark' and 'Light'. In each condition, neighboring colors were distributed on the gray background similarly with the one used in LUTCHI data set [2].

Table 1 shows the averaged CIELAB L* and C* values of 24 neighboring colors and Figure 3 shows the distribution of neighboring colors on CIELAB color space.

As shown in the Table 1, two conditions 'Desaturated' and 'Saturated' have similar average L* values, but different average C* values (10.6 in 'Desaturated' and 36.4 in 'Saturated'). This C* value difference was intended to see the effect of chroma of neighboring colors on color appearance. Likewise, 'Dark' and 'Light' have similar average C* values, but average L* values are different as 46.0 in 'Dark' and 76.9 in 'Light'. This L* value difference was also intended to see the effect of lightness of neighboring colors on color appearance. The 'Reference' condition consists of neighboring colors evenly distributed on CIELAB color space and it was used as a control group.

Table 1. Averaged CIELAB L* and C* values of Neighboring color conditions

Neighboring Color Condition	CIELAB L*	CIELAB C*
Reference	61.1	28.3
Desaturated	52.2	10.6
Saturated	55.9	36.4
Dark	46.0	24.8
Light	76.9	24.5

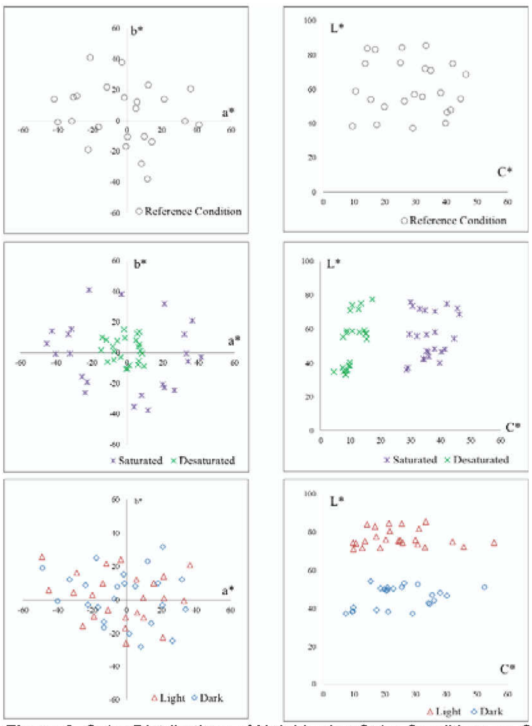

***Figure 3**. Color Distributions of Neighboring Color Conditions on CIELAB color space*

Participants

In this experiment, total of 20 participants evaluated each neighboring color condition. They were all Korean and university students who had a normal color vision who passed Ishihara test. Among all, ten were males and the other were females.

Psychophysical experiment procedure

Figure 4 summaries the overall flow of the experiment.

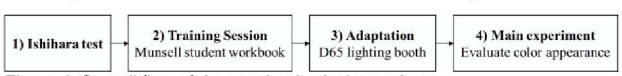

Figure 4. Overall flow of the psychophysical experiment

As a first step, Ishihara test was conducted to check if each participant had a normal color vision. Then, the room became dark with the D65 lighting turned on inside the viewing booth.

Before initiating the experiment, a training session was given to clarify the concepts of three color attributes – hue, colorfulness, and lightness – which would be evaluated. Munsell student's workbook was utilized as a tool.

Then, participants were asked to stare at the bottom of the viewing booth for 5 minutes to adapt to the lighting D65. The overall instruction for the experiment was given while the participants were adapting to the lighting.

In the main experiment, each participant was asked to evaluate the color appearance of 22 test colors presented on 5 different neighboring color conditions. The test colors were shown in a randomized order in each neighboring color condition. To evaluate color appearance, hue, colorfulness and lightness were scaled by using a magnitude estimation method allocating a number to each color attribute.

Evaluating hue was done by describing it as proportion of two neighboring primaries among 4 psychological primaries: red, green, yellow and blue. First, participants decided whether they could perceive any hue or not. If yes, participants decided the predominant one among four primaries. If participants perceived a trace of any other primaries, then they identified it. Finally, participants evaluated the proportions in which the two primaries stand. For instance, an orange color might be 60% red and 40% yellow. If participants could not perceive any hue, they evaluate it as 'Neutral'.

For evaluating colorfulness, participants were asked to assign a proper number to colorfulness of each test color. It was open-ended scale, so there was no upper limit and zero in the scale refers to neutral color. Total of 3 different reference colorfulness were selected as red (S2060-R, C*=44.7), green (S3060-G, C*=51.0) and blue (S2065-B, C*=36.7) in NCS atlas having CIELAB C* values similar with 47.9 which is the averaged value of the test colors. Different reference colorfulness was given over neighboring color conditions because its hue itself could affect the evaluations. Thus, the red one was given for 'Reference' and 'Desaturated', green for 'Dark' and 'Saturated', and blue for 'Light' condition. The very first given one was assigned as 50 and participants evaluated the colorfulness of each test color related to it. After moving on next neighboring color condition, participants were asked to allocate new number to reference colorfulness based on their memory of the previous one. Then the evaluation was continued.

Lightness was also evaluated by assigning a single number to it. As an anchor for evaluation, the lightness of reference white – always given side by side with test colors – was allocated to 100 and that of imaginary black was zero. Thus, higher value represents lighter perception ranging from 0 to 100.

To analyze the data, all participants' responses were averaged

Data analysis

Color appearance changes by neighboring colors

Figure 5 shows the comparison of color appearance results based on 'Reference' over neighboring color conditions. In each graph of the Figure, x-axis represents the averaged responses of each color appearance on 'Reference' and y-axis means the averaged responses on the other conditions – 'Desaturated', 'Saturated', 'Dark' and 'Light'.

As shown in the Figure 5, hue data points were mostly distributed along the 45degree line in the graph. Hue was not affected by neighboring color conditions.

However, some shifts are detected in colorfulness evaluation. Data points of 'Desaturated' tended to distribute above 45degree line, meaning that participants tended to evaluate colorfulness higher than 'Reference'. In contrast, data points of 'Light' mostly distributed below 45degree line and it suggest that colorfulness tended to be evaluated lower when the neighboring colors have high lightness. A paired t-test was conducted to compare colorfulness evaluation in 'Reference' versus 'Desaturated' and 'Light', respectively. Both conditions showed significantly different results in colorfulness evaluation for 'Desaturated'; t(21) = -3.183, p = .005* and 'Light'; t(21) = 4.899, p = .000*. -

In case of lightness, data points of 'Light' condition could be seen mostly below the 45degree line. Participants might perceive the colors relatively darker when neighboring colors became lighter. A paired t-test was also conducted to compare lightness evaluation between 'Reference' and 'Light' conditions showing the significantly different results; t(21) =5.266, p=.000*. This result can be explained by Simultaneous Contrast effect. As intended, the average CIELAB L* value of 'Light' was set high as 76.9. So, participants might evaluate lightness of same test colors lower in 'Light' condition because the condition consisted of relatively lighter neighboring colors, so test colors might be perceived relatively darker comparing with neighboring colors.

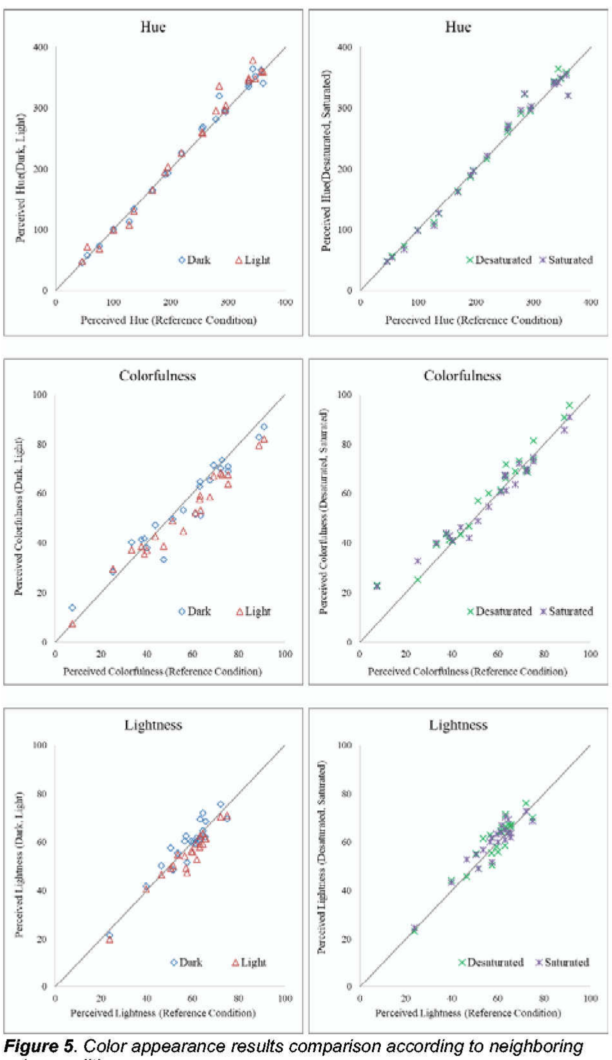

***Figure 5**. Color appearance results comparison according to neighboring color conditions*

Conclusion

The aim of the experiment was to investigate the effect of neighboring colors on color appearance. The color appearance experiment was carried out in a dark room by using a D65 lighting booth. Total of 5 different neighboring color conditions were used in the experiment and those were 'Reference', 'Desaturated', 'Saturated', 'Dark', and 'Light'. Each participant evaluated hue, colorfulness, and lightness of 22 test colors by using magnitude estimation method. Total of 20 participants evaluated in each neighboring color condition.

As findings of the experiment, colorfulness and lightness tended to be affected by neighboring colors. Firstly, colorfulness was evaluated higher when neighboring colors were desaturated. Both colorfulness and lightness tended to be evaluated lower when neighboring colors were lighter.

This research showed that the composition of neighboring colors could affect the color appearance of the stimuli. Further research requires to handle more various neighboring color conditions and viewing scenarios.

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Author Biography

Semin Oh received his BS degree in 'Human factors and affective engineering' (2013) and MS degree in 'Human factors and systems engineering' (2015) both from Ulsan National Institute of Science and Technology (UNIST), Ulsan, South Korea. Currently, he is taking his Doctorate course of 'Human factors engineering' in UNIST. His major research interests are color appearance and color emotion of lightings.

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