Influence of colors on reaction time in progress of dark adaptation

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Abstract

Rapid change of illuminance brings us difficultly of judging accurate colors because that the color perception is influenced by the illuminance. In this study, we experimented on reaction time to color chips in progress of dark adaptation. We think that the reaction time is an index of visibility. The results may bring useful information for avoiding car accidents in dark places. Especially, the purpose of the experiment is to investigate relationship between the reaction time and the three elements of colors, hue, value, and chroma in the Mansell color-order system. As the result, we can conclude that the value is the most effective factor, because the brighter colors could be found in a shorter time. It is also clarified that the reaction time is influenced by the chroma and the hue, through an additional experiment with color chips having the same value.

***Key words**: Reaction time, Dark adaptation, Illuminance, Munsell color system*

1 Introduction

Our eyes can response a wide range of illumination levels from 100000lx to 0.001lx because of the visual functions like the light (photopic) adaptation and the dark (scopic) adaptation. Thus we can correctly recognize objects under either midsummer sun or the starry sky. But the visual functions sometimes fail to adapt for the envelopments temporarily, for example, immediately after going into a tunnel in a car[1]. Actually, plane accidents have happened from losing view of pilots [2].

On the other hand, colors often are used as an effective means to represent visual signs. They enable us to identify objects intuitively. However, rapid change of illuminance brings us difficultly of judging accurate colors because that the color perception is influenced by the illuminance. Previously, few researches have reported color perception in progress of dark adaptation[2]. Thus, in this study, we take an approach from the viewpoint of the color perception to cope with such accidents by investigating relationship between the reaction time and the three elements of colors, hue, value, and chroma in the Mansell color-order system.

2 Methods

2.1 Environment

The environment of experiments is shown in Fig1. The experiments were carried out in the room where the illuminance was set to about 0.3lx. This illuminance level is almost lower limit of the twilight vision, namely, minimum brightness in which colors are recognized.

The participants sat a chair in front of two black boards (Munsell number: 5.3GY 2.20/0.40) on a desk. One black board was set on the desk. The another blackboard was stood up on the desk, and the center of the black board had a square hole(20 × 14 cm) so that the participants may look in a color chip as the stimulus through the hole.

Moreover, a white box was made from styrene boards and shone by a fluorescent lamp (MITSUBISHI, OSRAM・BB-1・FPL27EX−N). The illuminance of the boxes inside was adjusted about 8000lx, typical value on overcast days.

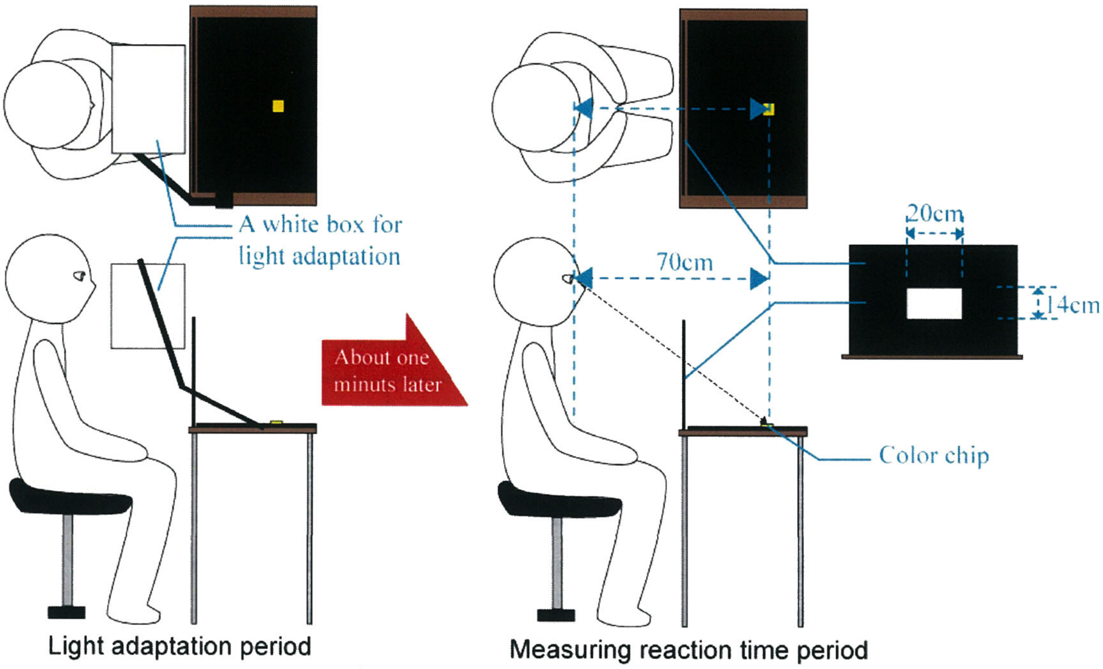

Figure1. Experiment Environment

2.2 Procedure

The participants sat on the chair which was adjusted so that the horizontal distance from a color chip on the desk to the eyes might become about 70 cm. At first, the participants looked in the white box for the light adaptation box. One minute later, the lights turned out and a stop watch was started at the same time. Then, the eyes of the participants started the dark adaptation to the indoor illuminance of about 0.3lx. When the participants could observe a color chip of 5×5cm put on the black board in progress of the dark adaptation, they stopped the stop watch.

2.3 Result of a pilot experiment

In the pilot experiment, we used 24 color chips which had various hue, brightness, and chroma. These were 3 tones of PCCS(Practical color coordinate system), the blight tone(b), the vivid tone(v), and deep tone(dp). From the result, we can conclude that the value of color is the most effective factor to control the reaction time of color chip, because the brighter colors could be found in a shorter period of time (Fig.2). However, Fig.2 also shows probability that the hue and the chroma affect the reaction time in the progress of the dark adaptation.

2.4 Stiimuli

The experiment aimed to clarify whatever the hue and the chroma of the color chips affected the reaction time in the progress of the dark adaptation. We prepared new 24 color chips. The selected colors covered the entire range of hue, value and chroma of the colors. They had the same value and the same chroma in any hue in the Munsell color system. The value of colors was fixed about 5, and the chromas prepared were 3 levels, the low level(L), the middle level(M), and the high level(H).

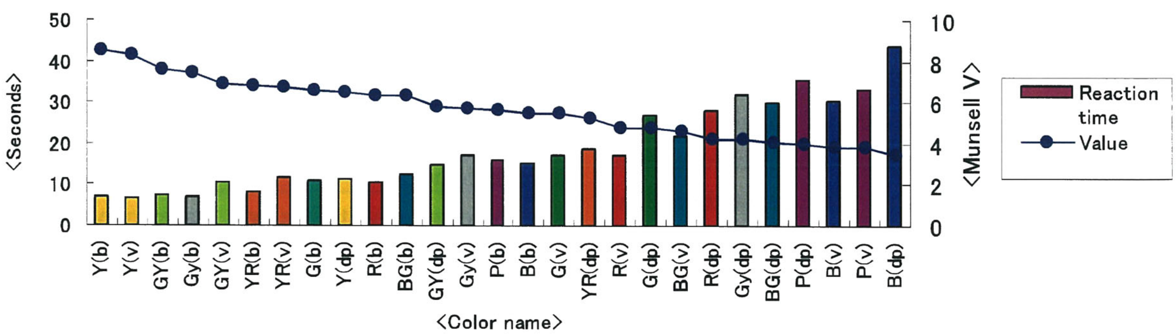

Figure 2. Result of a pilot experiment

The color chips were made by using an inkjet printer (CANON, PIXUS-MP600) and two sided print papers without luster. This size of the color chip was 5cm×5cm. Table 1shows the details of each color chips.

3 Results and Discussion

Figure 3 and 4 show the standardized average of reaction time to each color chip. The results shown in Fig.3 are arranged in order of each chroma in each hue, and the same results shown in Fig.4 are rearranged in order of hue in the each chroma.

Table1. Details of color chips

Chroma	Color Name	Munsell Code	Chroma	Color Name	Munsell Code
Low	Red	5.0R 5.50/2.10	Midium	Green	5.0G 5.50/6.10
	Orange	4.7YR 5.50/2.00		Turquoise	5.5BG 5.60/5.90
	Yellow	4.9Y 5.60/1.90		Blue	4.7B 5.50/6.00
	Yellow Green	5.3GY 5.50/1.80		Purple	4.7P 5.60/6.00
	Green	5.0G 5.50/1.90	High	Red	5.1R 5.50/9.60
	Turquoise	5.3BG 5.50/2.00		Orange	4.9YR 5.60/9.60
	Blue	4.8B 5.50/2.20		Yellow	4.7Y 5.60/9.00
	Purple	4.6P 5.60/3.00		Yellow Green	5.3GY 5.60/9.10
Midium	Red	4.7R 5.50/5.90		Green	5.3G 5.60/9.10
	Orange	4.6YR 5.50/6.00		Turquoise	4.8BG 5.40/10.20
	Yellow	4.7Y 5.50/6.00		Blue	5.3B 5.50 10.20
	Yellow Green	5.2GY 5.50/5.90		Purple	5.0P 5.50/10.20

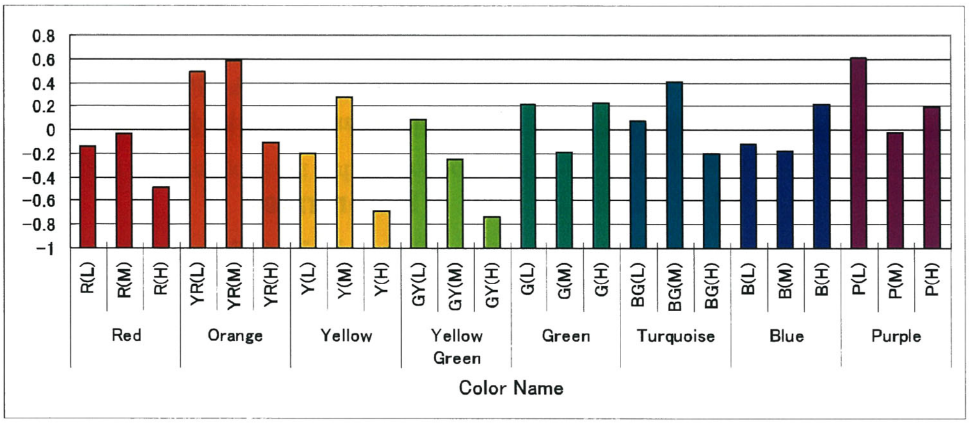

Figure3. Standardized average of the reaction time (chroma order in each hue)

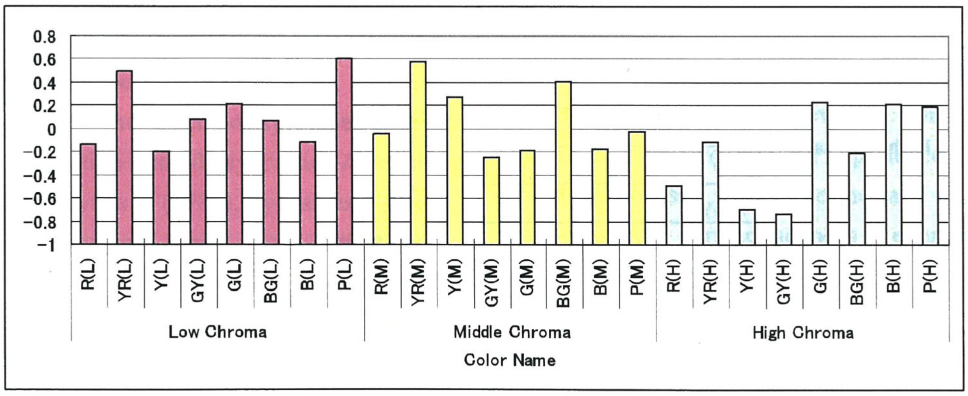

Figure4. Standardized average of the reaction time (hue order in each chroma)

The color with the shortest reaction time was Y(H), yellow of high chroma, and it took 8.72 seconds. On the other hand, the color with the longest reaction time was P(L), purple of low chroma, and it took 12.28 seconds. There was about 4 seconds difference between those reaction times although they had the same value.

2-way analysis of variance of hue, 8 levels, and chroma, 3 levels, revealed significant main effects for the both hue and chroma [$F(7, 168) = 3.79$, $p = .0008$, $MSe = 6.92$ and $F(2,48) = 8.32$, $p = .0008$, $MSe = 3.50$, respectively]. Interaction between hue and chroma was also significant. The results were subjected to multiple post hoc comparisons by Ryan's method. Table 2 shows the significant combinations (0.05 significant level).

The result of our pilot experiment showed that the value of color is the most effective factor to control the reaction time of color chips. In addition, from the results of this experiment, it is considered that the hue and the chroma influence to the reaction time. Because there is an interaction between these factors, the influence of chroma depends on the hue of colors.

Table2. The significant combinations

Main Effect		Multiple post hoc comparisons
Chroma		Low × High
		Middle × High
Hue		YR × GY
		R × YR
		P × GY
		Y × YR
Interaction	Chroma × YR	Middle × High
		Low × High
	Chroma × Y	Middle × High
	Chroma × GY	Low × High
	Hue × Low Chroma	No Effect
	Hue × Middle Chroma	No Effect
	Hue × High Chroma	G × Y
		G × GY
		GY × B
		B × Y
		P × GY
		P × Y

As for comparing, the reaction times of each hue, the high chroma colors of long wavelength (R-GY) tend to show shorter reaction time than that of short wavelength (G-P). The colors of low and middle chroma did not show any tendency to depend on the hue clearly like the high chroma colors. It seems that the spectral power distribution influences the reaction time. However, though 555nm and 507nm have the maximum luminosity efficiency in photopic and scotopic visions, the results doesn't consistent with the spectral luminous efficiency.

We need to think about other factors of color.

4 Conclusions

In this study, we investigated relationship between the reaction time in the progress of dark adaptation and the three elements of colors, hue, value, and chroma in the Mansell color-order system. The following points were revealed.

The value of color is the most effective factor to control the reaction time of color.

The hue and the chroma influence to the reaction time. And there is an interaction between them.

The mechanism to affect the reaction time is not clear, but it is possible that the spectral power distribution influences the reaction time.

The maximum difference of reaction times was 4 seconds in this experiment, although they had the same value. We have to carefully select color, if the environment has a possibility of suddenly illuminance change, and the dark adaptation.

5 References

[1]Tsukada. Y., & Toyofuku. Y., Aoki. Y. (2005). Visual Characteristics under Sudden Change of Adaption Stimulus. *Report of N.T.S.E.L.*, **No.8**, 31- 41.

[2]Visual guidance system (1999), Aviation Administration of Ministry of Transport, *Japan Civil Aviation Promotion Foundation.*, 172-174