Considerations of the Affective Factors for Appreciating a Printed-Color Picture

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Abstract. The appearance of a printed-color picture is determined by characteristics of the observer and the observing environment. This experimental study investigates the preferable appearance of a printed-color picture by using the semantic differential (SD) method under several lighting conditions (incandescent lamp, fluorescent lamps, and white light emitting diode (LED) lightings). This study examines the important affective factors of observing printed-color pictures in younger participants (approximately 20 years old) and elderly participants (over 65 years old). The results suggest that there are age-related differences in that the preferable appearance for younger participants consists of affective factors such as “naturalness” and “calmness,” while the preferable appearance for elderly participants consists of visual factors such as “easy to see” and “clarity.”

Keywords: Appearance, Aging, Lighting condition, White LED.

1 Introduction

According to World Population Prospects, over the past 50 years the proportion of people with over 65 years of age has increased from 5.2% to 7.6%, while the proportion of people below 15 years of age has decreased from 34.3% to 29.2% (1950-2010).[1] Thus, it is important that age-related changes should be considered when designing environments for elderly people to observe objects. In particular, recent progress in color-print technology has resulted in a higher quality of colored documents and color-pictures. This suggests the importance of investigating the preferable environment for observing printed-color pictures for elderly persons.

The appearance of a printed-color picture is affected not only by the layout of color but also by the observation conditions, such as lighting. For example, the shape and color of objects are clearer in a bright room than dim one. Components of the lighting (spectral distribution) are associated with the appearance of objects. Lighting can be organized in these environmental conditions. This means that a lighting condition might be adjusted to create the preferred appearance of a printed-color picture

according to the type of observer's visual characteristics, namely to whom you want to show it to and how you want to show it.

This study investigates how lighting conditions are associated with the preferred appearance of printed-color pictures in elderly people through a lighting assessment experiment. The results of the study identify the affective factors related to the preferred appearance of printed-color pictures. After identification of these factors, this paper discusses its findings to the applicability of lighting design. Finding significant affective factors associated with the preferred appearance helps individuals design a human-friendly environment that reflects the designer's intent when showing printed-color pictures to elderly people.

2 Experimental Method

2.1 Participants

Fifteen younger participants (9 male, 6 female; mean = 21.6 years old, SD = 4.26) and 20 elderly participants (16 male, 4 female; mean = 65.4 years old, SD = 4.01) participated in the experiment. Participants were volunteers recruited through advertisements. All participants had normal vision with no visual impairment. Some participants wore their own glasses or contact lenses during this experiment.

2.2 Assessment Target

The assessment target was a color picture printed by an ink-jet printer (Canon, BJ F9000). The picture depicted a color-balanced, natural, still object. The size of the picture was A4 (210 mm $\times$ 297 mm). Figure 1 blow shows the design used in the experiment.

Fig. 1. The printed-color picture used in the experiment

2.3 Assessment Method under Experimental Lightings

The semantic differential (SD) method was used to find the affective factors on the preferred appearance of printed-color pictures under experimental lighting conditions. Ratings for the SD method consisted of a five-point scale with 15 bipolar adjectives: pleasant-unpleasant, distinct-indistinct, fatigue-indefatigable, prefer-dislike, warm-cool, calm-not calm, gaudy-modest, conspicuous-inconspicuous, natural-unnatural, easy to see-difficult to see, vivid-somber, bright-dark, three-dimensional-flat, clear-muddy and beautiful-not beautiful. These were selected from previous studies[2, 3].

2.4 Experimental Conditions When Observing the Printed-Color Picture

The present experiment applied five lighting conditions by using three different types of lighting devices to observe a printed-color picture: incandescent lamp (IL), two fluorescent lamps (FL) and two white LEDs (LED). Table 1 summarizes the characteristics of these five lighting conditions represented by Light A, B, C, D and E, respectively.

Although among the lighting conditions, Lights B and C were the same fluorescent lamps, Light C produced a different correlated color temperature (CCT) from Light B because of its use of a conversion filter for CCT. Similarly, Lights D and E were the same white LED, but Light D was produced by using a conversion filter for CCT.

Thus, these five lighting conditions differ in their type of lighting devices. CCT and spectral distribution are associated with lighting type and CCT. Each of the lighting devices used in the experimental apparatus are shown in Figure 1. Illuminance on the table and the printed-color picture as the assessment target was adjusted to 500 lx.

Table 1. Characteristics of lighting conditions to observe the printed-color picture

	Light A	Light B	Light C	Light D	Light E
Type of lighting device	Incandescent lamp	Fluorescent lamp	Fluorescent lamp	White LED	White LED
Correlated color temperature (K)	2700	4100	4900	4000	5300
Color of light	Warm	White	Natural white	White	Natural white
General color rendering index (Ra)	100.0	87.5	87.5	84.0	85.0

Fig. 2. Experimental apparatus for the lighting devices used in the experiment (mm)

2.5 Procedure

First, only the experimental lighting (e.g., Light A) was turned on in a dark room. After each participant gave informed consent for the experiment, they were instructed to rest for ten minutes to adapt to the brightness in the room.

Next, participants laid their forehead on the head rest to fix their posture and were instructed to observe the printed-color picture for ten seconds. Then, the assessment questionnaire with SD adjectives was handed to them and they assessed the appearance of the printed-color picture by using the SD method. After participants completed the assessment, the lighting was changed to another light (e.g., Light B). This procedure was repeated for each type of lighting. The lighting order was randomized among participants.

Fig. 3. Experimental schedule

3 Results

This study assessed the appearance of a printed-color picture under different lighting conditions by using the SD method to find the important affective factors for the preferred appearance of the printed-color picture. Among 15 SD adjectives,

beautiful-not beautiful, pleasant-unpleasant and prefer-dislike appeared comprehensive, and appearance-evaluative adjectives, which were referred to as beauty, pleasantness and preference aspects, respectively, also appeared comprehensively. To obtain the affective components related to the appearance of the printed-color picture, a multiple regression analysis (stepwise method) was conducted using three adjectives (beautiful-not beautiful, pleasant-unpleasant, and prefer-dislike) as objective variables and the other 12 adjectives as explanatory variables according to age group. This multiple regression analysis led to the results shown in Table 2.

Table 2. Results of the multiple regression analysis for younger group

Objective variable: Beauty aspect ($R^2 = 0.57, p < .01$)

	Standardized coefficients	<i>t</i>	<i>p</i>
intercept	0		
calm-not calm	0.28	2.88	< .01
natural-unnatural	0.23	2.34	< .05

Objective variable: Pleasantness aspect ($R^2=0.66, p < .01$)

	Standardized coefficients	<i>t</i>	<i>p</i>
intercept	0		
calm-not calm	0.22	2.11	< .05
natural-unnatural	0.28	2.95	< .01
distinct-indistinct	0.34	3.57	< .01
clear-muddy	-0.29	-2.83	< .01
fatigue-indefatigable	0.25	2.38	< .05
easy to see-difficult to see	0.26	2.35	< .05

Objective variable: Preference aspect ($R^2=0.72, p < .01$)

	Standardized coefficients	<i>t</i>	<i>p</i>
intercept	0		
calm-not calm	0.24	2.85	< .01
natural-unnatural	0.43	5.61	< .01
vivid-sombre	0.18	2.22	< .05
clear-muddy	0.16	2.15	< .05
fatigue-indefatigable	0.30	3.60	< .01
three-dimensional-flat	0.20	2.56	< .05

For the younger group, the analysis obtained the same adjectives in the following three aspects: The beauty aspect contains “calm-not calm” and “natural-unnatural.” The pleasantness aspect, however, also contains “distinct-indistinct,” “clear-muddy” and “easy to see-difficult to see,” representing visual clarity and visibility, and “fatigue-indefatigable,” representing the physical-mental statement. The preference

aspect contains “vivid-somber,” “clear-muddy,” “three-dimensional-flat,” and “fatigue-indefatigable” that relate to visual clarity, visibility and the physical-mental statement as well as the pleasantness aspect.

Table 3. Results of the multiple regression analysis for elderly group

Objective variable: Beauty aspect ($R^2 = 0.68, p < .01$)

	Standardized coefficients	<i>t</i>	<i>p</i>
intercept	0		
bright-dark	0.47	5.47	< .01
easy to see-difficult to see	0.32	4.11	< .01
three-dimensional-flat	0.27	3.15	< .01

Objective variable: Pleasantness aspect ($R^2 = 0.68, p < .01$)

	Standardized coefficients	<i>t</i>	<i>p</i>
intercept	0		
calm-not calm	0.29	3.81	< .01
distinct-indistinct	0.32	3.25	< .01
easy to see-difficult to see	0.37	4.07	< .01
conspicuous-inconspicuous	-0.23	-2.70	< .01
three-dimensional-flat	0.19	2.13	< .05

Objective variable: Preference aspect ($R^2 = 0.67, p < .01$)

	Standardized coefficients	<i>t</i>	<i>p</i>
intercept	0		
calm-not calm	0.23	2.85	< .01
natural-unnatural	0.18	2.41	< .05
bright-dark	0.35	4.17	< .01
three-dimensional-flat	0.33	3.80	< .01

For the elderly group, “three-dimensional-flat” adjectives were included in all three aspects, whereas the standardized coefficients were low. In addition, the beauty aspect contains “bright-dark” and “easy to see-difficult to see,” adjectives that were associated with visibility. The pleasantness aspect contains “calm-not calm,” representing the physical-mental statement and “distinct-indistinct,” “easy to see-difficult to see,” and “conspicuous-inconspicuous” adjectives that are related to visibility. The preference aspect contains “calm-not calm,” “natural-unnatural,” and “bright-dark” adjectives that represent how the appearance relates to the physical features of environment. The adjectives “bright-dark” were common in the beauty and preference aspects and was the highest standardized coefficient in both. Considering the highest standardized coefficients of “easy to see-difficult to see” in the

pleasantness aspect, the results demonstrate the importance of visual satisfaction components in showing printed-color images to elderly people.

A comparison of the younger and elderly groups suggests that there are age-related differences in the assessment of the appearance of a printed-color picture. The beauty aspect indicates that visibility-related components are the main aspect of the viewing and that the affective statement was closely involved in the elderly group and the younger group, respectively. For the pleasantness aspect, visibility-related components were common inclusions in the appearance of the printed-color picture in both age groups, whereas the physical-mental statement regarding “fatigue-indefatigable” was unique in the younger group. This tendency was similar to the preference aspect in both age groups. The adjectives “bright-dark” in the elderly group had the highest coefficient, while the younger group had a relatively low coefficient of similar adjectives, “vivid-somber,” and a relatively high coefficient of “fatigue-indefatigable,” among other adjectives.

These results suggest that the relationship between affective aspects and affective components was obtained in each age group when the participants observed a printed-color picture. More specifically, the relationship of the younger group was that of the beauty aspect-calm component, the pleasantness aspect-fatigue and distinct component, and the preference aspect-natural and fatigue component. The relationship of the elderly group was the beauty aspect-bright component, the pleasantness aspect-easy to see and distinct component, and the preference aspect-bright and nature component. Controlling these components that each group contributed might be achieved by varying some lighting characteristics. Any subsequent analysis should aim to examine the effect of CCT and the type of lighting devices in the lighting characteristics used in the experiment.

A two-way ANOVA using a score of “bright-dark” was performed to analyze the relationship between age groups (younger and elderly) and lighting conditions (Light A, B, C, D, and E). The results show an interaction between age group and lighting condition ($F(4,124) = 3.85, p < .01$). The test for the simple main effect revealed that, for Light A, the score of the elderly group was higher than that of the younger group, for Light E, the score of the elderly group was lower than that of the younger group, and that, for the younger group, the scores of Light A and B were lower than that of Light E ($MSe = 0.63, p < .05$; $MSe = 0.88, p < .05$; $MSe = 0.62, p < .05$).

A two-way ANOVA using a score of “calm-not calm” was performed to test the relationship between age groups and lighting conditions. The analytical results indicate an interaction between age group and lighting condition ($F(4,124) = 2.75, p < .05$). The test of the simple main effect showed that, for Light C, the score of the elderly group was higher than that of the younger group, for Light D, the score of the elderly group was higher than that of the younger group, and that, for the younger group, the score of Light A was higher than that of Light C, D and E ($MSe = 0.61, p < .05$; $MSe = 0.80, p < .05$; $MSe = 0.74, p < .01$).

A two-way ANOVA using a score of “fatigue-indefatigable” for age groups and lighting conditions showed the main effect of age groups ($F(4,124) = 2.66, p < .05$). A multiple comparison of the effect of age group indicated that Light D was higher (lower fatigue level) than that of Lights C and E ($MSe = 0.73, p < .05$).

Although two-way ANOVAs for age groups and lighting conditions were performed using the score of “easy to see-difficult to see,” “distinct-indistinct,” and “natural-unnatural,” the results showed no significant differences ($F(4,124) = 1.12, ns$; $F(4,124) = 1.29, ns$; $F(4,124) = 0.72, ns$).

Figure 4 depicts the mean scores of each pair of adjectives for the two age groups.

Fig. 4. Comparison of mean score of six adjectives for each age group (Light A: incandescent lamp and 2700 K, Light B: fluorescent lamp and 4100 K, Light C: fluorescent lamp and 4900 K, Light D: white LED and 4000 K, Light E: white LED and 5300 K)

4 Discussion

This study was undertaken to identify the components associated with the preferred appearance of printed-color images through an appearance assessment experiment for a printed picture under several different lighting conditions, including incandescent lamp, fluorescent lamps and white LEDs. A comparison of the two age groups suggests that the components of a preferred appearance have age-related differences.

A multiple regression analysis indicates a relationship between the age groups and the components associated with beauty, pleasantness and preference aspects, which are regarded as evaluative adjectives representing comprehensive appearance. Subsequent analysis examined whether the different lighting conditions affect levels of the components obtained for an age group to discuss the adjustability of affective aspects of appearance by observing conditions. The results indicate that visual satisfaction from the viewpoint of the beauty aspect is closely involved in the appearance of a printed-color picture for the elderly group, while naturalness and the

physical-mental statement have a role for the younger group. This could be because of the change in visual function due to aging. Although visual satisfaction of the elderly group was mostly attributed to the bright component, assessment of brightness had no significant differences in the elderly group, but there was an age-related difference in bright assessment of Light A (IL). Considering that illuminance was constant, one of the reasons for this might be a decreased sensation to short-wavelength light in elderly people. Light A consisted mainly of long-wavelength light. When visual system look at the objects, it interprets them in combination with own visual function, environment condition and characteristics of objects. Light A with less short-wavelength light seemed to be inadequate for elderly people as seeing objects reflected short-wavelength light. Therefore, to show a printed-color picture in all its beauty, it is important to consider age-related changes in visual function.

The analysis for the younger group, however, suggests that the calm component plays a key role in the appearance of a printed-color picture in terms of its beauty aspect. For the younger group, Light A was assessed as higher than the other experimental lighting conditions. This finding fits with the view that the lower CCT lightings, as incandescent lamp, tend to be preferred by people when they want to relax and be comfortable[4].

The next discussion deals with the preferred appearance in terms of the pleasantness aspect. The common points each group contained are calm, distinct and easy-to-see component, while the unique point is fatigue in the younger group. This aspect might reflect a subjective assessment for environment when people observe objects. Therefore, an interpretation of the results is that there is a physical-mental statement of calm and visual satisfaction as distinct and easy-to-see extracted for pleasantness aspect in both age groups. However, lighting conditions can play different roles in the calm component between the younger and the elderly groups. In particular, since a calm assessment of Lights C and D were observed to have an effect in regards to age group, which were different CCT (4900 K vs. 4000 K) and different type of lighting device (FL vs. LED), it is likely that the effect of CCT indicates a significant differentiation in lighting device type.

In addition, although fatigue assessment was contained in the results of the younger group, the assessment of Light D is lower than that of Lights C and E in both age groups. The higher assessment might relate to the lighting characteristics associated with lighting device type. Furthermore, differing CCT levels of white LED likely affected fatigue levels more than did the fluorescent lamp. The pleasantness condition associated with the preferred appearance in the younger group might come by using control of fatigue levels in combination with white LED CCT levels.

Finally, in terms of the preference aspect, the calm and natural components were common in both age groups. The results of the multiple regression analysis support that a natural assessment might fully explain the preference aspect of appearance in the younger group, but do not indicate anything that could be explained in terms of the lower standardized coefficients in the elderly group. Therefore, these findings might indicate that a bright component may be necessary to control the preference aspect for the elderly group. To control the brightness component, it is important to operate illuminance levels that were not dealt with in the experiment. More effort should be

taken to determine the suitable levels of brightness to extend the effect of the brightness component for elderly people.

The results of the younger group indicated that the natural and fatigue components had an important influence upon the preference of appearance, which appears to be associated with rendering and CCT of lighting characteristics, respectively. Therefore, these results suggest that controlling observing environments would achieve the preferred appearance of printed-color pictures, but this conclusion requires examining acceptable levels for younger people. Moreover, due to few participants and assessment to the single printed-picture, these findings should be interpreted in the context of several limitations.

These results suggest the possibility that the appearance of printed-color pictures could be controlled by using variations in observing conditions associated with affective components. Owing to facilitate variation of illuminance and CCT, the white LED used in the experiment provides a useful lighting device against which observing condition can operate. However, by excluding the warm condition on white LED in the experiment, this study could not fully assess the effect of CCT with white LED. The findings of optimal conditions are likely to be important in application to the intended appearance of printed-color pictures, taking into account aging factors. It will be an important subject to design observing conditions by using white LEDs. Understanding the relationship between relevant affective components of the preferred appearance of printed-color pictures and optimal observing conditions might lead to observing conditions for appearance of objects on display, such as by some type of electrical color filter. This might clarify the design theory for preferred appearance of various age groups.

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