Categorical Effects In Printed Color for Elderly and Young People Under Different Color Temperature of Lighting

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Abstract

This study focused on printed color chips based on 12 categorical colors by elderly and young people under the difference in color temperature of lighting. The experimental subjects were comprised of 15 elderlies with the age of 60 – 70 years old and 30 young people with the age of 25 – 35 years. The subjects determined the printed color of 1,046 color patches and sorted them out into 12 category color boxes (Red, Red-Yellow, Yellow, Yellow-Green, Green, Green-Blue, Blue, Blue-Purple, Purple, Purple-Red, Pink and Brown). In case of no decision on color patch into the 12 color boxes, the patch was put into "Out" box. The viewing conditions were LED lamp with 2 correlated color temperatures (CCTs) of 6500 and 2700 K, with illuminance of 700 lux, and 0/45 degree observer. CIELAB, CIELCH color space of color patches, and color difference from reference color were evaluated and MANOVA was also applied in terms of statistical analysis. In addition, the 12 categorical colors perceived by the two groups were evaluated by using color difference (ΔE_{ab} and ΔE_{00}). The results revealed that the categorical colors affected on CIE L*a*b* significantly whereas group age and lighting condition had no significant difference. In addition, the categorical colors of elderly under 2700 K presented remarkable color difference compared to elderly under 6500 K, young under 6500 K and 2700 K. The findings suggested that the interaction between color categories and different groups of aging people and also using color design under different lighting condition should be considered.

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Introduction

Categorical colors simplified to apply color effectively to various visual applications (Ishida, 2002; Sagawa et al., 2003; and Lin et al., 2013) including packaging (Roullet, 2005). The categorical colors were mostly based on the theory of 11 basic color terms recommended by Berlin and Kay (1969), which were are red, orange, yellow, green, blue, purple, pink, brown, white, gray, and black. Ishida (2002) applied the 11 basic color terms by adding 2 color terms of "yellow-green" and "blue-green used in daily life of Japanese people to find out how 256 color chips selected from value planes of 4, 6 and 8 of Munsell color space were identified under fluorescent lamp with CIE x,y value at 0.34 and 0.35, respectively, and 4 illuminance levels of 1000, 10, 1 and 0.1 lux. He found that color identification decreased with illumination at 10 lux. Sagawa et al. (2003) studied on spans of 11 color categories indicated by using a criterion of similarity of colors for elderly and young people under white illumination of 2 illuminance levels of 500 and 0.5 lux by comparing each of 286 color chips to 20 reference color chips including the 11 basic colors. The findings revealed that the 11 color categories expressed in Value 5 plane of Munsell color space, which are 5R5/12(red), 5YR5/10(red-yellow), 5Y5/6(yellow), 5GY5/8(yellow-green), 5G5/8(green), 5BG5/8(blue-green), 5B5/8(blue), 5PB5/10(purple-blue), 5P5/10(purple), 5RP5/10(purple-red) and 5N(grey). Each of the 11 color boundary showed smaller area for the elderly than for the younger people. However the research of categorical color is still in the limit of realistic color used.

According to a survey by the United Nations Population Division (UNDP), the ratio of the aging population closely turned up two decades, from 7.73% in 2015 to 15.49% in 2035 (up to the global average). Thailand is one of the two countries with the major fraction of aging population (23.39 percent) (Srimalee, 2018). Declines in color vision with age can undesirably affect Elderly daily life (Ishiharaa et al, 2001) including packaging (Endestad et al., 2016 and Roullet et al., 2005). According to Ishihara et al.(2001) study, they found that some elderly people fail to discriminate between some combination of colors such as blue/green, purple/dark red. The elderly people have difficulties in their daily lives resulting from their color mistake causing from the age-related yellow vision. Endestad et al. studies on Pharmaceutical packaging color and drug expectancy, they found that red and brown packaged drugs are perceived more costly than yellow boxes. Red and brown packaging are also perceived as designed for serious illness comparing to green and yellow packaging. (Endestad et al. 2016)

Young designers should select proper color on elderly customers. The present study aims to find out the effects of categorical colors in printed color for elderly and young people under different color temperature of lighting.

Experimental procedure

Categorical colors

In the present study, 12 categorical colors of Munsell color space used based on the previous research (Berlin et al., 1958; Ishida, 2002; Sagawa et al., 2003), which were Red (5R5/12), Red-Yellow (5YR5/10), Yellow (5Y5/6), Yellow-Green (5GY5/8), Green (5G5/8), Blue-Green (5BG5/8), Blue (5B5/8), Purple-Blue (5PB5/10), Purple (5P5/10), Purple-Red (5RP5/10), Pink (7.5 RP 5/14), Brown (5YR5/6).

Figure 1. The 12 categorical colors of Munsell color space, Red (5R5/12), Red-Yellow (5YR5/10), Yellow (5Y5/6), Yellow-Green (5GY5/8), Green (5G5/8), Blue-Green (5BG5/8), Blue (5B5/8), Purple-Blue (5PB5/10), Purple (5P5/10), Purple-Red (5RP5/10), Pink (7.5 RP 5/14), Brown (5YR5/6)

Experimental room and stimuli

The experiment was conducted in an experimental room of 1.8 × 1.8 × 2.3 m (width × length × height), and the walls were painted a neutral gray. An adjustable LED light (HH-LC714A) from PANASONIC with a color rendering index (CRI) of 85 was mounted on the ceiling of the room. The 2 lighting conditions were generated, with combinations of 2700 and 6500 K CCT and illuminance of 700 lux (Clare et al., 2016 and Hegde et al., 2012).

The color ships used in the experiment were 1,046 printed color patches provided by Toyo Ink. Each chip size is 2.4 x 2.4 cm. (width x length).

Test procedure

In total, 45 experimental subjects with normal color vision were divided into two groups according to their range of age. The first group was 15 elderly people (12 female and 3 male) with age ranging from 60 to 70 years old while the second one was 30 young people (16 female and 14 male) with age ranging from 25-35 years old. Each subject sat in a chair under the 2 different lighting conditions with about 3 minutes allowed for adaptation to each condition (Viénot et al., 2009). Then each subject looked at the 12 categorical colors reference until all were memorized. Afterward each subject was asked to place 1,046 color chips into boxes which were associated to the twelve categorical colors by written reference only. No actual color comparisons to the reference colors were made. The viewing distance and angle were 30 cm and 0/45 degrees, respectively. If the subjects could not decide any color chips associated to the 12 categorical colors, the chips would be put into box named "out".

Figure 2. Subject arranged the 1,046 color chips according to the 12 categorical colors.

Data Analysis

CIELAB and CIELCH of all color chips in each categorical color box were evaluated and compared to the 12 reference colors. Mean, standard deviation, and MANOVA were analyzed. In addition, Color difference ΔE_{ab} and ΔE_{00} between mean of CIELAB and the reference were evaluated.

Results and discussion

Color patch arrangement into the 12 reference categories The results obtained from arranging 1,046 color chips into 12 reference color box are shown in Figure 3 and 4. The plots of a* and b* value of CIELAB of each color chip chosen by elderly subjects provide mostly the same direction as young subjects under both

lighting conditions of 6500K and 2700K. The darker point at the center of the graph represents the mean of a* and b* value of each categorical color, which was mainly in quadrant corresponding to categorical color name for both groups under the both lighting conditions.
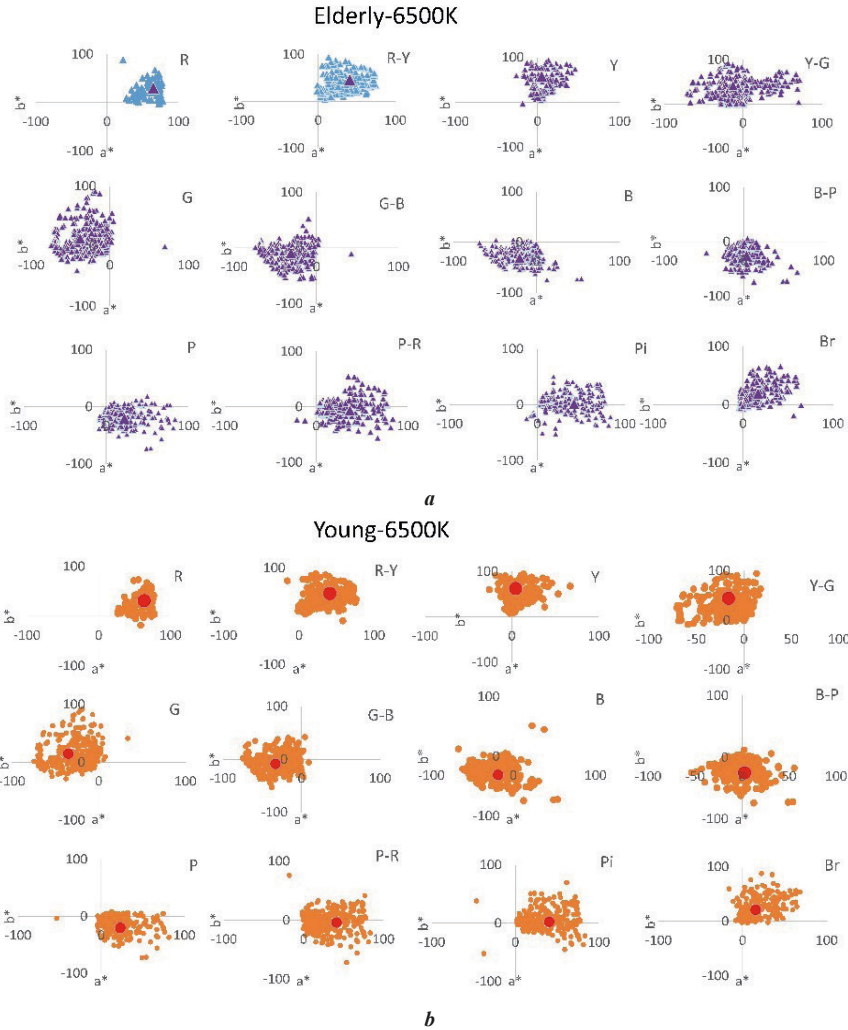

Figure 3. *The plots of a*b* value of color chips chosen in each reference box named such as Red (R), Red-Yellow (R-Y), Yellow (Y), Yellow-Green (Y-G), Green (G), Green-Blue (G-B), Blue (B), Purple-Blue (P-B), Purple (P), Purple-Red (P-R), Pink (Pi), Brown (Br) of two groups of subjects under 2 different color temperatures; a) Elderly under 6500 K b) Young under 6500 K*

Figure 4. *The plots of a*b* value of color chips chosen in each reference box named such as Red (R), Red-Yellow (R-Y), Yellow (Y), Yellow-Green (Y-G), Green (G), Green-Blue (G-B), Blue (B), Purple-Blue (P-B), Purple (P), Purple-Red (P-R), Pink (Pi), Brown (Br) of two groups of subjects under 2 different color temperatures; a) Elderly under 2700 K and b) Young under 2700 K.*

CIELAB of the categorical color and MANOVA analysis

Color value from Munsell color space of the 12 categorical colors were converted into CIELAB by using Munsell Conversion Version 6.5.9 WallkillColor. CIELAB of each categorical color as shown in Table 1 is reference color for color difference comparison to the corresponding mean of CIELAB of the selected color chips.

Categorical Color	L*	a*	b*
Red	51.57	50.73	26.61
Red-Yellow	51.57	26.2	53.09
Yellow	51.57	-1.07	44.02
Yellow-Green	51.57	-25.02	50.55
Green	51.57	-42.45	13.23
Green-Blue	51.57	-38.59	-7
Blue	51.57	-21.72	-26.63
Blue-Purple	51.57	3.75	-40.26
Purple	51.57	31.24	-29.94
Purple-Red	51.57	42.46	-4.57
Pink	51.57	59.69	1.53
Brown	51.57	16.82	31.13

Table 1. *CIELAB of the 12 categorical colors*

According to Multivariate analysis of variance (MANOVA), the results in Table 2 indicated that only categorical color significantly impacted CIELAB [$F(36, 277988.315) = 11222.254$ (Wilk's Lambda) p-value<0.001)] whereas lighting condition and group of subjects (elderly and young) have no significant effect on CIELAB.

Items	Wilks' Lamda	F	Sig.
Intercept	.081	356352.833b	0.000
Categorical color	.071	11222.254	0.000
Group (elderly and young)	1.000	b	
Group detail (elderly with 6500 K, young with 6500 K, elderly with 2700 K, and young with 2700 K)	1.000	b	
Light type (6500 K, 2700 K)	1.000	b	
Categorical color*Group	1.000	b	
Categorical color*Group detail	1.000	b	
Categorical color*light type	1.000	b	
Group*Group detail	1.000	b	
Group*light type	1.000	b	
Group detail*light type	1.000	b	
Categorical color *Group*Group detail	1.000	b	
Categorical color *Group*light type	1.000	b	
Categorical color *Group detail*light type	1.000	b	
Group*Group detail*light type	1.000	b	
Categorical color *Group*Group detail*light type	1.000	b	

Table 2. Multivariate analysis of variance (MANOVA) result of lighting, age groups, and categorical color by Wilks' Lambda satatistic

Color difference comparison

Figure 5 and 6 showed that color difference between the reference color and the color chips observed by elderly under CTT 2700 K provided wider range than by young under CCT 2700 K, elderly under CCT 6500 K, and young under CCT 6500 K, especially in red color. The blue and green-blue color exhibited less color difference when viewing by elderly and young people under both CCTs 6500 and 2700 K.
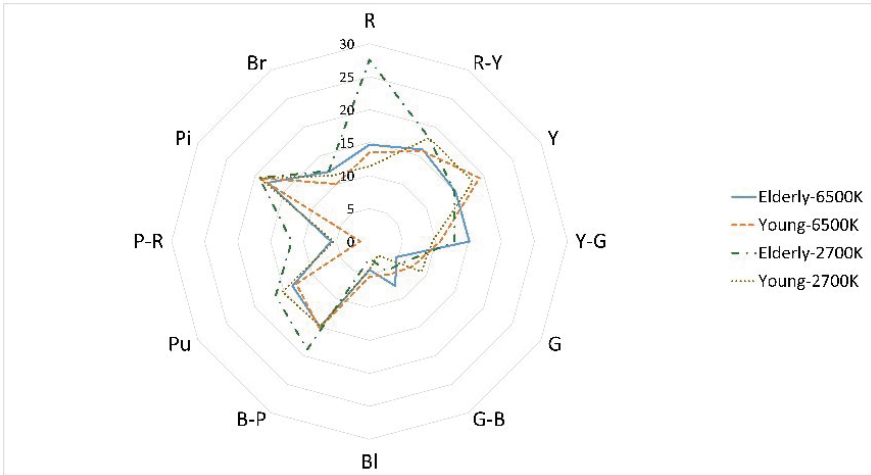
Figure 5. *Color difference comparison (ΔE*ab) between CIELAB of the categorical reference and mean of corresponding CIELAB of the selected color chips of elderly and young under 6500 K and 2700 K*
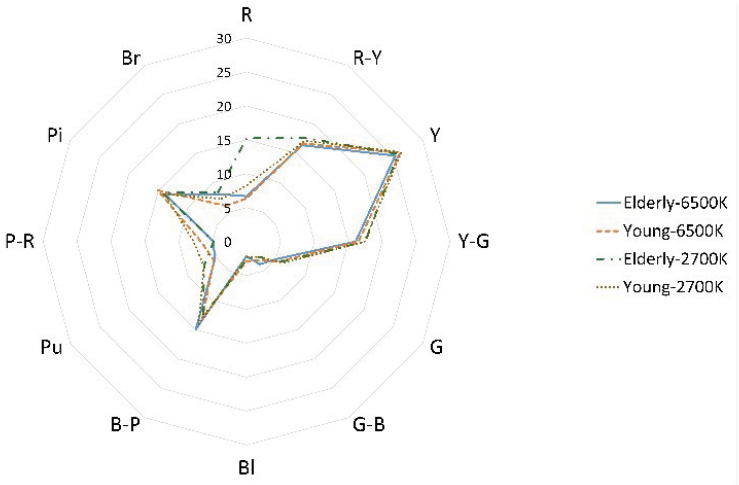

Figure 6. *Color difference comparison (ΔE*00) between CIELAB of the categorical reference and mean of corresponding CIELAB of the selected color chips of elderly and young under 6500 K and 2700 K*

Conclusion

Based on the categorical color concept, the printed color chips used for printing design were categorized by elderly and young people under CCT 6500, 2700 K and illumination 700 lux. It was shown that the categorical color was the most significant impact on CIELAB. The proper color for design on packaging print should be chosen with consideration given to both young and elderly customers.

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