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RESEARCH ARTICLE OPEN ACCESS

The influence of color temperature on atmosphere preference and Air Temperature

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ABSTRACT
It is desirable for making atmosphere more comfortable or pleasant to clarify how color temperature and air temperature affect psychological preferences in interior lighting. The psychological evaluation experiments was conducted by using a laboratory whose air temperature was kept at a constant value.The experiments demonstrated the following, on condition that subject compare the test side booth with the standard side booth, whose color temperatures were different each other. The air temperature to which the subjects were exposed was low, as in winter, the atmosphere in a booth was more preferable at a low color temperature than at a high color temperature, immediately after the lighting was turned on. On the other hand, the air temperature was high, as in summer, it was more preferable at a high color temperature than at a low color temperature.
Keywords: color temperature, air temperature, preference of atmosphere, psychological evaluation, interior lighting

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I. INTRODUCTION

It is desirable to have basic data for a lighting planning procedure to improve preference of atmosphere by means of selecting the appropriate color temperature. An experiment for psychological evaluation was implemented in order to clarify the effects of color temperature and air temperature on preference of atmosphere in a room. Subjects compared preferences of atmosphere between two booths of test side and standard side [1)]. Two booths had different color temperature, each other. The first purpose of our study is to make the relationship clear between preference of atmosphere and color temperature, with parameter of air temperature, and to compare the relationship with Kruithof's result [2)]. The second is to make the relationship clear between preference of atmosphere and air temperature, with parameter of color temperature [3)].

II. METHODS

2.1 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 [4)].

For the luminaire [5)], a lighting apparatus with a 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 [6)].
The results of measurements taken of the chromaticity of the lighting colors used in the experiments showed that either one of them was close to blackbody radiation. It can therefore be assumed that the color rendering index is approximated to a given value even with different color temperatures [7)].

2.2 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 color temperature close to that of commonly used fluorescent lamps was used [8)].

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

℃ to assume summer, 23℃ to assume spring and fall, and 10℃ to assume winter. Humidity was 50%RH in either case.

2.3 Evaluation Methods

A method was used to compare preferences of atmosphere between two booths of different color temperatures, the standard and test sides [9]. Fig. 2 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 [10], 5 min., and 10 min. after the lighting had been turned on, thereby comparing and evaluating preferences for atmosphere. 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. 3.

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.

2.4 Subjects

The subjects were a total of eight males of ages ranging from 25 to 30, wearing similar clothing to each other [11].

III. RESULTS AND DISCUSSION

3.1 Average values of evaluation marks

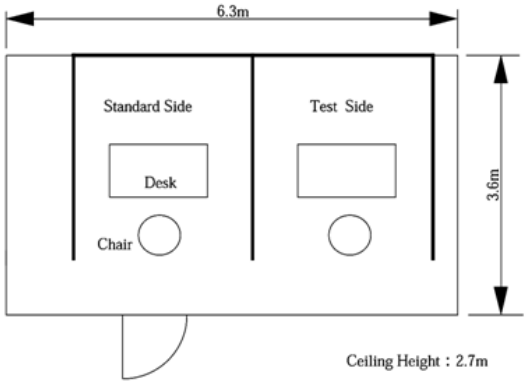

Figure 1 Plan View of Experimental Room

Table 1 Experimental Condition of Lighting

	Illuminance (lx)	Color Temperature (K)
Standard Side	1000	4800
Test Side	1000	3700 5500 7000

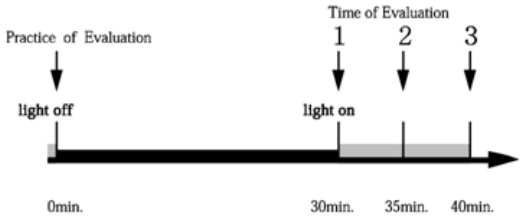

Figure 2 Time Schedule of Evaluation

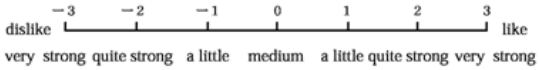

Figure 3 Rating Scale

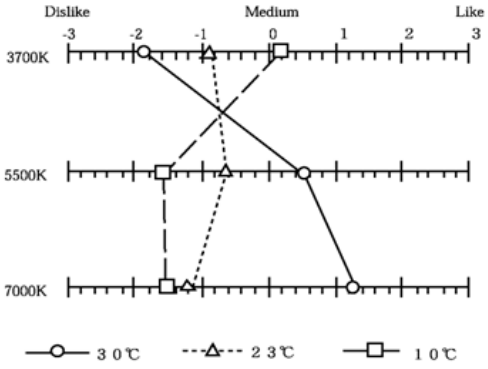

Figure 4 Preference of Test Side(Time-1)

Fig. 4 shows the results of evaluation of the test side as compared with the standard side at timing immediately after the lighting was turned on. Fig. 4 represents a plotting of the average values of evaluation marks of the eight subjects.

We examined the order of preferences for air temperature under three different color temperatures. As a result, the preferences were in the order of 10℃, 23℃, and 30℃ at 3700K. At 5500K and 7000K, they were in the order of 30℃, 23℃, and 10℃. The same preference order was also true in Time-2. The fact that the plotted point of 23℃ is located between those of 30℃ and 10℃ suggests that there is a correlation between air temperature

and preferences of atmosphere. Among the three different color temperatures on the test side of these experiments, subjects preferred 7000K or 5500K most at 30℃ and 3700K at 10℃. It has been suggested that atmosphere was preferable at a high color temperature when the subjects are exposed to a high air temperature, while atmosphere was preferable at a low color temperature when they are exposed to a low air temperature 12).

3.2 Results of Appraisal of Preference

How the preference of atmosphere in the test side changed with the combination of color temperature and air temperature as demonstrated is shown in Fig. 5. It is noted that preference largely changed depending on the color temperature and air temperature [13]. Thus, the effect on preference of each factor of color temperature and air temperature will be quantitatively discussed in the following [14].

3.3 Comparison with Kruithof's Results

Kruithof [15] found that there was a range of illuminance to be felt comfortable for each color temperature through an experiment and demonstrated the comfortable zone in two-dimensional coordinates with color temperature on the x axis and illuminance on the y axis. This indicated that low illuminance was pleasant in the case of low color temperature and high illuminance was pleasant in the case of high color temperature. The border line of the pleasant and unpleasant areas was also demonstrated.

Comparisons of the results at Time-1 in the present study and Kruithof's are shown in Fig.6. The white area shows a pleasant area and the shaded area an unpleasant one. Larger sizes of the circle get more preferable state. In evaluation of 30℃ with an illuminance of 1000 lx, color temperature becomes higher, the size of the circle becomes larger. In evaluation of 10℃, color temperature becomes higher, the size of the circle becomes smaller. Within the range of Kruithof's "pleasant" area [16], the present results showed preference of less than "medium" at 30℃ with 3700K, at 10℃ with 5500K, and at 10℃ with 7000K. On the other hand, the present results showed preference of more than "medium" at 10℃ with 3700K, at 30℃ with 5500K and at 30℃ with 7000K. Among the present lighting types included in Kruithof's "pleasant" area, some combinations indicate low preference and the other indicates high preference. Accordingly, it is strongly expected that the preference varies depending on the air temperature and color temperature in a room immediately after the lighting is turned on. This means Kruithof's results were not a suitable theory in a specific range of illuminance 1000lx to predict pleasantness in the room [17].

3.4 Relationship between Color Temperature and Preference of Atmosphere

Fig. 7 shows the evaluation results at Time-1 with the horizontal axis representing color temperature and the vertical axis representing preference. For 3700K, preferences were stronger in 10℃ than in 30℃ and for 5500K and 7000K, preferences were stronger in 30℃ than in 10℃.The evaluation results at Time-2 and Time-3 had similar trends to those at Time-1.

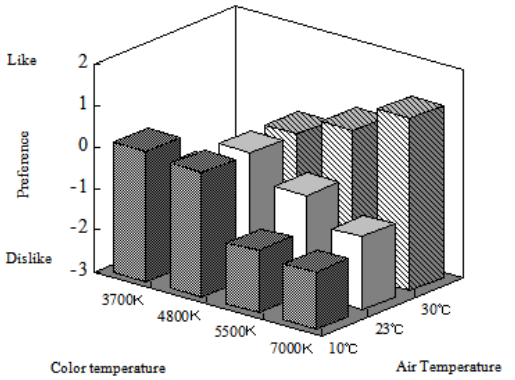

Figure 5 Effect of Air Temperature and Color Temperature (Time-1)

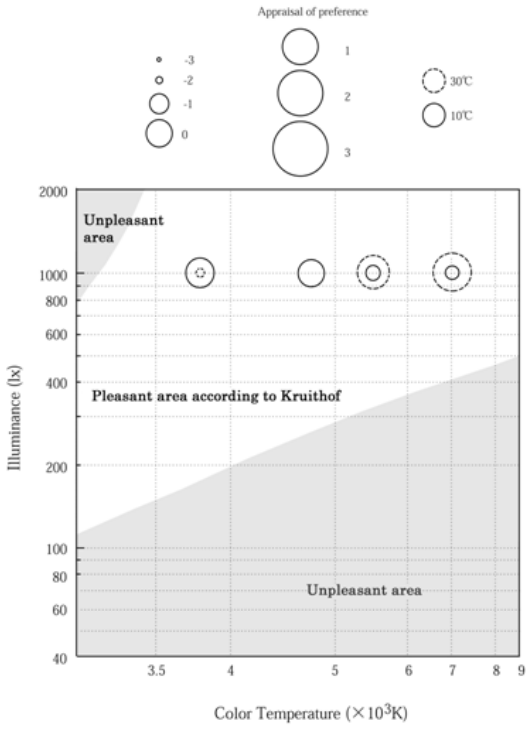

Figure 6 Comparison with Kruithof's Results

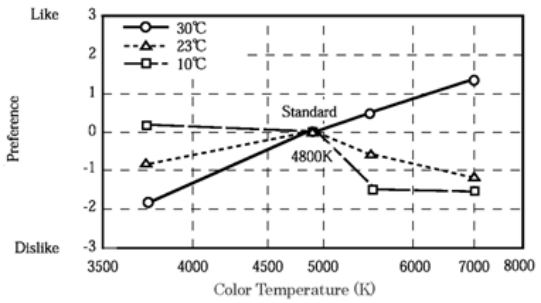

Figure 7 Relationship between Color Temperature and Preference of Test side (Time-1)

3.5 Relationship between Air Temperature and Preference of Atmosphere

Fig.8(a) and 8(b) show the relationship between air temperature and preference of atmosphere 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 3700 K, 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 [8].

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 [9]. That is, the difference in preference levels between 10℃ and 30℃ in Fig. 8(a) is slightly greater than in Fig. 8(b). It indicates that the time elapses after the lighting is turned on helps make the impression of preference faint.

Laurentin [10] conducted an experiment of effect on visual comfort appraisal on twenty subjects in one room, with different thermal conditions and light source type. She found that thermal conditions did not influence visual comfort appraisal. In her experiment, the workplace in the middle of the room was used to get an appraisal from one subject, without comparing it with the standard side [18].

In the present experiment, after comparing test side with standard side, subjects made a preference appraisal of test side. If subjects stay in the same place for a while, as her experiment, subjects will be in the adaptation of the lighting in the place. Accordingly subjects may not feel the strong difference of preference appraisal between the lighting in the place and the one set before the lighting, because the adaptation helps to make psychological effects of lighting faint. However if subjects compare the test side with the standard side of different lighting condition, subjects will feel the strong difference between the test side and the standard side. This may be the reason why the strong difference of preference appraisal was made between 10℃,20℃ and 30℃. The other reason why it happened may be the difference of range in temperature change, that is, in her experiment, temperature settings were 20℃ and 27℃ while in this experiment they were ranging from 10℃ to 30℃.

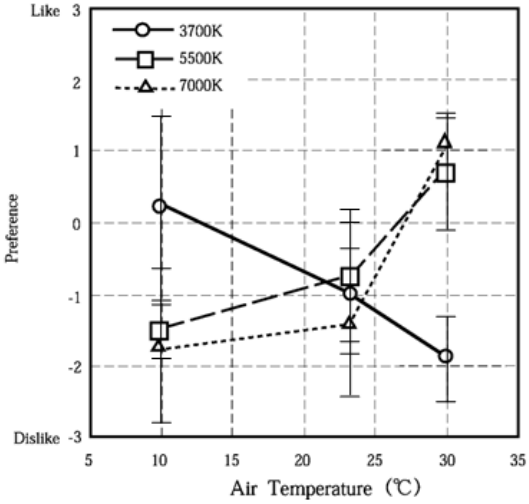

Figure 8(a) Relationship between Air temperature and Preference of Test side (Time-1) : The error bars around each point represent the 95 percent confidence interval about the mean rating.

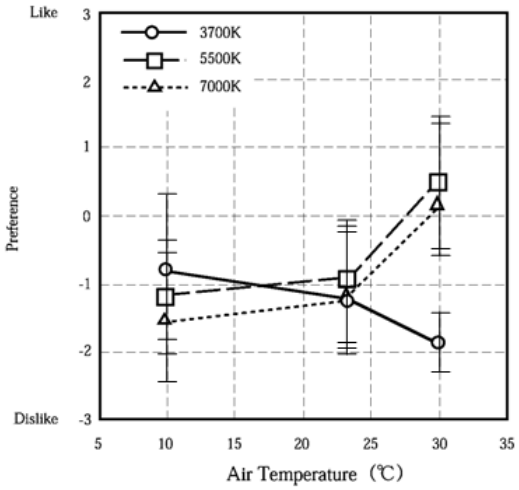

Figure 8(b) Relationship between Air Temperature and Preference of Test side (Time-3) : The error bars around each point represent the 95 percent confidence interval about the mean rating.

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