

QUANTITATIVE EXAMINATION OF COLOR CONSTANCY ACROSS DIFFERENT LIGHTING ENVIRONMENTS BY USING COLOR NAMING METHOD

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Keywords: color constancy, color adaptation, elementary color naming

ABSTRACT

The extent of color constancy was examined by elementary color naming method. Subjects did color naming for three achromatic and forty chromatic Munsell color chips under three illuminants D, A, and A' whose color temperature was lower than A. In the color naming task, subjects reported perceived components of whiteness, blackness, and chromaticness out of 100%. And then chromaticness was divided into red, yellow, green, and blue components following the color opponency rule. The results were plotted and the distributions were compared in a polar coordinate system where the chromaticness was taken as radius and hue (rate of red, yellow, green, and blue) as angle. The color constancy index was defined by overlapping area of distributions from two different illuminants. The index was higher, that is higher color constancy, between D and A than that of D and A'.

INTRODUCTION

We can perceive the color of surface of reflecting objects constantly even under varying illumination conditions. This phenomenon is called color constancy. Although many studies have focused on the color constancy, there were a few studies examining quantitatively. Elementary color naming is one of the color naming method and the main purpose of the present study was to quantify color constancy by using this color naming method and that is useful for revealing subjective color appearance of an observer under various illuminant conditions. In elementary color naming method, an observer is asked to report a perceived color of object in terms of its whiteness, blackness, and chromaticness; an observer report, for example, that a perceived color contains 40% whiteness, 30% blackness, and 30% chromaticness. If chromaticness is perceived, the observer is further asked to estimate percentages of color components (i.e., red, yellow, green, and blue) contained in the perceived color following the color opponency rule: for example, an observer report that 40% redness and 60% yellowness is contained. In the present study, we measured subject's color appearance to various color chips under different illuminants with (adaptation condition) or without adaptation (no adaptation condition) to the illuminants. If we assume that no color constancy is achieved in the no adaptation condition, we can determine the amount of color constancy in some illuminant condition by calculating differences in the subject's color appearance (measured by the color naming method) in the adaptation condition relative to those in the no adaptation condition. In the present study, we compared the color constancy between different illuminant conditions.

METHOD

Three subjects (RN, KF, RI) who had normal color vision participated in the experiment. 43 Munsell color chips were used. 20 of them had value 6 and chroma 6, another set of 20 had value 4 and chroma 4, and the remaining 3 were achromatic. Hue of chips was selected to be evenly distributed along the hue circle: 5R, 10R, 5YR, 10YR, 5Y, 10Y, 5GY, 10GY, 5G, 10G, 5BG, 10BG, 5B, 10B, 5PB, 10PB, 5P, 10P, 5RP, or 10RP. Achromatic color chip was N4, N6, or N8. The chips were located in a board (10×20cm). Except for the center part (1.4×1.4cm), the surface of the board was N5 and experimenter set chips at center. Three illuminants were used: D, A, A' illuminants. The coordinates of those illuminants were (x=0.307, y=0.331), (x=0.442, y=0.391), and (x=0.528, y=0.406), respectively. To measure the color appearance without adaptation to the illuminants, we used a tube subtending 36 cm in length and 0.7 cm in diameter. The experiment was conducted in a room under one of the three illuminants. Before an experimental session, subjects practiced the task for several trials until they were familiarized with the task. At the beginning of each trial, one of chromatic or achromatic chips was presented and the order in each trial was random. There were 18 sessions for each subject (6 conditions × 3 times). The task of subjects was to report a perceived color of chip by estimating percentages of its whiteness, blackness, and chromaticness in a way that the total percentage of these attributes was 100%. If the chromaticness was perceived, subjects were further asked to estimate percentages of color components (i.e., red, yellow, green, and blue) included in the perceived color in a way that the total of proportions was also 100%. Note that in the second task, the subjects followed the color opponency rule in which we described above.

RESULTS AND DISCUSSION

All data obtained were plotted as polar coordinates in which the percentage of chromaticness was taken as radius and hue (red, yellow, green, and blue) as angle. Fig.1. shows the result of one subject (RN) in (a) the adaptation and (b) the no adaptation condition. Each marker in the figure represents the results of color naming under D (diamonds), A (squares), and A' (triangles) illuminants. Open symbols show the results for the N6 chip under each illuminant. As shown in the figure, plots are quite similar across the three illuminants in the adaptation condition (see Fig. 1a), suggesting that the color constancy is highly achieved. On the other hand, plots were shifted to the y, r, quadrant as color temperature was dropped, suggesting that none of the color constancy is achieved. Note that the data for the N6 chips were almost centered in the adaptation condition while in the no adaptation condition, the data were shifted to y, r quadrant as color temperatures drop. The result of color naming to achromatic N6 had no chromaticness under D illuminant (even in without adaptation condition) so we considered data of under D illuminant as the base and we tried to quantify the degree of color constancy between D and A or D and A' illuminants. Fig.2 is pattern diagram of each condition. We considered the data of in without adaptation condition as degree of color constancy is zero and if perfect color constancy is achieved, plotted data under A and A' illuminants are same as under D illuminant. Fig.2. (0) is data of in without adaptation condition and Fig.2.(1) is with adaptation. Fig.2. (2) shows expected result if color constancy is perfect. Let D_n (n=0,1,2) be the area of plotted results of under D illuminant (which are shown by solid line) in each condition and let C_n (n=0,1,2) be the overlap area between results of under D and other illuminants (which are shown by grey color in Fig.2). Then the color constancy index (CCI) is $(C_n - C_0)/(D_n - C_0)$ and $D_2 = D_1 = C_2$. CCI is on a scale of 0 to 1, where 1.0 would be perfect constancy. This index was calculated for each subject. Fig.3 shows the indices of between D and A (it is shown DA in Fig.3) or D and A' illuminants (it is shown DA' in Fig.3) for 3 subjects. Left is value/chroma = 6/6. Right is value/chroma = 4/4. Diamonds show the indices of subject RN. The indices of subject KF and RI are shown by Filled square and open triangles respectively. From the data obtained, we found the tendency. The degree of color constancy between D and A

illuminants were higher than that of between D and A' illuminants. This tendency was common among subjects.

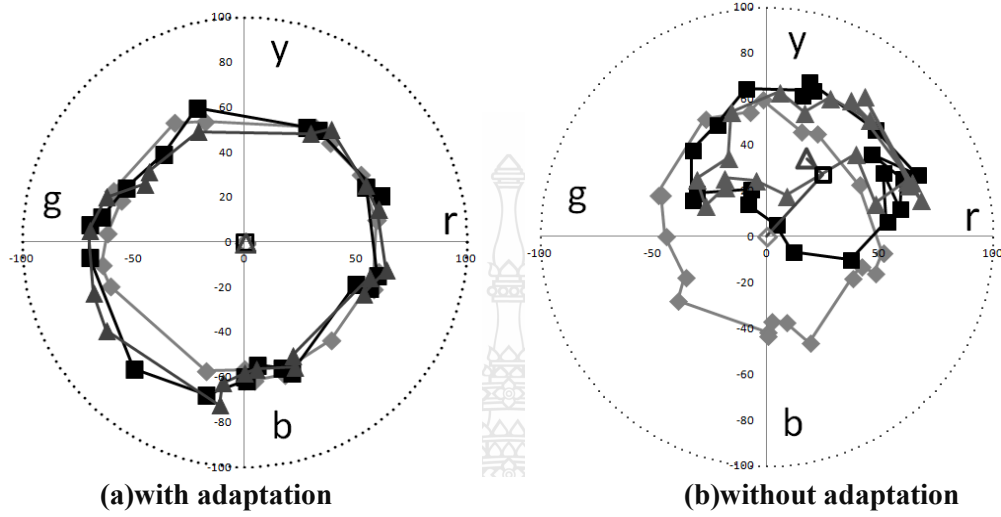


Figure.1 Result of subject RN(Value/Chroma=6/6)

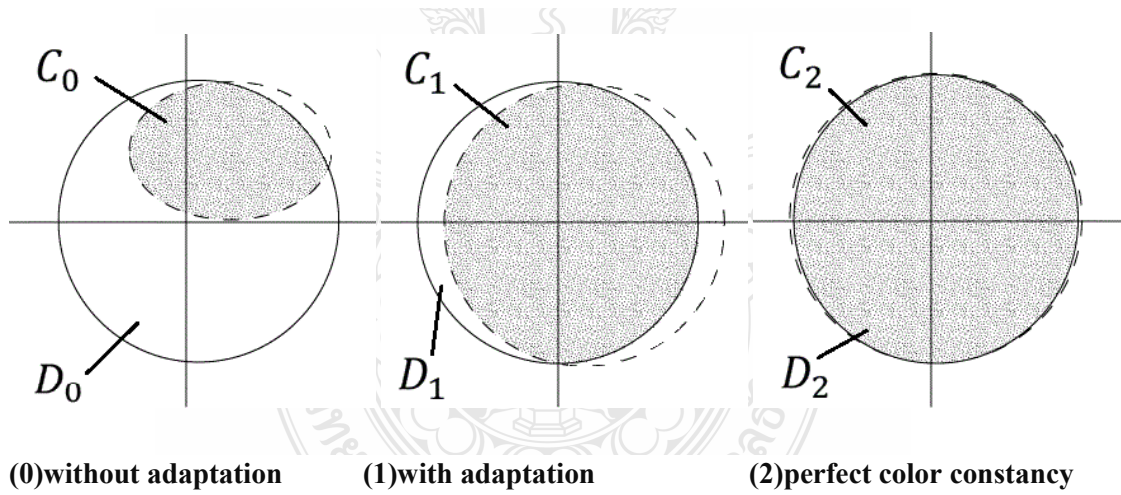


Figure.2 Pattern diagram

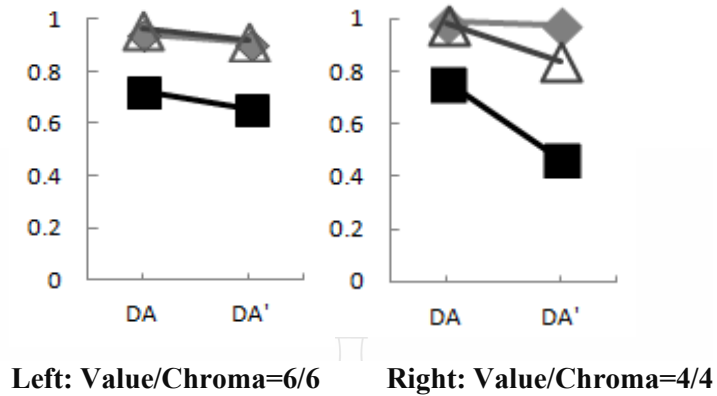


Figure.3 Degree of color constancy

CONCLUSION

In this study, we proposed a new color constancy index. The results showed individual difference but we found the tendency. As color temperature drop, the degree of color constancy is drop(see Fig.3). This tendency has also been reported in other study^[1]. This method has improvement. For example, this method can't use to achromatic color chips. To resolve this point is one of the future tasks.

REFERENCES

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