Interpersonal Distancing in Cooperation

Effect of Confederate's Interpersonal Distance Preferences

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Abstract. Personal space is a dynamic spatial component of interpersonal relations. This paper presented an empirical study that investigated a dynamic process of adjusting interpersonal distance in a cooperative situation.

In the experiment, there were four factors: (a) cooperative task, (b) orientation, (c) gender combination, and (d) long-short relation of interpersonal distance preferences among an evaluator and a confederate. Twenty-eight participants (14 females) joined the study. The data collection was performed by employing a standard procedure of the stop-distance method. One hundred and twelve data were obtained under the different conditions. A multiple comparison test was performed for preferred interpersonal distances.

The results revealed that: (1) interpersonal distance was shortened in a cooperative task; (2) individuals standing face-to-face produced longer interpersonal distance than those standing side-by-side; (3) male pairs produced longer preferred interpersonal distance than female pairs when pairs stood face-to-face, however, this difference was not significant when pairs stood side-by-side. In particular, the present study suggested (4) the shortening of interpersonal distance in a cooperative situation was affected by long-short relation of interpersonal distance preferences among an evaluator and an apporacher. Implications to proxemics for the design of spatial behaviors of socially assistive robots including a nursing-care robot were also discussed.

Keywords: Interpersonal distance · Personal space · Cooperation

1 Introduction

1.1 Personal Space Issue in the Design of User-Centered Human Services

Personal space is a dynamic spatial component of interpersonal relations [9]. It can be defined as "an area individuals actively maintain around themselves into which others cannot intrude without arousing some sort of discomfort" [11, 19]. Everyone possesses and utilizes it in their everyday social situations, however, most of the time, while they are comfortable with the other, they are unaware of its sophisticated and dynamic functioning.

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Personal space concept is a useful tool to investigate human spatial behavior in our everyday social situations. Research on human spatial behavior influenced various design issues not limited to the area of architecture and environmental design [9], but extended to the design of human services and education. For example, the practices of nursing-care, medical-care and human services essentially involve various types of human interactions with their users, typically in a relatively close distance. Apparently in such an interaction, not only viewpoints from professional service providers such as doctors and experts but also users' are useful and essential. The consideration of personal space issue gained the increased importance in the user-centered design and improvements of humane services and comfortable environments. In particular, personal space concept has recently been emphasized as an interesting research issue in the design of proxemics in human-robot interaction.

1.2 Investigating Interpersonal Distance in Cooperative Situation

In this study, the term, interpersonal distance (IPD), was used to describe human spatial behavior by using the measurement of the space between two or more interacting individuals [18].

The dimensions of interpersonal distance are not fixed. Research findings suggested that interpersonal distance is a function of various factors, which can be classified into, at least, four broader categories: personal, social, physical, and cultural [9]. For instance, interpersonal distance can be influenced by: personal characteristics including age [22], gender [4], personality [8], psychological disturbance and disabilities [20], and arousal [15]; social factors including such as attraction [21], emotional expression [16], eye-contact [2], approach angle [24], social status [8], and situational factors such as task [12] and competition [23]; physical settings and environmental factors including room size [6], ceiling height [17], lighting [1], and indoors-outdoors [5]. Culture is also a major modifier of interpersonal distance. The space utilization varies across cultures such as non-contact or contact-culture [3]. For example, consistent findings from past empirical studies include: males typically use longer IPD than females; young adults use longer IPD than children; interpersonally warm and non-anxious individuals choose shorter IPD than others; competitive relation is associated with longer IPD, etc.

There are more than thousand studies on the determinants of interpersonal distance to describe them. However, few studies were concerned with dynamic processes of interpersonal distancing in cooperative situations (e.g. [23, 12]), although its importance has been increasing, especially in the domains of medical and nursing services and education. This study emphasized interpersonal distance preferences in a cooperative situation in which multiple individuals interact each other.

It is quite natural that these factors combine in everyday social settings. The reality is not simple. The combinations of these factors sometimes produce interpersonal distance that are different from what would be expected from consideration of each influence by itself [9], especially in a cooperative situation. In this study, it is very important, to consider a combined effect of related factors as well as a primary determinant of interpersonal distance preferences in a cooperative situation.

1.3 Interaction Among Individuals Having Heterogeneous IPD Preferences

Individual's preference of interpersonal distance is not same even in the same physical condition. As previously described, typically in a social interactive situation such as cooperation, multiple individuals who have heterogeneous personal IPD preferences, interact each other (see Fig. 1). For instance, the practices of nursing-care involve various human interactions among multiple individuals who prefer different interpersonal distances.

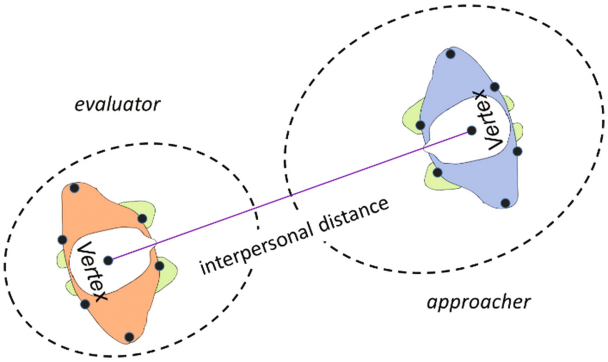


Fig. 1. Interpersonal distance in a cooperative task (face-to-face).

Past rigorous laboratory studies had made much efforts on individual's personal space from the *"me"-centered* view, but made little emphasis on interaction between multiple interpersonal spaces. A simple research question raised here is: what change occurs in human spatial behavior when heterogeneous interpersonal spaces interact each other? This study made our initial attempt to investigate this research question.

1.4 Our Aims and Approach

Preferences of Interpersonal Distance in Cooperation. Cooperation is an essential component of our everyday social situation [10]. The present study aimed to investigate IPD preferences in a cooperative situation in which multiple individuals interact each other. In particular, we focused on the differences of IPD preferences between cooperative and non-cooperative tasks.

Combined Influences to IPD Preferences in a Cooperative Task. The present study investigated how known determinants including "angle of orientation" and "gender" altered IPD functioning in a cooperative task. Possible combined effects of related known factors in addition to a primary effect of "cooperative task" were also examined.

Influence of the Confederate's IPD Preferences. The present study attempted to investigate a dynamic process in which an individual and a confederate who have heterogeneous IPD preferences collaboratively interact each other. Especially, it shed

light on how the confederate's IPD preferences influenced individual's IPD preferences in a cooperative task.

2 Empirical Study

This experiment investigated a dynamic process of adjusting interpersonal distance. Especially, it emphasized situational factors of cooperation, and also long-short relation of IPD preferences among collaborators. There were four factors in the present study. The within-subject factors were *"task"* (2 levels: no particular task vs. cooperative task) and *"angle of orientation"* (2 levels: face-to-face vs. side-by-side). The between-subject factors were *"gender combination"* (4 levels: male-male vs. male-female vs. female-male vs. female-female) and *"long-short relation of IPD"* (2 levels: an evaluator's preferred interpersonal distance is {longer vs. shorter} than an approacher's). The experimental design of the study is shown in Table 1.

Table 1. Experimental design

Factors		Levels	
Within subjects	Task	2	no task, cooperative task
	Angle of orientation	2	face-to-face, side-by-side
Between subjects	Gender combination (*: evaluator)	4	male*-male, male*-female, female*-male, female*-female
	Long-short relation of preferred interpersonal distance (evaluator vs. approacher)	2	longer, shorter

2.1 Participants

Twenty-eight healthy university students (14 males and 14 females, age range: 18–23 years) participated. The participants were recruited individually and were informed that the study dealt with spatial preferences. They gave their informed consent before participation in the study. All the participants were divided into fourteen pairs, who were not acquaintances each other. Data collection was performed by each pair of participants. The distribution of gender combinations of participants' pairs were: male-male (8), male-female (6), female-male (6) and female-female (8).

2.2 Method

Measurement and Apparatus. In order to capture interpersonal distance in a cooperative situation, we adopted the *"center-center" model* [12] which employs the distance between the vertexes of participants of each dyad. An interpersonal distance was measured by using a laser range finder (BOSCH GLM7000). The materials used for cooperative task consisted of a notebook-PC (Macbook Pro) and a jigsaw puzzle application.

Procedure. Data collection was performed by fourteen different pairs (A and B) of participants, who were not acquaintances each other. At first, one of participants (A) took a role of an evaluator and the other participant (B) took a role of an assistant experimenter (approacher). The stop-distance method [11] was employed to measure preferred interpersonal distances.

At first, an approacher initially stood three meters from an evaluator and then approached an evaluator, in small steps (approx. 25 cm per step) at a constant slow velocity (approx. one step per two sec.) until an evaluator began to feel uncomfortable about the closeness. When an evaluator said "stop", an approacher's approach halted. In order to minimize a measurement error, an evaluator was allowed to make fine readjustment of their positions. The preferred interpersonal distance between the vertexes of their bodies was measured (see Fig. 1).

Also in a cooperative task condition, the experimenter asked an evaluator and an approacher to stand in a distance at three meters and approach slowly to build jigsaw puzzles together. They then freeze their movements when they performed a cooperative task for approximately one to two minutes in a distance that was comfortable to an evaluator. An evaluator was allowed to make fine readjustment of their positions. The interpersonal distance between the vertexes of their bodies was measured.

According to the experimental design (Table 1), a set of four data of the interpersonal distances under different conditions were obtained per each participant. After all the data was obtained from a participant A, the participants exchanged their roles.

Setting. The data collection was carried out during daytime, in an empty and quiet class room (6.3 m $\times$ 5.5 m with a ceiling height of 3.0 m) of a university located in Tokyo metropolitan area. The brightness was appropriately maintained with an indoor lighting instead of natural light from outside. It took approximately one hour per participant.

Data Analysis. There were four factors. The within-subject factors were "task" and "angle of orientation". The between-subject factors were "gender combinations" and "long-short relation of IPD". A multiple comparison test was performed for preferred interpersonal distances. We applied Bonferrroni-Dunn's procedure by using SPSS (ver. 23).

Reference Value of Individual Preferred Interpersonal Distance (IPD_{F2F}). In this study, preferred interpersonal distance obtained under the condition of "no task" and "face-to-face" was used as the reference value of interpersonal distance preference of each participant. This value is transcribed as *"IPD_{F2F}"*. Each participant has his/her own IPD_{F2F}.

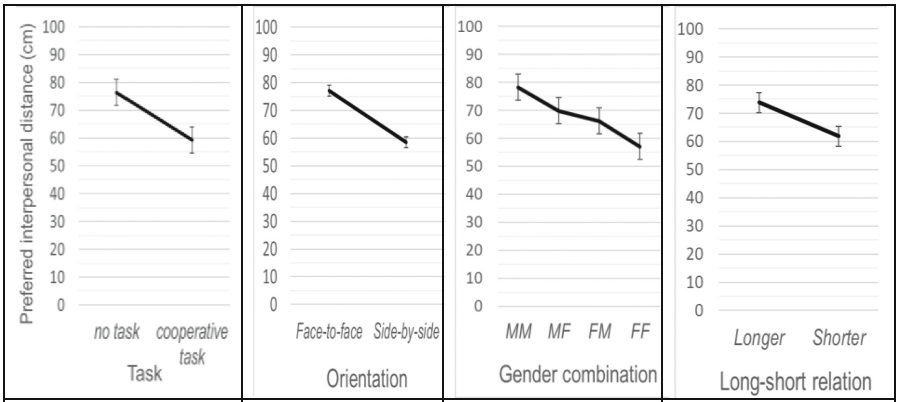
Long-Short Relation of Preferred Interpersonal Distance (IPD_{F2F}) Among Each Dyad. Among each pair of an evaluator and an approacher, preferred interpersonal distances usually differ. According to the comparison of the reference value of interpersonal distance (i.e. IPD_{F2F}) among each dyad, there were two cases. In case that an evaluator's IPD_{F2F} was longer (or shorter) than an approacher's, all the data obtained from this participant was indexed as "longer" (or "shorter"). In this study, fourteen participants (including 7 females) were classified into "longer" condition and other fourteen participants (including 7 females) were classified into "shorter" condition.

3 Results

3.1 Analysis I: Multiple Comparison

One hundred and twelve data of preferred interpersonal distances under four different conditions were obtained from the participants. Mean of all the interpersonal distances obtained under all the conditions is 69.82 (male: 76.74 and female: 62.89) cm.

Task. The factor of "task" had two levels (no particular task vs. cooperative task (jigsaw puzzles)). Simple main effect of the factor "task" was statistically significant ($p < 0.01$). This result indicated that preferred interpersonal distance of "no particular task" was longer than "cooperative task" ($\mu_1 - \mu_2 = 17.10$, standard error (SE) = 4.88, $p < 0.01$) (Fig. 2a). However, this main effect is qualified by the following meaningful interactions.



(a) Task | (b) Angle of orientation | (c) Gender combination | (d) Long-short relation of IPD_{F2F}

Fig. 2. Mean of preferred interpersonal distance: (a) task, (b) angle of orientation, (c) gender combination and (d) long-short relation of IPD_{F2F}.

Interaction. There was a statistically significant interaction between three factors of "task", "angle of orientation" and "long-short relation of IPD_{F2F}" ($p < 0.05$). In particular, in the case of "side-by-side" condition, preferred interpersonal distance of "no particular task" was longer than "cooperative task" under either condition of the "longer-short relation of IPD_{F2F}": "longer" ($\mu 1 - \mu 2 = 15.71$, SE = 5.90, $p < 0.05$), "shorter" ($\mu 1 - \mu 2 = 14.20$, SE = 5.90, $p < 0.05$) (Fig. 3). On the contrary, in the case of "face-to-face" condition, this difference was statistically significant only under the condition of "longer", but not statistically significant under the condition of "longer" ($\mu 1 - \mu 2 = 28.60$, SE = 8.73, $p < 0.01$), but not statistically significant under the condition of "shorter" ($\mu 1 - \mu 2 = 9.85$, SE = 8.73, $p = 0.27$) (Fig. 3).

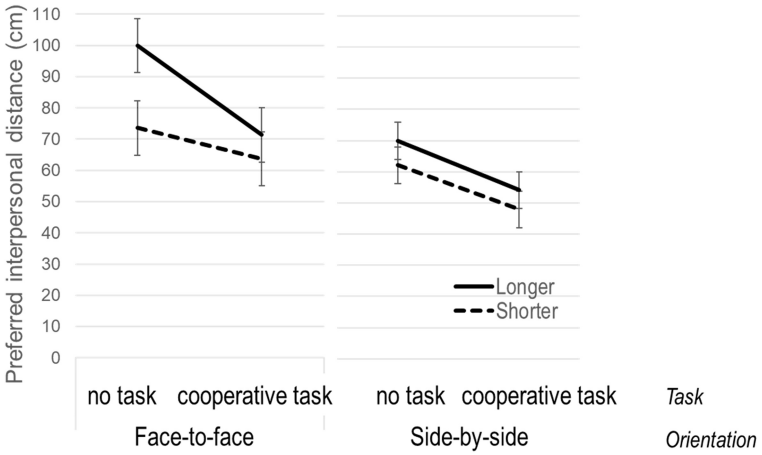
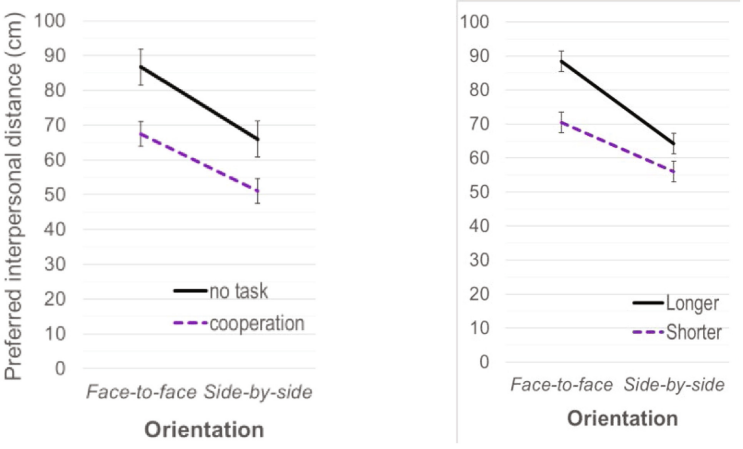


Fig. 3. Mean of preferred interpersonal distance: "task", "angle of orientation" & "long-short relation of IPD_{F2F}".

On the other hand, there were no statistically significant interactions of the "task" with the other factors, i.e. "angle of orientation" (Fig. 4a), "gender combinations" (Fig. 5a), or "long-short relation of IPD_{F2F}" (Fig. 6a).

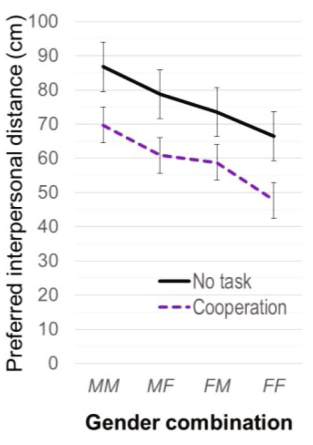
Angle of Orientation. The factor of "angle of orientation" had two levels (face-to-face vs. side-by-side). Simple main effect of the factor "angle of orientation" was statistically significant ($p < 0.01$). In particular, the result indicated that preferred



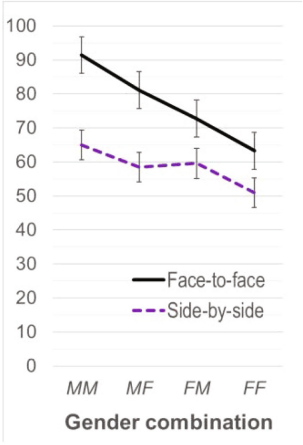
(a) "angle of orientation" & "task"

(b) "angle of orientation" & "long-short relation of IPD_{F2F}"

Fig. 4. Mean of preferred interpersonal distance: (a) "angle of orientation" & "task", and (b) "angle of orientation" & "long-short relation of IPD_{F2F}".

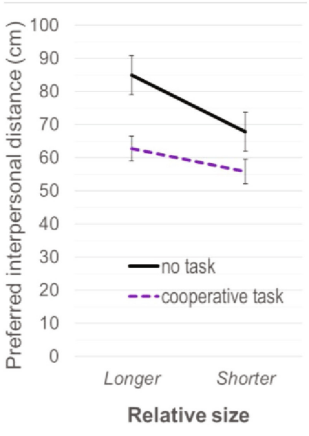


(a) "gender combination" & "task"

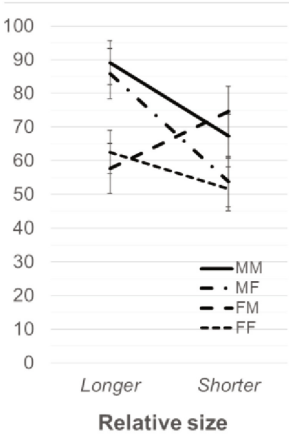


(b) "gender combination" & "angle of orientation"

Fig. 5. Mean of preferred interpersonal distance: (a) "gender combination" & "task", and (b) "gender combination" & "angle of orientation".



(a) "long-short relation of IPD_{F2F}" & "task"



(b) "long-short relation of IPD_{F2F}" & "gender combination"

Fig. 6. Mean of preferred interpersonal distance: (a) "long-short relation of IPD_{F2F}" & "task", and (b) "long-short relation of IPD_{F2F}" & "gender combination".

interpersonal distance of "face-to-face" was longer than "side-by-side" ($\mu_1 - \mu_2 = 18.63$, SE = 1.95, $p < 0.01$) (Fig. 2b).

Interaction. There were statistically significant interactions of the "angle of orientation" with the factors of "gender combination" ($p < 0.05$) and with the factor of "long-short relation of IPD_{F2F}" ($p < 0.05$). In particular, preferred interpersonal

distance of "face-to-face" was longer than "side-by-side" under either condition of the "gender combination" (MM, MF, FM, FF) ($p < 0.01$) (Fig. 5b), also under either condition of the "long-short relation of IPD_{F2F}": "longer" ($\mu_1 - \mu_2 = 23.61$, SE = 2.75, $p < 0.01$), "shorter" ($\mu_1 - \mu_2 = 13.65$, SE = 2.75, $p < 0.01$) (Fig. 4b).

On the other hand, there was no statistically significant interaction between the "angle of orientation" and the "task" (Fig. 4a).

Gender Combination. The factor of "gender combination" had four levels (MM vs. MF vs. FM vs. FF). Simple main effect of the "gender combination" was statistically significant ($p < 0.05$). In particular, the result indicated that preferred interpersonal distance of "MM" pair was longer than "FF" pair ($\mu_1 - \mu_4 = 21.13$, SE = 6.56, $p < 0.05$) (Fig. 2c). However, this main effect is qualified by the following meaningful interactions.

Interaction. There was a statistically significant interaction between the "gender combinations" and the "angle of orientation" ($p < 0.05$). In particular, only under the condition of "face-to-face", preferred interpersonal distance of "MM" pair was longer than "FF" pair: "face-to-face" ($\mu_1 - \mu_4 = 28.18$, SE = 7.71, $p < 0.05$) (Fig. 5b). However, this difference was not statistically significant under the condition of "side-by-side".

There was also a statistically significant interaction between the "gender combinations" and the "long-short relation of IPD_{F2F}" ($p < 0.05$). In particular, only under the condition of "longer", preferred interpersonal distance of "MM" pair was longer than "FM" pair: "longer" ($\mu_1 - \mu_3 = 31.48$, SE = 10.02, $p < 0.05$) (Fig. 6b). However, this difference was not statistically significant under the condition of the "shorter".

However, there was no statistically significant interaction between the "gender combination" and the "task" (Fig. 5a).

Long-Short Relation of Preferred Interpersonal Distance (IPD_{F2F}). The factor of "long-short relation of IPD_{F2F}" had two levels (longer vs. shorter). Simple main effect of the factor "long-short relation of IPD_{F2F}" was statistically significant ($p < 0.05$). In particular, the result indicated that preferred interpersonal distance of "longer" was longer than "shorter" ($\mu_1 - \mu_2 = 12.00$, SE = 5.01, $p < 0.05$) (Fig. 2d). This result can be easily predicted because long-short relation of preferred interpersonal distance in the condition of "no task" and "face-to-face" (i.e. IPD_{F2F}) can be related to those length of the other conditions. However, this main effect is qualified by the following meaningful interactions. This result will also be re-examined in a succeeding section, Analysis II.

Interaction. There was a statistically significant interaction between the "long-short relation of IPD_{F2F}" and the "angle of orientation" ($p < 0.05$). In particular, only under the condition of "face-to-face", preferred interpersonal distance of the "longer" group was longer than "shorter" group: "face-to-face" ($\mu_1 - \mu_2 = 16.99$, SE = 5.89, $p < 0.01$) (Fig. 4b). However, this difference was not statistically significant under the condition of "side-by-side".

There was also a statistically significant interaction between the "long-short relation of IPD_{F2F}" and the "gender combination" ($p < 0.05$). In particular, under both conditions of "MM" and "MF", preferred interpersonal distance of the "longer" group was longer than "shorter" group: "MM" ($\mu_1 - \mu_2 = 21.86$, SE = 9.27, $p < 0.05$), "MF"

($\mu_1 - \mu_2 = 32.13$, SE = 10.71, $p < 0.01$) (Fig. 6b). However, this difference was not statistically significant under either condition of "FF" and "FM". Especially in "FM" condition, a contrary tendency was observed. That is, in "FM" condition, interpersonal distance of the "longer" group seemed shorter than "shorter" group, however, this difference was not statistically significant ($p = 0.13$) (Fig. 6b). Further empirical study be needed.

On the other hand, there was no statistically significant interaction between the "long-short relation of IPD_{F2F}" and the "task" (Fig. 6a).

3.2 Analysis II: Influence of Confederate's Interpersonal Distance Preferences

Shortening Between the "No Task" and the "Cooperative Task". The results of Analysis I indicated that preferred interpersonal distance of the "cooperative task" condition was shorter than that of "no task" condition. Hereafter, the amount of shortening of preferred interpersonal distances between the "no task" and the "cooperative task" conditions is transcribed as "*Δ_coop*". Also, Δ_coop of a particular *condition* is transcribed as "Δ_coop (*condition*)". Mean of Δ_coop was 19.37 cm (SD = 30.74) in the "face-to-face" condition and 15.04 cm (SD = 20.0) in the "side-by-side" condition.

Comparing the Amount of Shortening Among "Longer" vs. "Shorter" Cases. Table 2 summarizes preferred interpersonal distances of the "no task" and the "cooperative task" conditions, and the amount of shortening of preferred interpersonal distances (Δ_coop) under either case of "longer" and "shorter". Each value was calculated individually in the "face-to-face" and the "side-by-side" conditions.

Table 2. Shortening of interpersonal distance between "no task" and "cooperative task"

Orientation	Long-short relation	N	Mean		$\mu_A - \mu_B$	SD	Ratio of shortening
			A: no task	B: cooperative task	Shortening (Δ_coop)		
Face-to-face	Longer	14	100.21 cm	71.60 cm	28.61 cm	38.58	22.5
	Shorter	14	73.49 cm	63.36 cm	10.13 cm	12.78	13.0
Side-by-side	Longer	14	70.37 cm	54.29 cm	16.08 cm	20.77	38.3
	Shorter	14	61.54 cm	47.53 cm	14.00 cm	18.38	30.3

On the other hand, by considering a procedure of the stop-distance method, preferred interpersonal distance is determined by an evaluator. It can be inferred that this value has no relation to an approacher's preferred interpersonal distance. Therefore, it can also be inferred that Δ_coop has no relation to the "long-short relation of IPD_{F2F} " among an evaluator and an approacher. There should be no significant difference of Δ_coop among "longer" and "shorter" conditions. In other words, the null hypothesis H_0: Δ_coop ("longer") = Δ_coop ("shorter").

We tested the hypotheses of the equality of mean of Δ_coop among "longer" and "shorter" groups, by using t-test. Under the "face-to-face" condition, there was a statistically significant difference of Δ_coop among "longer" and "shorter" groups (df = 13, t = 2.14, p = 0.05). On the other hand, under the "side-by-side" condition, there was no statistically significant difference of Δ_coop among "longer" and "shorter" groups (df = 13, t = 1.22, p = 0.24). The result indicated that, in the "face-to-face" condition, Δ_coop ("longer") was not equal to Δ_coop ("shorter"). That is, when a dyad initiated a cooperative task "face to face", the amount of shortening of interpersonal distance was affected by the long-short relation of whether an evaluator's preferred interpersonal distance was longer or shorter than an approacher's (Fig. 7).

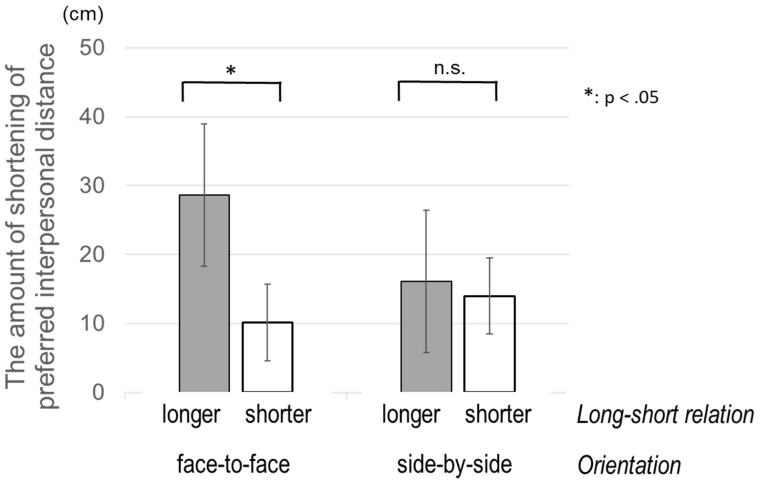


Fig. 7. The amount of shortening of preferred interpersonal distance between"no task" and "cooperative task": "longer" group vs. "shorter" group.

However, under the "side-by-side" condition, there was no statistically significant difference of Δ_coop among "longer" and "shorter" groups (df = 13, t = 1.22, p = 0.24).

4 Discussion

Influence of the Difference of IPD_{F2F} Among an Evaluator and a Confederate. According to the "me"-centered view, interpersonal distance preference of an evaluator is considered independent from that of an approacher. However, the present study indicated a significant influence of the long-short relation of interpersonal distance preferences among an evaluator and an approacher.

On the other hand, our recent another empirical study [13] attempted to approach this issue by applying a correlation analysis. The result of that study indicated that preferred interpersonal distances were shortened in "cooperative task" condition. It also suggested that the amount of shortening between "no task" and "cooperative task"

(*i.e.* Δ_coop) had a meaningful correlation to the mount of difference of IPD_{F2F} among an evaluator and an approacher, at least under the condition of standing face-to-face. That is, the shortening of the preferred interpersonal distance in a cooperative situation can be affected by the amount of the difference of preferred interpersonal distance among an evaluator and an approacher. The initial analysis results of the present study and that study both supported the importance of consideration for an influence related to interpersonal distance preferences of a confederate. In order to examine more rigorously an influence of a confederate, further empirical studies by having more participants will be useful.

Implication to Spatial Behavior of Socially Assistive Robots. Personal space concept or proxemics has recently been emphasized as one of the important component in the design of human-robot interaction for socially assistive robots (*e.g.* [14]). For instance, Garzotto, et al. developed a mobile inflatable interactive robot for children with Neurodevelopmental Disorder, which employed their "Interactional Spatial Relationship Model" [7]. Spatial awareness is essential issue in the field. Theoretical and empirical studies on proxemics of a cooperative situation are expected to provide with a useful basis for the design of appropriate spatial behaviors of socially assistive robots including a nursing-care robot.

5 Conclusion

The present study investigated a dynamic process of adjusting interpersonal distance by emphasizing four factors: cooperative task, angle of orientation, gender combination, and long-short relation of IPD_{F2F}.

Cooperation. The influence of cooperative task was statistically significant. The results revealed that individuals performing a cooperative task produced shorter preferred interpersonal distances than those performing no particular task.

Orientation. The influence of angle of orientation was statistically significant. The results revealed that individuals standing face-to-face produced longer preferred interpersonal distance than those standing side-by-side. This result was consistent under either condition of "task", "gender combination", and "long-short relation of IPD_{F2F}".

Gender. The influence of "gender combination" was statistically significant. Generally, males needed longer interpersonal distances than females. In particular, male pairs produced longer preferred interpersonal distance than female pairs when pairs stood face-to-face. However, this difference was not significant when pairs stood side-by-side. Interestingly, in this study, when a confederate was male who had a shorter IPD_{F2F}, female evaluators produced shorter preferred interpersonal distance than male evaluators. However, this difference was not significant in case a confederate was female.

Influence of Confederate's IPD Preferences. Interpersonal distance among a dyad was shortened in a cooperative situation. At least when a dyad initiated a cooperative task "face to face", the amount of shortening of interpersonal distance was affected by the long-short relation of whether an evaluator's preferred interpersonal distance was longer or shorter than a confederate's.

In order to carefully identify an influence of a confederate, further empirical study will be needed. However, the present study suggested the importance of consideration for a possible influence from a confederate's preference of interpersonal distance as well as other factors related to the interactiveness of adjusting of interpersonal distance in a cooperative situation.

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