**ORIGINAL ARTICLE**

How do the Indoor Illumination Levels Affect Social and Cognitive Behaviors?

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**Abstract:** The indoor illumination levels affect emotional states, interpersonal impressions, and psychological distance between the self and others. In this study, we conducted experiment on the effect of the brightness of the room on face-to-face communication between participants as interviewee and the interviewer. Conducting a two-factor mixed analysis of variance on “illumination levels × pre- and post-evaluation,” we observed that in dim conditions, the interpersonal distance between the participants and interviewer became significantly closer. The psychological distance to the interviewer was evaluated to be closer in the dim condition. In terms of the degree of satisfaction with the conversation, in the dim condition, the evaluation of two items—“conversation was friendly” and “conversation was valuable”—increased. These results indicate that the dim condition, such as the lowest allowable level of illuminance according to illumination design guidelines, may have a positive effect on the first face-to-face communication.

**Keywords:** Illumination levels, Psychological distance, Satisfaction with conversation

1. **INTRODUCTION**

Living while to build and maintain good interpersonal relationship to the others is one of the important goals of human beings as social beings. To that end, it is necessary to talk to others, understand each other, and increase familiarity with them every day. Psychological distance is one of the indicators of better interpersonal relationships. Individuals of small psychological distance are more likely to be trusted than those of large psychological distance [1]. A group with a high level of personal trust will foster higher levels of cooperation [2]. Cooperation in the assurance game was more frequent when the other player was a high truster than a low truster [3]. Research from the areas of environmental psychology and grounded cognition have revealed that brightness and darkness affect interpersonal cognition and behavior such as impression formation, empathy, interpersonal distance, duration of speaking time, and self-disclosure [4-10].

Thus, it should be of particular interest to examine how indoor brightness influences interpersonal cognition and behavior, especially concerning the first face-to-face communication. Lighting conditions have significant effects on the impression formation and the conversational behavior [7]. Specifically, the pleasant and relaxing feelings associated with dim lighting can enhance interpersonal attractiveness and self-disclosure. The interviewer’s evaluative factor which had high loadings for pleasant, good-humored, familiar, pretty, and modest was rated significantly higher in the dim lighting. The participants in the dim lighting spoke longer than those in the bright lighting. However, not all changes in the relationship between participants and interviewers have been revealed. Evaluating the affective change behind communication behavior is a very important research subject for Kansei engineering. It is expected to clarify whether social cognition and behavior such as the interpersonal attractiveness and the duration of conversation time are related to communication outcomes, namely familiarity with the other and the satisfaction with conversation. Regarding the relationship between brightness and psychological distance, it has been pointed out that darkness promotes “oneness”, that is, the perception of close psychological distance [8, 9]. In addition, we suppose that conversational behavior and conversation satisfaction are also influenced by brightness. For example, it has been pointed out that the amount of conversation may increase in a dim lighting condition [7, 11]. And the amount of conversation is related with positive cognition of conversation [12].

Based on these previous researches, first, we hypothesized that participants would feel closer to the other in dim lighting than in bright lighting (H1). Second, the dim lighting would promote intimate conversation than the bright lighting (H2). Third, the satisfaction with the
conversation in the dim lighting would be greater than in
the bright lighting (H3). The objective of this study was to
demonstrate the effects of the indoor illumination levels on
social cognition and behavior. Specifically, we conducted
experiment on the face-to-face communication in a room
where the illumination levels could be manipulated and
examined the effects on communication outcomes such
as the expectation of trust, psychological distance, and
the satisfaction with conversation.

2. MATERIALS AND METHODS

This experimental design used a mixed design; we
compared two levels of indoor illumination, a bright
condition and a dim condition, with the indoor illumina-
tion levels as the between-participant factor and two
levels of timing, a pre and post evaluation of face-to-face
communication, with the timing of the questionnaire
measurement as the between-participant factor.

2.1 Participants

We recruited 30 men living in Tokyo between 20 and 49
years of age with white collar jobs as participants. During
recruitment, we asked the participants about their
frequency of domestic and international travel and their
communication skills on a scale called ENDCOREs [13, 14].
We excluded candidates with extreme responses to
ENDCOREs. Finally, we included participants to ensure
that there was no difference in terms of domestic and
international travel frequency and ENDCOREs responses
between experimental conditions. The average age of
participants was 40.2 years (n = 15) for the bright
condition and 37.6 years (n = 15) for the dim condition;
thus, there was no significant difference between the two
groups (t(28) = 1.14, p = .26).

2.2 Experimental environment

In previous studies on face-to-face communication
[7, 9, 10], experimental conditions for brightness were
created based on horizontal illuminance. In the
present study as well, a room that can stably control the
horizontal illuminance was selected as the experiment
room. In the experiment room (width = 2,870 mm and
length = 2,980 mm), ceiling lights were installed with
the horizontal illuminance that could be controlled and a
blackout sheet was placed between a closed blind and
window to block outdoor light (Figure 1). According
to lighting design guidelines for indoor spaces [15],
horizontal illuminance suited to recognizing facial
expressions is 1,000–4,000 lx, and the minimum horizontal
illuminance allowed is 100–200 lx. Based on these
guidelines, we controlled the ceiling lights so that
illuminance would be near the upper limit of facial
expression recognition in the bright condition and near
the lowest allowed level in the dim condition. As a result,
horizontal illuminance at the center of the experiment
room was M = 3,808 lx (SD = 23.7) for the bright condi-
tion and M = 384 lx (SD = 23.9) for the dim condition.
The average horizontal illuminance of the separate room,
where the pre- and post-evaluation was performed, was
1,441 lx (SD = 54.4).

2.3 Communication Methods

2.3.1 Interviewer

We hired a male actor who could consciously control
his facial expressions and behavior to be the interviewer
in the experiment. We instructed him to minimize his
responses, such as smiling and providing verbal feedback
to participants and to suppress behaviors that could make
participants have a favorable impression of him.

2.3.2 Topic of communication

The topic of communication in the interview between
the interviewer and participants was “what kinds of
new tourist destinations and buildings would be well
received by foreign tourists visiting Japan for the 2020
Olympics?”

2.3.3 Procedure

At a time, a single participant was instructed to sit on a
chair in the experiment room; they were left in the room
for one minute. Subsequently, we led the participant to a
separate room, where they responded to the questionnaire
How do the Indoor Illumination Levels Affect Social and Cognitive Behaviors?

for the pre-evaluation on a computer: impression of the experiment room, emotional state, impression of the interviewer, psychological distance from the interviewer, and the expectation of the communication and the trust. Thereafter, we led the participant back to the experiment room and left them with the interviewer. The interviewer and the participant communicated with each other about a predetermined topic. The interviewer ended the communication about 15 minutes later. We led the participant back to the separate room again, where they responded to the post-evaluation on a computer: in addition to the same items as the pre-evaluation, satisfaction with the conversation, and retrospective time estimation. After the post-evaluation was completed, the participant was debriefed, their consent to the experiment was confirmed again, and the experiment was completed.

In the pre-evaluation, the participants responded in relation to their impressions of visual factors in the experiment room, their emotional state, the psychological distance from the interviewer, their impression of the personality of the interviewer, their expectations for the communication, and their expectation of trust in the interviewer. During the communication, we obtained data on utterance and silence behaviors and the interpersonal distance between the interviewer and participants. In the post-evaluation, participants responded regarding their level of satisfaction with the conversation, and they performed retrospective time estimation.

2.4 Questionnaire

2.4.1 Impression of the experiment room

For the impression of the experiment room, we elicited participants’ responses on a seven-point scale using the semantic differential method: “light–dark” in relation to brightness; “large–small” and “three-dimensional–two-dimensional” in relation to the size of the room; “colorful–monotone” and “warm–cold” in relation to color; “complex–simple,” “round–angular,” and “soft–hard” in relation to texture; and “natural–artificial” with regard to the natural properties by using the semantic differential method [16-18].

2.4.2 Emotional state

To measure emotions that change over a short period of time when facing others, we used a two-dimensional mood scale [19]. Specifically, we had participants rate eight items—“energetic(P1),” “lively(P2),” “lethargic(N1),” “listless(N2),” “relaxed(P3),” “calm(P4),” “irritated(N3),” and “nervous(N4)”–on a six-point scale. We assessed participants’ level of pleasure and arousal using these eight items.

Pleasure level = (P1 + P2 + P3 + P4 − N1 − N2 − N3 − N4) / 2

Arousal level = (P1 + P2 + N3 + N4 − P3 − P4 − N1 − N2) / 2

2.4.3 Impression of interviewer’s personality

10 items personality scale was used in a personality impression evaluation that assumed an interaction with someone new using photographs of people [20]. This study is also an evaluation of the person who met for the first time and uses this scale. Specifically, it consists of the following items: “cooperative,” “moral,” “tolerant,” and “considerate,” which presented high factor loading for the primary factor (communion), and “rational,” “cold,” “dominant,” “strong,” and “intellectual,” which presented high factor loading for the secondary factor (agency). These ten items were evaluated using a seven-point scale.

2.4.4 Psychological distance from the interviewer

The Inclusion of Other in the Self (IOS) was used for evaluation of psychological distance from the interviewer [21]. From among seven types of figures, ranging from two approaching circles, circles with slowly increasing overlap, and two mostly overlapping circles, we asked participants to choose the type that represented their relationship with the interviewer the best.

2.4.5 Expectation of the communication and the trust

To evaluate the expectation of the communication, we referred to items that have been previously used in the literature [22-24] and evaluated six items—“the two of us can have concrete discussions,” “accurate ideas can be proposed on the spot,” “the two of us can have multifaceted discussions,” “unpredicted ideas can be proposed on the spot,” “the two of us can have frank discussions,” and “smooth discussions can be had on the spot”—on a seven-point scale. And to evaluate the expectation of trust in the interviewer, we had “I can trust the other person” evaluated on a seven-point scale.

2.4.6 Satisfaction with the conversation

To evaluate the level of satisfaction with the conversation during the post-evaluation, we used a questionnaire on cognitive aspects of interpersonal communication [25] that comprised 18 items including “I could manage the conversation well,” “I was bored during the conversation,” and “the conversation was cooperative,” which were evaluated on an eight-point scale.

2.4.7 Retrospective time estimation

In the post-evaluation, we had participants estimate the length of the conversation in the communication with the interviewer in minutes by using a linguistic estimation method [26].
2.5 Measurement of communication behavior

2.5.1 Utterance and silence behaviors

We recorded the communication behavior between the interviewer and participants using a video camera placed on the table. The analyst evaluated utterance and silence between the interviewer and participants with one second as a unit based on the recorded audio and visual data and analyzed six items: total duration of utterances, number of utterances, duration of each utterance, duration of silence, number of silences, and duration of each silence. The duration from the initial utterance by the interviewer to the utterance by the interviewer announcing the end of the interview was divided in two, and the first and second half of the total duration were analyzed separately.

Because the analysis of utterance and silence behavior includes the subjectivity of the analyst, one analyst analyzed 30 participants, of which ten participants were analyzed by another analyst also. For the analytical results of the communication of the ten participants with the two analysts, we calculated the consistency and Cohen's $\kappa$ coefficient to confirm the reliability of the analytical results.

2.5.2 Interpersonal distance

The interviewer and each participant engaged in face-to-face conversation, and we recorded them from their side. With one second as a unit, we estimated the distance in 1cm increments between the tips of their noses by referring to a scale attached to the side of the table (Figure 2). We used this distance as the interpersonal distance between the interviewer and participants. The distance between the tip of their noses is an estimate that includes the subjectivity of the analyst. Therefore, to confirm the reliability of the analysis results, we calculated the consistency and Cohen’s $\kappa$ coefficient in the same way as the analysis of the utterance and silence behavior.

3. RESULTS

3.1 The brightness of the experiment room

For visual factors of the indoor space, we performed a two-factor mixed analysis of variance for the brightness x questionnaire measurement timing. For the impression of “light–dark,” the interaction was significant ($F(1,28) = 5.60, p = .03, \eta^2_p = .17$). The result of a simple effect test showed that in the pre-evaluation, the bright condition ($M = 4.93, SD = 0.88$) was evaluated to be bright than the dim condition ($M = 3.80, SD = 1.26$) ($F(1,56) = 7.63, p = .01, \eta^2_p = .12$). In the post-evaluation, the “light–dark” impression in the bright condition was between “uncertain” and “slightly bright” ($M = 4.60, SD = 1.06$), and similarly in the dim condition, it was between “uncertain” and “slightly bright” ($M = 4.13, SD = 1.25$). There was no significant difference in the “light–dark” impression ($F(1,56) = 1.29, p = .26, \eta^2_p = .02$). There was no simple main effect for measurement timing.

3.2 Emotional state of participants

We performed a two-factor mixed analysis of variance on the emotional state of participants. Interaction was significant for “relaxed” mood ($F(1,28) = 5.24, p = .03, \eta^2_p = .16$). The result of the simple effect test showed no significant difference in “relaxed” mood between bright and dim conditions in the pre-evaluation ($F(1,56) = .51, p = .48, \eta^2_p = .01$). In the post-evaluation, the dim condition ($M = 2.73, SD = 1.33$) led to a “relaxed” mood significantly more than the bright condition ($M = 2.07, SD = 0.80$) ($F(1,56) = 3.15, p = .08, \eta^2_p = .05$). In the dim condition, participants were more “relaxed” in the post-evaluation ($M = 2.73, SD = 1.33$) than in the pre-evaluation ($M = 2.13, SD = 0.83$) ($F(1,28) = 4.33, p = .05, \eta^2_p = .13$). No significant difference was observed between the preliminary and post-evaluations for the bright condition ($F(1,28) = 1.34, p = .26, \eta^2_p = .05$).

With regard to the level of arousal on the two-dimensional mood scale, interaction showed a significant trend ($F(1,28) = 3.68, p = .07, \eta^2_p = .12$). The result of the simple effect test showed no significant simple effect for brightness. In the dim condition, the arousal level significantly decreased in the post-evaluation ($M = -0.40, SD = 1.21$) compared with the pre-evaluation ($M = 0.33, SD = 0.86$) ($F(1,28) = 4.23, p = .05, \eta^2_p = .13$). In the bright condition, no significant difference was observed in the arousal level in the preliminary and post-evaluations ($F(1,28) = 0.43, p = .52, \eta^2_p = .02$).

![Figure 2: Interpersonal distance](image-url)
3.3 Evaluation of the interviewer

3.3.1 Impression of personality

We performed a two-factor mixed analysis of variance regarding the impression of the interviewer’s personality. The result showed that only the main effect of the questionnaire measurement timing on the “good” impression was significant ($F(1, 28) = 4.62, p = .04, \eta^2_p = .14$), wherein participants had a “good” impression of the interviewer in the post-evaluation ($M=5.23, SD=0.86$) compared with the pre-evaluation ($M=4.83, SD=1.21$).

3.3.2 Psychological distance

We performed a two-factor mixed analysis of variance on psychological distance from the interviewer. The result showed that the main effect of the brightness was the only significant trend ($F(1, 28) = 3.02, p = .09, \eta^2_p = .10$), wherein the psychological distance to the interviewer was less in the dim condition ($M=2.73, SD=1.44$) than the bright condition ($M=2.07, SD=1.29$) (Figure 3). The results support our hypotheses H1.

3.3.3 Expectation of the communication and the trust

We performed a two-factor mixed analysis of variance on the expectation of communication and of trust in others. The result showed that only the main effect of the questionnaire measurement timing was significant for the expectation that “the two of us can have multi-faceted discussions” ($F(1, 28)=5.90, p=.02, \eta^2_p=.17$), which was lower in the post-evaluation ($M=4.07, SD=0.98$) compared with the pre-evaluation ($M=4.73, SD=1.44$). Similarly, only the main effect of the questionnaire measurement timing for the expectation of “unpredicted ideas can be proposed on the spot” showed a significant trend ($F(1, 28)=4.17, p=.05, \eta^2_p=.13$), which decreased in the post-evaluation ($M=.90, SD=1.52$) compared with the pre-evaluation ($M=4.43, SD=1.04$).

3.3.4 Satisfaction with the conversation

In terms of the degree of satisfaction with the conversation, we performed an unpaired t-test on the difference between the mean values between the dim and bright conditions (Table 1). As shown in Table 1, the result showed that the evaluation of “the conversation felt cold” significantly increased in the bright condition than in the dim condition ($t(28)=-2.23, p=.03, d=0.82, 95\% CI[-2.81, -0.12]$). In addition, the evaluations of “the conversation was friendly” ($t(28)=2.19, p=.04, d=0.80, 95\% CI[0.08, 2.45]$) and “the conversation was valuable” for the expectation of “unpredicted ideas can be proposed on the spot” showed a significant trend ($F(1, 28)=4.17, p=.05, \eta^2_p=.13$), which decreased in the post-evaluation ($M=.90, SD=1.52$) compared with the pre-evaluation ($M=4.43, SD=1.04$).

Table 1: Difference in the mean values of brightness conditions in regard to the degree of satisfaction with the conversation (significant variables in bold)

| Items                                      | Dim condition | Bright condition | $t$   | $p$    | Cohen’s $d$ |
|-------------------------------------------|---------------|-----------------|-------|--------|-------------|
| I could manage the conversation well.     | 4.87          | 3.93            | 1.71  | .10    | 0.62        |
| I was bored of the conversation.          | 2.07          | 3.00            | 1.77  | .12    | 0.59        |
| The conversation was cooperative.         | 5.13          | 4.33            | 1.23  | .23    | 0.45        |
| The conversation was harmonious.          | 4.40          | 3.93            | 0.87  | .39    | 0.32        |
| The conversation was unsatisfactory.      | 2.93          | 3.67            | -1.31 | .20    | 0.48        |
| The conversation was smooth.              | 4.20          | 4.07            | 0.25  | .80    | 0.09        |
| The conversation felt cold.               | 3.07          | 4.53            | -2.23 | .03    | 0.82        |
| The conversation was tense.               | 4.80          | 5.13            | -0.54 | .59    | 0.20        |
| The conversation was friendly.            | 5.47          | 4.20            | 2.19  | .04    | 0.80        |
| We both spoke actively.                   | 4.47          | 3.33            | 1.90  | .07    | 0.69        |
| We both had a positive attitude during the conversation. | 5.40 | 4.53 | 1.75 | .09 | 0.64 |
| The conversation was boring.              | 2.20          | 3.20            | -1.75 | .09    | 0.64        |
| The conversation was valuable.            | 5.20          | 3.67            | 2.35  | .03    | 0.86        |
| The conversation was slow.                | 5.60          | 4.80            | 1.67  | .11    | 0.61        |
| The conversation was difficult.           | 3.20          | 4.13            | -1.29 | .21    | 0.47        |
| The focus of the conversation was unclear.| 2.73          | 3.40            | -1.28 | .21    | 0.47        |
| I was absorbed in the conversation.       | 4.33          | 3.13            | 1.86  | .07    | 0.68        |
| We were both interested throughout the conversation. | 4.47 | 3.47 | 1.61 | .12 | 0.59 |
(t(28) = 2.35, p = .03, d = 0.86, 95%CI[0.19, 2.87]) were significantly higher in the dim condition than in the bright condition (Figure 4). The results support our hypotheses H3.

3.4 Retrospective time estimation

We analyzed the difference in mean values between the dim condition and bright condition for the total duration of the actual conversation, retrospective time estimation, and the discrepancy between the retrospective time estimation and the total duration of the actual conversation (i.e., retrospective time estimation – total duration of the conversation) by conducting an unpaired t-test (Table 2). In Table 2, there was no significant difference in the mean values of all the measures.

To determine the discrepancy between the retrospective time estimation and actual duration of the conversation, we performed a correlation analysis on the impression of visual factors of indoor space, emotional state of self, psychological distance between the self and others, impression of others’ personalities, expectations of communication, expectations of trust in others, and the degree of satisfaction with the conversation. The results revealed that there was a moderately significant correlation in nine items: the emotional state of “relaxed” in the post-evaluation (r = .43, p = .02); “the two of us can have concrete discussions” (r = .41, p = .03), “accurate ideas can be proposed on the spot” (r = .41, p = .03), “the two of us can have multi-faceted discussions” (r = .41, p = .02), and “the two of us can have frank discussions” (r = .45, p = .01) with regard to expectations of communication; and “conversation felt cold” (r = -.44, p = .02), “we both actively spoke” (r = .41, p = .03), “I was absorbed in the conversation” (r = .43, p = .02), and “we were both interested in the conversation” (r = .47, p = .01) in relation to the degree of satisfaction with the conversation. The results are related to our hypotheses H2.

3.5 Communication behavior

3.5.1 Utterance and silence behaviors

We performed an unpaired t-test on utterance and silence behaviors to verify the difference in the mean values between the bright and the dim conditions (Table 3). As shown in Table 3, there was no significant difference between the bright and dim conditions for all the items. Although there was no significant difference, if we include the effect size, then the total duration of the conversation, total duration of utterances, and total duration of utterances during the first and the second halves were longer under the dim condition, and the duration of each period of silence in the second half was shorter. The results are related to our hypotheses H2.

3.5.2 Interpersonal distance

We used an unpaired t-test for the interpersonal distance data analyzed from the images of the interpersonal distance to examine the difference between the mean values of the two brightness conditions (Table 4). As shown in Table 4, the mean value for interpersonal distance was significantly shorter in the dim condition than in the bright condition (t(28) = 2.11, p = .04, d = 0.77, 95%CI[0.19, 12.07]). Similarly, the mean value of interpersonal distance during the first half of the conversation was significantly shorter in the dim condition than in the bright condition (t(28) = 2.23, p = .03, d = 0.81, 95%CI[0.50, 11.85]). The results support our hypotheses H1.

If we include effect sizes of those without a significant difference, the dim condition had lower mean values in comparison to the bright condition for the minimum interpersonal distance in the first half of the conversation (t(28) = 1.44, p = .16, d = 0.53, 95%CI[1.85, 10.65]), the maximum interpersonal distance in the first half of the conversation.

Table 2: Difference in mean values of retrospective time estimation between the dim and bright conditions

| Measure                          | Dim condition | Bright condition | t     | p     | Cohen’s d |
|---------------------------------|---------------|-----------------|-------|-------|-----------|
|                                 | Mean (min)    | SD              | Mean (min) | SD  |         |           |
| A : Total duration of the conversation | 18.46         | 5.63            | 15.97 | 4.31 | 1.36     | .18       | 0.50      |
| B : Time estimation            | 20.73         | 7.77            | 16.33 | 7.35 | 1.59     | .12       | 0.58      |
| Discrepancy (B – A)            | 2.28          | 7.09            | 0.36  | 4.62 | 0.87     | .39       | 0.32      |
Table 3: Difference in mean values of utterance and silence behaviors between the dim and bright conditions

| Measure                                    | Cond. | Mean (sec) | SD  | t     | p    | Cohen’s d |
|--------------------------------------------|-------|------------|-----|-------|------|-----------|
| Total duration of the conversation         | D     | 1107.47    | 337.68 | 1.36  | .18  | .50       |
|                                           | B     | 958.13     | 258.45 |       |      |           |
| Total duration of utterances               | D     | 592.67     | 352.85 |       |      |           |
|                                           | B     | 463.73     | 192.42 |       |      |           |
| Duration of utterances in the first half   | D     | 267.53     | 171.99 | 1.04  | .31  | .38       |
|                                           | B     | 214.40     | 96.51  |       |      |           |
| Duration of utterances in the second half  | D     | 325.13     | 183.36 | 1.40  | .17  | .51       |
|                                           | B     | 249.33     | 100.97 |       |      |           |
| Total number of utterances                 | D     | 106.73     | 22.01  | 0.27  | .79  | .10       |
|                                           | B     | 103.07     | 47.23  |       |      |           |
| Total duration of the conversation in the first half | D     | 57.93      | 12.54  | 0.49  | .63  | .18       |
|                                           | B     | 54.67      | 22.59  |       |      |           |
| Total duration of utterances in the first half | D     | 48.80      | 11.18  | 0.05  | .96  | .02       |
|                                           | B     | 46.70      | 25.92  |       |      |           |
| Duration of each utterance                 | D     | 4.93       | 2.42   | 0.55  | .58  | .20       |
|                                           | B     | 4.46       | 2.30   |       |      |           |
| Duration of each utterance in the first half | D     | 4.11       | 1.83   | 0.46  | .65  | .17       |
|                                           | B     | 5.78       | 3.70   |       |      |           |
| Duration of each utterance in the second half | D     | 6.78       | 3.70   | 0.07  | .95  | .03       |
|                                           | B     | 6.91       | 6.53   |       |      |           |
| Total duration of silence                  | D     | 325.07     | 160.07 | 0.47  | .64  | .17       |
|                                           | B     | 299.80     | 129.71 |       |      |           |
| Duration of silence in the first half      | D     | 173.13     | 97.30  | 0.56  | .58  | .21       |
|                                           | B     | 154.53     | 82.46  |       |      |           |
| Duration of silence in the second half     | D     | 151.93     | 70.05  | 0.29  | .78  | .10       |
|                                           | B     | 145.27     | 56.89  |       |      |           |
| Total number of periods of silence         | D     | 80.20      | 40.97  | 0.20  | .84  | .07       |
|                                           | B     | 80.57      | 40.27  |       |      |           |
| Number of periods of silence in the first half | D     | 43.00      | 11.39  | 0.35  | .73  | .13       |
|                                           | B     | 40.93      | 19.62  |       |      |           |
| Number of periods of silence in the second half | D     | 39.60      | 12.43  | 0.05  | .96  | .02       |
|                                           | B     | 39.27      | 22.29  |       |      |           |
| Duration of each period of silence         | D     | 3.96       | 1.20   | 0.49  | .63  | .18       |
|                                           | B     | 3.96       | 1.07   |       |      |           |
| Duration of each period of silence in the first half | D     | 3.88       | 1.66   | 0.02  | .98  | .01       |
|                                           | B     | 3.87       | 1.28   |       |      |           |
| Duration of each period of silence in the last half | D     | 3.70       | 1.17   | 1.03  | .31  | .37       |
|                                           | B     | 4.18       | 1.38   |       |      |           |

Note. D: Dim condition, B: Bright condition

Table 4: Difference in mean values of interpersonal distance between the dim and bright conditions (significant variables in bold)

| Measure                                    | Cond. | Mean (cm) | SD  | t     | p    | Cohen’s d |
|--------------------------------------------|-------|-----------|-----|-------|------|-----------|
| Minimum interpersonal distance             | D     | 93.40     | 9.11 | 0.70  | .49  | 0.25      |
|                                           | B     | 95.53     | 7.61 |       |      |           |
| Minimum interpersonal distance in the first half | D     | 94.73     | 8.65 | 1.44  | .16  | 0.53      |
|                                           | B     | 99.13     | 8.05 |       |      |           |
| Minimum interpersonal distance in the second half | D     | 94.80     | 9.45 | 0.98  | .33  | 0.36      |
|                                           | B     | 98.07     | 8.72 |       |      |           |
| Maximum interpersonal distance             | D     | 117.20    | 7.23 | 1.30  | .20  | 0.48      |
|                                           | B     | 120.40    | 6.19 |       |      |           |
| Maximum interpersonal distance in the first half | D     | 115.07    | 6.98 | 1.66  | .11  | 0.61      |
|                                           | B     | 119.27    | 6.88 |       |      |           |
| Maximum interpersonal distance in the second half | D     | 115.27    | 7.53 | 1.21  | .24  | 0.44      |
|                                           | B     | 118.40    | 6.62 |       |      |           |
| Mean interpersonal distance                | D     | 105.59    | 8.63 | 2.11  | .04  | 0.77      |
|                                           | B     | 111.72    | 7.19 |       |      |           |
| Mean interpersonal distance in the first half | D     | 105.65    | 8.35 | 2.23  | .03  | 0.81      |
|                                           | B     | 111.82    | 6.75 |       |      |           |
| Mean interpersonal distance in the second half | D     | 105.53    | 9.14 | 1.94  | .06  | 0.71      |
|                                           | B     | 111.62    | 7.99 |       |      |           |

Note. D: Dim condition, B: Bright condition
4. DISCUSSION

4.1 Perceived brightness

During pre-evaluation, when it was only a short while since entering the experiment room, there was significant difference in impressions regarding the brightness of the indoor space in the bright and the dim conditions. However, during the post-evaluation, when sufficient time had elapsed, there was no longer any significant difference. This result indicates that participants had adapted to the brightness of the experiment room.

Another explanation is that various behaviors have the appropriate brightness. In the pre-evaluation, we consider that participants evaluated brightness without assuming a specific behavior. On the other hand, the results indicate that in the post-evaluation they evaluated brightness by assuming conversation. Regarding the relationship between the brightness and communication, previous research shows that dim (soft) lighting encourages intimate communication [27].

4.2 Emotional state of participants

Under the dim condition, the participants became relaxed after the communication. There was a tendency for their arousal level to decrease.

Lighting conditions has been showed to effect on the emotional state of individuals [7]. It was revealed that the “pleasant—calming” factor which had high loading for pleasant, relaxing, and safe is increased in the dim condition compared to the bright condition. This concurs with the findings of the present study.

4.3 Evaluation in relation to the interviewer

There was no effect of brightness on participants’ impressions of the interviewer’s personality. The interviewer did not smile and minimized any reaction to the participants’ utterances. This was confirmed in the video recording of the communication. This factor prevented any differences in the impression of the interviewer’s personality between the bright and dim conditions. This suggests that the brightness of the experiment room did not affect the control of the interviewer’s behavior.

4.4 Communication behavior

Interpersonal distance during the entire conversation as well as during the first half of the conversation was significantly shorter in the dim condition than in the bright condition. In the dim condition, the psychological distance between the interviewer and participants was evaluated as less than in the bright condition. It was found that an indoor space’s darkness increased oneness with others, which promoted cooperative behavior with others [8]. Although their findings only discussed the effects of an indoor space’s darkness on the psychological distance with others, this appears to be consistent with the effects of the indoor space’s darkness on physical interpersonal distance and psychological distance as found in the present study.

Although there was no significant difference as the results showed, if we include the effect size, then the total duration of the conversation, total duration of utterances, and total duration of utterances during the first and the second halves were longer under the dim condition, and the duration of each period of silence in the second half was shorter.

The participants in the dim lighting spoke longer than those in the bright lighting [7]. In the present study, the interviewer was instructed to hold the conversation to motivate the participants to speak. Specifically, in order to ensure that the participants engaged in conversation, they were asked to think of new ideas and report it when they no longer had any ideas, or the interviewer was to repeat questions until a certain period of time had passed. Therefore, we assume that the total duration of the conversation, total duration of utterances, and shortness of silence are indexes of the participants trying to continue the conversation without giving up. In the present study, we were unable to confirm any significant difference between the dim and bright conditions. However, based on the overall effect size, it is possible that participants made a more active effort to communicate in the dim condition than in the bright condition. It was examined.
the effects of the brightness of the experiment room on self-disclosure and revealed that the duration of the participants’ utterances became significantly longer in the dim condition compared to the bright condition.

In the dim condition, the retrospective estimation of the duration of conversation tended to be longer than in the bright condition, and the retrospective estimations also tended to be longer than the actual duration of the conversation in the dim condition. The correlation analysis of retrospective time estimation demonstrated that the longer the duration of conversation was retrospectively estimated in comparison to the actual duration of the conversation, the greater the emotional state of self-impression of the other’s personality, expectations of trust and communication, and the degree of satisfaction with the conversation. It appeared that the retrospective estimate of the conversation duration tended to be longer in the dim condition than in the bright condition, which indicates that overall, communication-related cognition in the dim condition tended to be evaluated in a more positive manner.

In relation to the effects of the indoor space’s brightness on interpersonal behavior, because of various factors such as the level of light and context, brightness has been found to have positive effects in some cases [5, 28] and negative effects in others [7, 8]. It was found that the darkness of indoor space promotes communication in an experiment that presented a hypothetical counseling scenario, the results of which are consistent with that of the present study. This suggests that the dim lighting has a positive effect on the first face-to-face communication in interpersonal relationships that require trust and intimacy with the other.

4.4 Limitations
The contribution of this research is limited. First, the present research did not answer what lighting is optimal for the first face-to-face communication due to limited indoor illumination levels. In addition to the illumination level, important factors that control artificial light include color temperature, spatial distribution of light (uniformity or non-uniformity). In the present research, only two conditions of horizontal plane illuminance by lighting that uniformly illuminates the entire experiment room were compared, and the spatial distribution of lighting and the color temperature of lighting were not included in the experimental conditions. The color temperature of the lights affects social cognition. Dim warm light has positive effects on collaboration [6, 9]. And despite the fact that indirect light affects social cognition and behaviors [29], just as direct light affects it, we did not directly compare different spatial distributions and did not replicate the study using only indirect light.

Second, the participants of this research were limited to male in their 20s to 40s, and the interviewer is a male in his thirties. Gender and age are important factors in communication. The dyadic conditions (same gender, mixed gender) lead to differences in conversation behavior [30, 31]. There is a difference between intergenerational communication and intragenerational communication. Including gender and age as factors of the present research adds to the complexity, so we limited our research to communication between the same gender and the same generation.

Third, it could be argued that the experiment room setting (with the conspicuous exclusion of daylight and the extremely simple interior), participants limited to male and the interviewer played by a male actor may reduce the generalizability of findings to real contexts. And real-life communication is a continuous, cyclical, and long-term interaction. Therefore, field studies would certainly complement the present research. This may be a constructive area for future research.

5. CONCLUSION
In the present study, for the bright condition, we used the upper limit of horizontal illuminance, which is considered to be appropriate to recognize other people’s faces in the illumination design of indoor spaces, and we used the lowest allowable limit as the dim condition. Accordingly, we examined the effects of the indoor illumination levels on cognition and the behavior associated with face-to-face communication. The results suggested that in the dim experiment room, the participants became more relaxed with time, and both interpersonal distance and psychological distance became smaller. In addition, the participants tended to estimate the duration of the conversation to be longer than the actual conversation retrospectively. Furthermore, the degree of satisfaction of the conversation increased.

If the room for face-to-face communication were to be designed in accordance with Kansei engineering and the present results so as to promote intimate communication, it would be desirable to lower the horizontal illuminance. Such as consultation rooms in banks and legal offices, counseling rooms where patients discuss their personal issues, and restaurants and bars for two people who want to be intimate would be expected to designed in this way. By having conversations in such an environment, even
people who are meeting for the first time may feel close to each other, talk in a relaxed state, feel increased levels of satisfaction with the conversation, and be able to communicate more actively.

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