Influence of Air Temperature on Preference for Color Temperature of General Lighting in the Room

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Abstract

The color temperature of general lighting in an interior space is an important lighting factor that contributes to making lighting environment more comfortable or pleasant. It is desirable for making atmosphere more comfortable or pleasant to clarify how air temperature affects psychological preferences for the color temperature of general lighting. Two kinds of psychological evaluation experiments were conducted by using a laboratory whose air temperature was kept at a constant value. As a result of the experiment-1, it was cleared that the air temperature to which the subjects were exposed was low, as in winter, a low color temperature was preferred. On the other hand, the air temperature was high, as in summer, a high color temperature was preferred. Accordingly, it was cleared that the color temperature preference for general lighting varies depending on the air temperature in a room. In the next stage, the experiment-2 was made to study whether a sudden change like step in air temperature as experienced during ordinary activities in human life affects color temperature preference. As a result, it was cleared that the color temperature preference for general lighting in Room A immediately after entering Room A from Room B varies depending on air temperature in B.

Keywords : Color temperature, air temperature, psychological responsivity, evaluation experiment

Introduction

The color temperature of general lighting in interior spaces is an important factor in the perceived comfort or pleasantness of the room. It is known¹⁾ that when the color temperature of ordinary lighting is low, subjects in this lighting environment perceive a warmer impression. Conversely, when the color temperature is high, the subjects perceive a cooler impression. Since this shows that color temperature has a psychological effect similar to that of air temperature, a person's color temperature preference for general lighting may vary depending on the air temperature in the room. It is hypothesized that air temperature in an interior space affects preference, for color temperature, of the people who

occupy the space. In order to prove the hypothesis is true or not, an experimental study of subjective appraisal employing the semantic differential method was carried out, using experimental room capable of controlling air temperature and color temperature.

Experiment-1

Psychological evaluations of preferences for the color temperature were made under three different air temperatures controlled, and cleared relationships between air temperature and preference for color temperature. Based on the data obtained through the psychological evaluations, it was examined whether the air temperature affected the preferences for color temperature.

Methods

Experimental Apparatus

Fig. 1 shows the plan view of the experimental room used for the experiments. The room consisted of two booths of almost the same size, the standard and test booths partitioned by a curtain. Achromatic color of N8 for Munsell value was used for the color of the curtain to offer a resemblance to commonly found wall colors.

For the luminaire, a lighting apparatus with milk white panel and 36-W compact fluorescent lamps of different light colors was employed. Each booth was provided with four of these lighting apparatuses. Each of the lighting apparatuses is equipped with a total of seven compact fluorescent lamps - two of red, three of green, and two of blue light colors. The brightness of each of fluorescent lamps of these different light colors was independently adjusted to give off varying degrees of intensity, thereby changing the color temperatures.

Fig. 2 shows the chromaticities of the lighting colors presented to the subjects. Since each of the chromaticities was close to blackbody radiation, it can be assumed that the color rendering index approximates a given value even at different color temperatures.

Fig. 1 Plan View of Experimental Room

Experimental Conditions

Table 1 lists the conditions of illuminance and the color temperature presented to the subjects. The illuminance values are the measurements taken on the surface of the desk. The level of

Fig. 2 Chromaticity Co-ordinates of Lighting Colors

color temperature close to that of commonly used fluorescent lamps was used.

The air temperature in the experimental room was set with reference to the average air temperatures of each of the different seasons in Japan. Three different levels were set for the air temperature inside the experimental room; that is, 30°C to assume summer, 23°C to assume spring and fall, and 10°C to assume winter. Humidity was 50%RH in either case.

The subjects were a total of eight males of ages ranging from 25 to 30. In the 30°C environment, the subjects were in underwear, shirts, pants, socks, and slippers. In the 23°C and 10°C environments, they wore coats in addition. Therefore, in the 30°C environment, the type of clothing was different from those of 23°C and 10°C.

Table 1 Experimental Condition of Lighting

	Illuminance (lx)	Color Temperature (K)
Standard Side	1 0 0 0	4 8 0 0
Test Side	1 0 0 0	3 7 0 0
		5 5 0 0
		7 0 0 0

Evaluation Methods

A method was used to compare preferences for color temperature between two booths of different color temperatures, the standard and test sides. Fig. 3 shows the time schedule of evaluation. The subjects were left to standard booth in the experimental room with a temperature controlled to a given level for 30 min. to adapt themselves to the temperature.

The subjects observed the two booths with different settings of color temperature at timings of immediately, 5 min., and 10 min. after the lighting had been turned on, thereby comparing and evaluating preferences for color temperature. They examined both the standard and test booths and answered the questionnaire in terms of preference for the test side with respect to that of the standard side. The questionnaire was prepared by using the rating scale shown in Fig. 4. The questionnaire was filled out once in each environment.

The experimenter presented the color temperatures of three different levels in the direction of higher color temperature in the test side. He instructed the subjects to complete the experiment at each timing within 30 sec.

Fig. 3 Time Schedule of Evaluation

Fig. 4 Rating Scale

Results and Discussion of exp.1

Fig. 5(a) shows the results of evaluation of the test side as compared with the standard side at a timing immediately after the lighting was turned on. Fig. 5(b) shows those at a timing 10 min. after the lighting was turned on. These figs. represent a plotting of the average values of evaluation marks of the eight subjects. Each environment was evaluated in a seven scale. The standard deviation was computed from the evaluation data of the eight subjects. The nine standard deviation of preference for color temperature in the test side at Time-1 ranged from 0.46 to 1.55 (Fig. 5(a)). On the other hand, those at Time-2 were in the range from 0.46 to 1.25.

The order of preferences for air temperature was made under three different color temperatures. As a result, the preferences were in the order of 10°C, 23°C, and 30°C at 3700K. At 5500K and 7000K, they were in the order of 30°C, 23°C, and 10°C. The same preference order was also

true in Fig. 5(b). However, not all the subjects performed the same orders as the averaged value. In the 7000K environment, a half of the subjects showed the same orders as the average, and two subjects in 3700K and 5500K environments.

The fact that the plotted point of 23°C is located between those of 30°C and 10°C suggests that there is a correlation between air temperature and preferences for color temperature. The preference of 7000K was strongest at 30°C, and the one of 3700K was strongest at 10°C in Fig. 5(a) and Fig. 5(b). It has been suggested that a high color temperature is preferred when the subjects are exposed to a high air temperature, while a low color temperature is preferred when they are exposed to a low air temperature.

Fig. 6(a) and Fig. 6(b) show the relationship between air temperature and preference for color temperature at a timing immediately and 10 min. after the lighting has been turned on with three different color temperatures used as parameters. In either case, with the color temperature of 3700K, the higher the air temperature, the smaller the preference; at 5500K and 7000K, on the other hand, the higher the air temperature, the greater the preference. These trends demonstrate that the air temperature does have an influence on the preference for color temperature. Immediately after the lighting was turned on, the gradient of the graph was slightly greater than that after 10 min. That is, the difference in preference levels between 10°C and 30°C in Fig. 6(a) is slightly greater than in Fig. 6(b). It indicates that the time elapses after the lighting is turned on helps make the

Fig. 5(a) Preference for Color Temperature in Test Side (Time-1)

Fig. 5(b) Preference for Color Temperature in Test Side (Time-3)

impression of preference faint.

People have a strong impression of preference of color temperature immediately after the lighting is turned on in usual life. And the passage of time after the lighting is turned on makes the impression of preference faint.

Also, it is very often that people makes a decision whether the atmosphere in the room is good or not immediately after entering a room. Therefore, it is important that subject evaluates preference within short exposure time. This is the reason why exposure time is ten minutes as Fig. 3. Since these experiments were made in spring (April), the subjects adapted themselves to spring. It would be desirable that additional experiments are made in summer, fall, and winter. The illuminance value set for these experiments was 1000 lx only that is commonly used in offices and shops. In the future, it is also desirable that an attempt will be made to clarify effects of air temperature on preference for color temperature at different levels of illuminance.

Experiment-2

In the next stage after experiment-1, the experiment-2 of psychological evaluation was made to study whether a sudden change like step in air temperature as experienced during ordinary activities in human life affects color temperature preference. The experiment-2 was made by using two rooms, Room A and Room B in Fig. 1, whose air temperatures in the rooms was different from each other. It was examined whether air temperature in Room B would influence the color temperature preference level, of general lighting in Room A, immediately after he / she has entered Room A from Room B.

Fig. 6(a) Relationship between Air temperature and Preference for Color Temperature(Time-1)

Fig. 6(b) Relationship between Air Temperature and Preference for Color Temperature(Time-3)

Table 2 Experimental Condition of Lighting

Illuminance (lx)			Color Temperature (K)
Room A	Standard Side	1 0 0 0	4 8 0 0
	Test Side	1 0 0 0	3 7 0 0
			5 5 0 0
			7 0 0 0
Room B		7 5 0	4 8 0 0

Methods

Experimental Apparatus

As shown in Fig. 1, experimental rooms designated A and B with controllable air temperature were used. Subjects were asked to stay in the standard booth of Room A, move to and remain temporarily in Room B, and then return to Room A, to simulate exposure to the stepwise changes in air temperature experienced when going outdoors and then returning indoors.

The Room B was provided with a desk and a chair. The interior colors in Room B were similar to that in the booths of Room A. Ceilings had white color, and floor had gray color. The color temperature of the lighting in Room B was the same as in the standard side of Room A.

Experimental Conditions

Table 2 lists the lighting conditions and the air temperature conditions in each experimental room provided for the experiment. The illuminance in Room A was adjusted to 1000 lx based on the actual values in indoor spaces such as ordinary offices. The color temperatures on the standard side and test side were adjusted around the range between 3000K and 6700K, the color temperature range of commonly used fluorescent lamps. The illuminance in Room B was adjusted to 750lx based on outdoor illuminance at twilight. The humidity in both Rooms A and B was adjusted to 50%RH.

The evaluation was conducted in Room A. The subjects observed the lighting environment in the two booths under different color temperature settings. They examined both the standard and test booths and answered the questions in the questionnaire as to their preference for the color temperature of the lighting on the test side in comparison with that of the standard side. The questionnaire was prepared using the rating scale of seven grades. The experimenter raised the color temperature to three different levels on the test side. The experimenter instructed the subjects to complete the evaluation within 30 seconds. The experiment was conducted in the winter.

Evaluation Schedule

Fig. 7 shows the time schedule of the evaluation. In Experiment A, the subjects experienced the sudden changes in air temperature in the order of medium temperature, low temperature, then medium temperature again by moving from Room A to Room B and then returning to Room

A. In Experiment B, the subjects experienced the sudden changes in air temperature in a similar way in the order of medium temperature, high temperature, then medium temperature.

In Experiment A, the subjects experienced a stepwise increase in air temperature when they returned from Room B to Room A. Therefore, we can call Experiment A "Increased air temperature experiment" and Experiment B "Decreased air temperature experiment."

The details of evaluation are described below. The subjects entered Room A with the air temperature set at 23°C. The subjects rested on the chair in the standard booth for 25 minutes after entering Room A. Then they conducted Evaluation (1) of their preference as to color temperature of the general lighting on the test side as compared with the standard side. The subjects were exposed to the air temperature in Room A for 30 minutes.

Then, in the increased air temperature experiment, the subjects entered Room B with the air temperature set at 10°C: in the decreased air temperature experiment, the subjects entered Room B with the air temperature set at 35°C. In both experiments, the subjects stood by for 20 minutes then moved to Room A with the air temperature set at 23°C, and conducted the Evaluation (2) immediately after they had experienced the sudden change in air temperature. The subjects were the same as Experiment-1.

Results and Discussions of exp.2

Results of Evaluation (1)

The results of Evaluation (1) are shown in Fig. 8, which represents a plot of the average values of evaluation marks of the eight subjects. The results of Experiment A and Experiment B were similar to each other: this is not surprising because the air temperature at the time of evaluation was the same in both experiments.

Fig. 9 shows a plot of the Evaluation (1) results of Experiment A and Experiment B with the horizontal axis representing color temperature and the vertical axis representing preference. In Fig. 9, the level of preference for 4800K was set at zero, because if 4800K was presented to both the standard and test sides, the preference answered by the subjects for the test side would be expected to be "medium". Among the four different color temperatures shown in Fig. 9, 4800K was the most preferred.

Results of Evaluation 2

Fig. 10 shows the subjects' color temperature preferences for the test side in comparison with the standard side immediately after they had experienced the sudden change in air temperature. Six values of standard deviation in Fig. 10 were in the range from 0.74 to 1.64. Statistical significance of difference between mean ratings for Evaluation (2) of Experiment A and B is denoted as asterisks in Fig. 10. The level of preference for 3700K immediately after the subjects were exposed to the sudden change from 10°C to 23°C was higher than that immediately after the subjects were exposed to the sudden change from 35°C to 23°C.

As far as preferences for 5500K and 7000K are concerned, the preferences immediately after exposure to the sudden change from 35°C to 23°C were higher than those immediately after exposure to the sudden change from 10°C to 23°C. Therefore, it is very likely that the color temperature preference for Room A varies depending on the air temperature of Room B immediately before the subjects enter Room A even if the air temperature in Room A is the same. It is considered very likely that subjects who have

Fig. 7 Time Schedule of Evaluation

Fig. 8 Preference of Color Temperature in Test Side (Evaluation(1))

Fig. 9 Preference for Color Temperature on Test Side (Evaluation(1))

Fig. 10 Preference of Color Temperature on Test Side (Evaluation(2))

returned from a cold space to a warm space tend to prefer a somewhat low color temperature and those returning from a warm space to a cold space tend to prefer a somewhat high color temperature.

Fig. 11 shows the evaluation results of Experiment A and Experiment B with the horizontal axis representing color temperature and the vertical

axis representing preference. For 3700K, preferences were stronger in Experiment A than in Experiment B, and for 5500K and 7000K, preferences were stronger in Experiment B than in Experiment A. Fig. 11 shows a different trend from Fig. 9.

Fig. 11 Preference for Color Temperature on Test Side (Evaluation(2))

Conclusions

As a result of Experiment-1, it was cleared that the air temperature to which the subjects were exposed was low, as in winter, a low color temperature was preferred. On the other hand, the air temperature was high, as in summer, a high color temperature was preferred. Accordingly, it is cleared that the color temperature preference for general lighting varies depending on the air temperature in a room.

As a result of Experiment-2, the following were cleared. Immediately after experiencing a sudden rise in air temperature by moving from Room B (adjusted to low air temperature) to Room A

(medium air temperature), the subjects preferred a low color temperature in Room A to a high color temperature: immediately after experiencing a sudden lowering of air temperature by moving from Room B (adjusted to high air temperature) to Room A (medium air temperature), they preferred a high color temperature to low color temperature. It implied that the preference in the color temperature of general lighting in Room A may vary depending on the air temperature of Room B immediately before the subjects enter Room A even if the air temperature in Room A is the same.

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