

Figure 1: Experimental room

2.2 Emotion and color

We hypothesized that the lighting color that promotes a particular emotion was related to the recall color of that emotion. As a preliminary experiment, subjects ranked the recall colors for 45 colors corresponding to adjectives expressing various emotions based on the procedure in Ref. [8]. As a result, the color (R, G, B) = (255, 216, 40) was frequently recalled from the two adjectives “happy” and “noisy.” Conversely, that color was hardly recalled in the adjective “sad.” This color is named “Lighting color 1” for the two adjectives “happy” and “noisy.” On the other hand, the color (R, G, B) = (0, 38, 102) was frequently recalled by the adjective “sad,” but was hardly recalled from the two adjectives “happy” and “noisy.” This color is named “Lighting color 2.” In our experiment, we decided to use these three adjectives and two lighting colors. By assuming the sRGB color space, “Lighting color 1” and “Lighting color 2” appear as shown in Fig. 2.

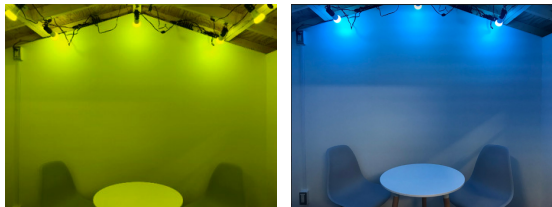


Figure 2: Experimental room. (left) Lighting color 1. (right) Lighting color 2.

For comparison, physically neutral white light (x, y) = (0.33, 0.33) and perceptually neutral colors derived as the median recall color for each adjective were also used in each experiment. Figure 3 summarizes the adjectives and corresponding colors.

	Happy	Noisy	Sad
Lighting color 1			
Lighting color 2			
Physically neutral			
Perceptually neutral			

Figure 3: Lighting colors for each adjective

2.3 Scenario for basic emotion

In this experiment, two subjects (Subjects A and B) had a short conversation based on scenarios to induce the three emotional states in Sec. 2.2. Table 1 shows the scenarios.

Table 1: Scenarios to trigger emotional states

“Happy”	A: It is written that sofa seats are recommended. It seems better to lie down and watch stars. B: Fun! This will be my first planetarium experience. A: We rarely have a chance to come. B: Yeah! I rarely watch the stars consciously. So I have really been looking forward to it.
“Noisy”	A: Jealousy? B: Jealousy! A: Being jealous is childish. B: I’m furious! I’m too lived to act like a grown-up!
“Sad”	A: Hey, what happened? B: What? A: You look angry. B: Don’t bother. A: It’s too early to go to the company! You don’t eat donuts! That’s weird!

2.4 Procedure

In order to confirm the emotions induced by the scenarios, the subjects first read the three scenarios silently under 180 lx white light, and evaluated the impressions they received only from the printed sentences by a semantic differential (SD) method (five-point scale). Two adjective pairs, “happy-sad” and “silent-noisy,” which included the three adjectives in Sec. 2.2, and the three additive adjective pairs of “masculine-feminine,” “pleasant-unpleasant,” and “hard-soft” were used for the evaluation.

Then, for each adjective, one color was randomly selected from four types of colors in Fig. 3, and the nine LED lights were illuminated so as to be spatially uniform. After 10 seconds, the adaptation time after illumination, the subjects were asked to talk based on the scenario. After the talking was over, the room was returned to white and the emotion at that time was evaluated by the SD method. After the evaluation was completed, the LED lights were switched to the next color. After 10 seconds for color adaptation, they talked again based on the same scenario and were evaluated. This evaluation was repeated for four randomly irradiated colors. When the evaluation for one adjective was completed, the next adjective was evaluated following the same procedure. Therefore, a total of 12 evaluations were performed for three adjectives under four lighting colors.

Two groups of college students participated in the experiment as subjects. One group consisted of two readers and one listener.

3. RESULTS

Factor analysis was performed on the five adjective pairs used in the SD method, and common factors were extracted. Approximately 87% of the variance in descriptions was explained by three factors. Therefore, as shown in Table 2, the variables into three factors named as “satisfied,” “dignified,” and “silent.”

Table 2: Classification by factor loading

Adjective pair	Fac.1	Fac.2	Fac.3	Fac. Name
Pleasant-Unpleasant	0.897	0.208	0.039	Satisfied
Happy-Sad	0.851	0.207	-0.087	
Masculine-Feminine	-0.207	0.706	-0.195	Dignified
Hard-Soft	-0.343	0.602	0.299	
Silent-Noisy	0.176	-0.056	0.578	Silent

3.1 Verification of emotion induction

We verify that the scenarios used in this experiment induced the desired emotional state.

Table 3 shows the average factor scores for impressions for each adjective obtained from only reading the scenario without conversation. Boldface in the table marks the scores of the factor name corresponding to each adjective. As shown in the table, the absolute values of the bold scores are the highest for each adjective, meaning that the conversation scenario correctly induced the emotion represented by the adjective.

Table 3: Emotional state felt from the scenario

	Satisfied	Dignified	Silent
Happy	0.98	0.67	0.71
Noisy	-0.99	0.60	-1.27
Sad	-1.22	0.00	-0.41

3.2 Different emotions under the same lighting color

We next show that even if the lighting color is equivalent, the induced emotional states might differ.

Table 4 shows the average of the factor scores when the conversation was performed based on the scenarios corresponding to “happy” and “noisy” under the same “Lighting color 1.” Regardless of the emotional state evoked by the scenario, if the same emotion is induced, the factor score distributions of both adjectives should be equal. However, as shown in the table, the factor “satisfied” factor score for “happy” was large, while that for “noisy” was small. This indicates that the same emotional color induced different emotional states.

Table 4: Emotional state under the same lighting color

	Satisfied	Dignified	Silent
Happy	0.54	0.21	0.00
Noisy	-0.69	0.30	-0.12

3.3 Relationship between lighting color and emotion

Table 5 shows the factor scores for each adjective by lighting color. Boldface in the table indicates the maximum value of the factor score for each adjective. As shown in Tables 5 (b) and (c), in the negative emotional states of “noisy” and “sad,” the factor scores were maximum for “Lighting color 1.” In comparison with neutral lighting, negative emotions were promoted. In contrast, as shown in Table 5 (a), in the positive emotional state “happy,” the factor score for the neutral state was high and the “Lighting color 1” did not promote the emotion.

Table 5: Emotional state under each lighting color

(a) Happy			
	Satisfied	Dignified	Silent
Lighting color 1	0.54	0.21	0.00
Lighting color 2	0.38	-0.41	0.82
Physically neutral	0.88	0.09	0.18
Perceptually neutral	0.94	-0.28	0.62
(b) Noisy			
	Satisfied	Dignified	Silent
Lighting color 1	-0.69	0.30	-0.12
Lighting color 2	-0.87	0.57	0.06
Physically neutral	-0.42	0.30	-0.08
Perceptually neutral	-0.85	0.30	-0.06
(c) Sad			
	Satisfied	Dignified	Silent
Lighting color 1	-0.95	-0.19	-0.72
Lighting color 2	-0.74	-0.50	0.02
Physically neutral	-0.61	-0.22	0.14
Perceptually neutral	-0.31	-0.10	-0.12

4. DISCUSSION

Our experimental results suggest that negative emotional states were promoted by “Lighting color 1.” However, the positive emotional state “happy” did not promote the emotion. In this section, we consider a method of illuminating the space with multiple colors to promote the emotional state of “happy.” Using a multiple-color scheme, we examined the effect of spatially opponent color irradiation based on physiological findings concerning an excitatory response to opponent colors in the central and peripheral receptive fields of ganglion cells.

In order to examine the effect of multiple colors, we conducted an additional experiment following the same procedure as in Sec. 2. The three lights installed in the center of the room were directed at the center and directly illuminated the subject. By irradiating the remaining six opponent color lights toward the wall, the space was organized so that the subject could clearly see opponent colors in central and peripheral vision.

In the additional experiment, we prepared two types of opponent colors: (1) selected from the 45 colors in Sec. 2.2 and (2) selected in sRGB color space. In Sec. 2, we used yellow as the recall color for “happy.” However, there was no higher recall color for “happy” among the opponent colors of yellow. Therefore, pink, which was also a higher recall color, was also used in the additional experiment. For comparison, (3) a single color was also prepared. The columns of the left in Table 6 summarize the irradiation combinations. In the experiment, a “happy” emotional state was elicited in subjects A and B through a short conversation based on two scenarios different from those in Table 1. Table 7 shows the scenarios.

Table 6: Emotional state for “Happy-Sad”















Lighting name	Central vision	Peripheral vision	Scenario 1	Scenario 2
(1)-1			0.83	0.67
(1)-2			0.83	0.67
(2)-1			0.34	0.50
(2)-3			0.83	0.67
(2)-4			0.50	0.50
(3)-1			0.67	0.50
(3)-2			0.50	0.33

Table 7: Scenarios to trigger emotional state “happy”

Scenario 1	A: Do you have classes this afternoon? B: No afternoon classes. A: OK! Shall we go to watch a movie? B: Good idea! A: Let’s go to karaoke after the movie. B: That’s great in the daytime on weekdays.
Scenario 2	A: Is it three days off this week? B: That’s right. A: Seriously! That’s the best. Would you like to go have fun somewhere? B: How nice! Let’s go to Tokyo in a while.

Three groups of university students participated in the experiment as subjects. In the experiment in Sec. 2, there was no difference in responses between the readers and listeners. Therefore, one group was composed of two readers. A total of six subjects evaluated the adjective pair “happy-sad” on a 5-point scale.

Regarding the scenario without conversation, in both Scenarios 1 and 2, the evaluation of “happy” was high, and it was confirmed that the emotion evoked by the conversation scenario in Table 7 corresponded to “happy.”

Next, the evaluation results for each irradiation method were obtained. The column on the right in Table 6 summarize the results. In both (1) and (2), the evaluation values were higher than for the monochromatic irradiation except for Condition (2)-1. In particular, the color scheme

of (1) was consistently highly evaluated regardless of whether the center color and the peripheral color were switched or not. This result suggests that a positive “happy” emotion is promoted by spatially combining the recall color and its opponent color corresponding to the emotion.

5. CONCLUSION

In this study, we set up an environment that induces a specific emotional state through conversation and conducted psychophysical experiments to investigate the lighting conditions that promote that emotional state. As a result, negative emotional states such as “noisy” and “sad” were significantly promoted under single lighting based on the color recalled from the emotion. It was also suggested that a positive emotional state “happy” could be promoted by illumination with a spatial combination of a color recalled from the emotion and its opponent color.

Future research should be conducted to accumulate and verify more data.

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