Dynamic Characteristics of the Transformation of Interpersonal Distance in Cooperation

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Abstract. This paper describes an empirical study that investigated how interpersonal distance under a cooperative situation varied in accordance with the differences of task, device, orientation of the body, and posture. Twenty young adults participated. The results revealed statistically significant effects of task ($p < .01$), device ($p < .01$), and orientation of the body ($p < .01$) on the transformation of inter-personal distance. In particular, there were statistically significant differences between "no particular task" > "holding a device" > "cooperative tasks"; between "face-to-face" > "side-by-side"; and between "notebook-PC" > "blackboard" or "smartphone". The results also suggested that not only a single cause but the complex of multiple factors of social interaction influenced the transformation of interpersonal distances. A new model of the measurement was also proposed.

Keywords: Personal space · Interpersonal distance · Measurement · Human services

1 Introduction

The *personal space* concept is a useful tool to investigate human spatial behavior in a relatively closer domain. It can be defined as "an area individuals actively maintain around themselves into which others cannot intrude without arousing some sort of discomfort" [13]. Research on human spatial behavior influenced various design issues not limited to the area of architecture and environmental design [4], but can be extended to the design of human services such as care-giving [12], and proxemics of social robots.

The present paper describes an experimental study that investigates dynamic characteristics of human spatial behavior in a cooperative situation.

1.1 Interpersonal Distance in a Cooperation

The dimensions of personal space are not fixed but vary according to internal states, culture, and context [14]. Research findings suggested that the influences upon interpersonal distance were caused by various factors including gender [5], attractiveness [5], personality traits [4], attitudes, culture, psychological disorders, approach angle [17], task [7], eye contact [1], and environmental factors including room size, lighting

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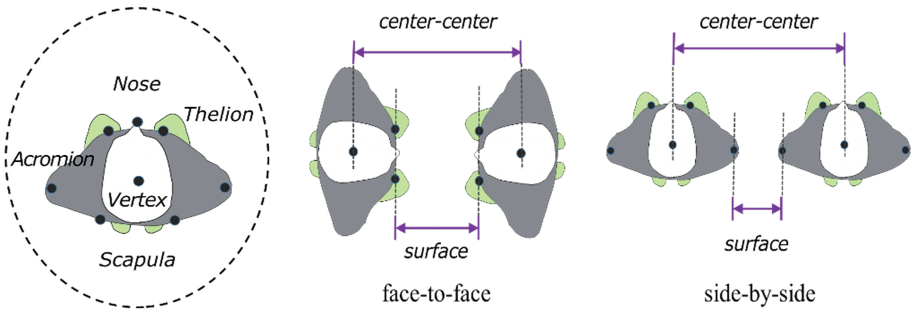
conditions and outdoor/indoor [3]. Also, some conventional literature reported other factors such as race, age, cortical arousal seemed to play a minor role [16].

On the other hand, a cooperation occupies an important dimension of everyday life, however, few studies of the personal space were concerned with a cooperative situation (*e.g.* [15]). Note that unique and interesting movements of the body often appear in human spatial behavior of a cooperative situation. The present study shed light on the dynamic characteristics of human spatial behavior in a cooperation.

1.2 Re-Examining the Measurement of Interpersonal Distance

The stop-distance method had been widely used as a feasible and reliable technique for measuring an interpersonal distance [6]. In this method, the distance is usually measured by a foot position. It well works especially when participants stand in upright posture in a sufficient distance. However, a considerable error possibly occurs under a sort of situation such as a cooperative task. For example, collaborators sometimes move their upper bodies and lean back or bend their heads toward a partner, without moving their feet positions. Kinoe et al. [7] re-examined the measurement of interpersonal distance through their empirical study. In addition to a foot position, they focused on several landmarks on human body, which included Acromion, Thelion, Scapula, Vertex, and the tip of the nose (Fig. 1-a). Based on their previous study, we propose three different concepts of modeling an interpersonal distance: (i) *the "surface" model* which employed the distance between body surfaces, (ii) *the "center-center" model* which employed the distance between the centers of the bodies, and (iii) *the "center-to-surface" model*. As we focused on a cooperative situation, we adopted the "center-center" model (Fig. 1-b).



(a) PS and bodily landmarks: adapted from [7]

(b) Center-center model (upper) and surface model

Fig. 1. Landmarks of human body and models for measuring interpersonal distance

1.3 Our Approach

Our approach to the present study is threefold: (a) to shed light on the dynamic characteristics of the transformation of interpersonal distance with the emphasis on a cooperative situation, (b) to focus on the influences of four factors including task, device, orientation of the body, and posture, based on the framework by Kinoe and Hama [8], and (c) to employ a new model of the measurement effective for capturing the transformation of interpersonal distance in a cooperative situation. Based on the study, we also discuss the enhancement of a measurement technology, and the necessity as well as the difficulty of an empirical study of elderly persons on interpersonal space needs in a cooperation.

2 Empirical Study

The present study aimed to investigate the dynamic characteristics of the transformation of interpersonal distance between individuals in a cooperative situation (Fig. 2).

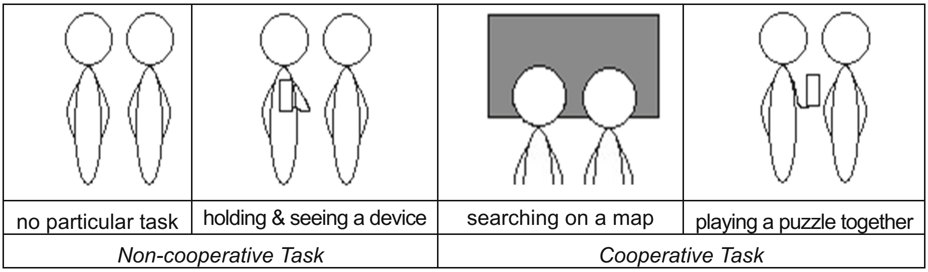


Fig. 2. Spacing behavior in non-cooperative and cooperative situations

2.1 Method

The experimental design of the present study is shown in Table 1. There were four factors in the present study. The within-subject factors were "posture" (2 levels: standing vs. chair-sitting), "orientation of the body" (2 levels: side-by-side vs. face-to-face), "task" {6 levels: (no task vs. before a cooperative task (= holding a device) vs. during a cooperative task) x (searching on a map vs. jigsaw puzzle)} (see Fig. 2), and "device" (3 levels: smartphone vs. notebook-PC vs. blackboard) (see Table 1). Due to the nature of a cooperative task using a blackboard, a "face-to-face" position as well as a "puzzle" task, were not available under the condition of "blackboard".

Table 1. Experimental Design

Factor		**Level**		
Within subject	Posture	2	standing, chair-sitting	
	Body orientation	2	side-by-side, face-to-face	
	Device	3	smartphone, notebook-PC, blackboard	
	Task	6	map	no task - before task (holding a device) - during task (using a device)
			puzzle	no task - before task (holding a device) - during task (using a device)

Participants. Twenty healthy university students (6 males, 14 females, age range: 18–23 years, who were educated between 13–16 years) participated. The participants were recruited individually and were informed that the study dealt with spatial preferences.

Materials and Apparatus. The materials consisted of combinations of three devices and two types of applications. The devices were a smartphone (iPhone; H: 123.8 × W: 58.6 × D: 7.6 mm, 112 g), a notebook-PC (Macbook Pro; H: 247.1 × W: 358.9 × D: 18 mm, 2.04 kg), and a blackboard (H: 1.50 × W: 3.40 m). The applications were puzzles (Jigty Jigsaw Puzzles ver.3.0) and maps which included Google Maps and a printed map (H: 375 × W: 295 mm) put up on a blackboard.

Procedure. The data collection was performed by ten different pairs of participants (A and B) who were not acquaintances. 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 data collection was performed in order of “no task”, “holding a device”, and cooperative tasks including “searching on a map” and “jigsaw puzzle”. According to the experimental design, a set of 42 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.

The stop-distance method was employed to measure interpersonal distances. At first, an assistant experimenter 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. By saying stop, an assistant experimenter’s approach halted. In order to minimize a measurement error, an evaluator was allowed to make fine re-adjustment of their positions. A foot position was used under non-cooperative task conditions (i.e. “no task” and “holding a device”). On the other hand, in a cooperative task condition, the experimenter asked an evaluator and an assistant experimenter to freeze their movements when they performed a cooperative task for approximately one minute in a distance comfortable to an evaluator. The remaining distance between the centers of their bodies was measured (see Fig. 1-b).

The data collection was carried out during daytime, in an empty and quiet class room (approx. 6.5 m × 6.3 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. The data were collected in January 2015.

Data Analysis. A multiple comparison test was performed. We applied Bonferrroni-Dunn’s procedure by using SPSS (ver. 22). It is not necessary to test the null omnibus hypothesis using an ANOVA prior to tD statistic [9]. In a case of using a foot position for measuring the distance, data correction was made with the center-center model, by using the anthropometric database [10] available from Digital Human R.C. of AIST.

2.2 Results

Means and standard deviations of all the interpersonal distances obtained under the condition of standing posture are given in Table 2. The observed data of standing posture ranged between 11.0 (face-to-face, searching on a map, smartphone) and 186.7 (face-to-face, no task) (mean = 50.36, SD = 24.89) cm. According to Hall's zone system, the observed data widely ranged from the intimate distance (0–18 in.), to the close phase of social distance (4–7 ft.).

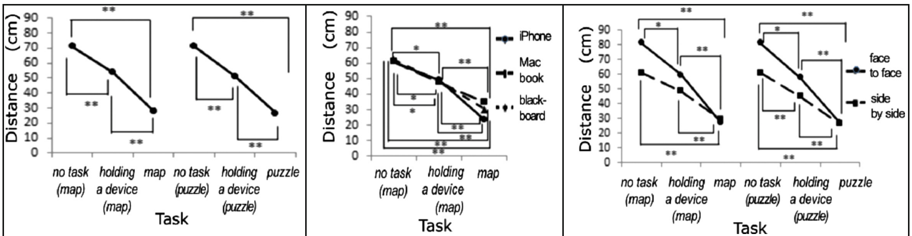
Table 2. Means and standard deviations of interpersonal distances (center-center model)

Factors			Task														
			no particular task			before MAP task *(holding a device)*			during MAP task			before PUZZLE task *(holding a device)*			during PUZZLE task		
Posture	Orientation of the body	Device	n	Mean (cm)	SD	n	Mean (cm)	SD	n	Mean (cm)	SD	n	Mean (cm)	SD	n	Mean (cm)	SD
standing	side-by-side	smartphone	20	61.07	18.36	20	49.02	8.06	20	23.50	5.67	20	46.07	8.60	20	20.03	4.89
		notebook-PC	20	*61.07	18.36	20	47.65	8.80	20	34.78	7.00	20	43.85	8.09	20	32.78	7.03
		blackboard	20	62.24	18.90	20	48.30	6.77	20	30.28	4.40		n/a			n/a	
	face-to-face	smartphone	20	81.26	29.2	20	58.87	9.59	20	20.78	7.03	20	58.40	9.96	20	18.35	6.35
		notebook-PC	20	*81.26	29.2	20	59.90	10.34	20	33.23	8.25	20	56.82	10.96	20	35.35	11.55

Note *: The data under the "no task" condition of a smartphone was the same as that of a notebook-PC.

The result revealed that there were statistically significant simple main effects of the "task" ($p < .01$), the "device" ($p < .01$), and the "orientation of the body" ($p < .01$). On the other hand, neither a simple main effect of the "posture" nor an interaction related to the "posture" was statistically significant. In the present paper, the scope of analysis hereafter is narrowed down to the condition of posture "standing".

Task. The factor of "task" had six levels {(no task vs. before a cooperative task (= holding a device) vs. during a cooperative task) x (searching on a map vs. jigsaw puzzle)}. The simple main effect of the "task" was statistically significant ($p < .01$). In particular, under the condition of either cooperative task, there were statistically significant differences between "no particular task" > "holding a device" ($p < .01$) > "searching on a map" ($p < .01$), and between "no particular task" > "holding a



(a) task | (b) task(map) & device | (c) task & orientation of the body

Fig. 3. Mean of interpersonal distance

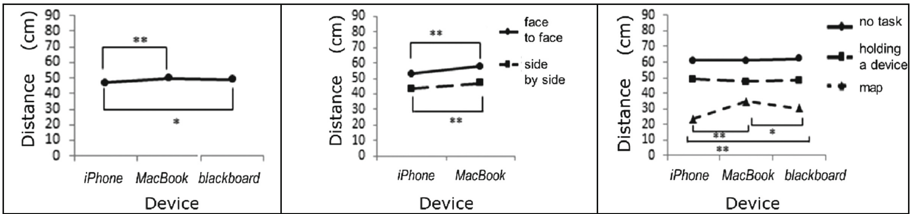
device" (p < .01) > "jigsaw puzzle" (p < .01) (Fig. 3-a). On the other hand, there was no statistically significant difference between "searching on a map" and "jigsaw puzzle".

Interaction of the Task and the Orientation of the Body. Under either condition of "side-by-side" or "face-to-face", there were statistically significant differences between "no particular task" > "searching on a map" (p < .01), between "no particular task" > "jigsaw puzzle" (p < .01), between "holding a device" > "searching on a map" (p < .01), and between "holding a device" > "jigsaw puzzle" (p < .01) (Fig. 3-c). Furthermore, statistically significant differences between "no particular task" > "holding a device" were found under the condition of "face-to-face" (p < .05), and under the combination of the conditions "side-by-side" and "jigsaw puzzle" (p < .01) (Fig. 3-c).

Interaction of the Task and the Device. Under each device condition of "smartphone", "notebook-PC", and "blackboard", there were statistically significant differences between "no particular task" > "holding a device" (p < .05) > "searching on a map" (p < .01). Also, under either device condition of "smartphone" and "notebook-PC", there were statistically significant differences between "no particular task" > "holding a device" (p < .05) > "jigsaw puzzle" (p < .01). (Fig. 3-b).

The above result indicated that interpersonal distances were reduced by initiating a cooperative task, under the condition of either cooperative task (map or puzzle), or either orientation of the body (face-to-face or side-by-side), or either device (smartphone, notebook PC or blackboard). Also interestingly, interpersonal distances were reduced when an evaluator held either portable device (a smartphone or a notebook PC).

Device. The factor of "device" had three levels (smartphone vs. notebook-PC vs. blackboard). The simple main effect of the "device" was statistically significant (p < .01). In particular, there were statistically significant differences between "notebook-PC" > "smartphone" (p < .01) and between "blackboard" > "smartphone" (p < .05) (Fig. 4-a). Under either condition of "side-by-side" or "face-to-face", there was a statistically significant difference between "notebook-PC" > "smartphone" (p < .01) (Fig. 4-b).

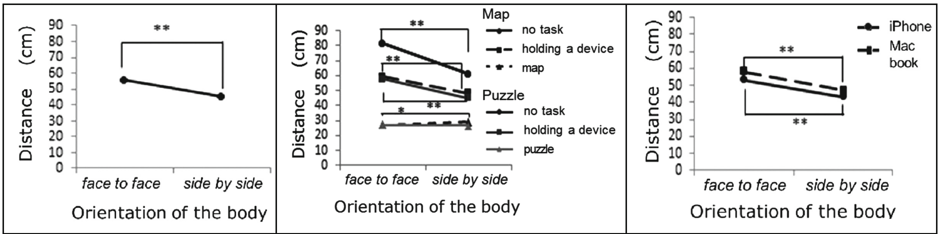


(a) device | (b) device & orientation of the body | (c) device & task (map)

Fig. 4. Mean of interpersonal distance

Interaction of the Device and the Task. Under the task condition of "searching on a map", there were statistically significant differences between the "notebook-PC" > the "smartphone" (p < .01), between the "blackboard" > "smartphone" (p < .01), and between “notebook-PC” > “blackboard” ($p < .05$) (Fig. 4-c). At least, under the condition of a certain cooperative task such as “searching on a map”, the bigger size of a device did not always contribute to increase the interpersonal distance.

Orientation of the Body. The factor of “orientation of the body” had two levels (face-to-face vs. side-by-side). The simple main effect of the “orientation of the body” was statistically significant ($p < .01$). In particular, there was a statistically significant difference between “face-to-face” > “side-by-side” ($p < .01$) (Fig. 5-a). Also, under either condition of “smartphone” or “notebook-PC”, there were significant differences between “face-to-face” > “side-by-side” ($p < .01$) (Fig. 5-c).



(a) orientation of the body | (b) orientation of the body & task | (c) orientation of the body & device

Fig. 5. Mean of interpersonal distance

Interaction of the Orientation of the Body and the Task. There were statistically significant differences between “face-to-face” > “side-by-side” under the condition of non-cooperative task (i.e. “no particular task” ($p < .01$) or “holding a device” task ($p < .01$)) (Fig. 5-b). Conversely, under the condition of the “searching on a map” task, there was a statistically significant difference between “face-to-face” < “side-by-side” ($p < .05$) (Fig. 5-b). At least, this result obtained under the condition of a certain cooperative task was different from the anisotropy observed under the condition of non-cooperative task described above (“face-to-face” > “side-by-side”).

3 Discussion

The Dynamic Transformation of the Interpersonal Distance in a Cooperation. The interpersonal distance was dynamically transformed according to the differences in situational factors involving cooperation, type of devices, and orientation of the body. The results also revealed interesting statistically significant interactions of task and orientation of the body, and the interaction of task and device. Interpersonal distance varies with a complex of multiple causes rather than a single and identifiable cause such as device size. This results reflected not only the flexibility of individual personal space but the complexity of a cooperation. It is suggested that interpersonal space is actively co-constructed as a result of the cooperative process by two individuals who shared the same environment. The transformation can be facilitated by a kind of social interaction.

Technology for Capturing Dynamic Nature of Interpersonal Distance. The interpersonal distance frequently changes especially in a cooperative situation. The conventional stop-distance method has a methodological limitation, as it requires to freeze participants' physical movements for a moment. It is expected a new measurement approach using a sensor technology will provide a viable solution to capture its dynamic nature.

Multidisciplinary Study of Personal Space of Elderly Persons in a Cooperation. Personal space was considered as a meaningful element to be concerned by those giving care to or co-working with the elderly persons [11]. However, there was few study of personal space needs of elderly persons, especially, limited attention to an interactive situation.

In conventional studies on personal space of the decades, it had been considered the age factor played a minor role [16], except for their attentions to the developmental changes in childhood. For instance, it is known that the children tend to be happy to be physically close to each other but personal space gets bigger as they grow older. Developmental changes of personal space needs had been identified at least from infancy to adolescence [6].

On the other hand, recent neuro-cognitive literature [2] discussed the relationship between the neurological changes in older adults and the degradation of their peripersonal space representations compared with that of young adults. Those changes may influence their personal space needs and spatial behavior. However, surprisingly little is known about developmental changes of personal space needs in late adulthood [4]. Different age groups may have heterogeneous characteristics of personal space. Further multidisciplinary study is needed to address this issue appropriately from multiple related aspects, and to develop a viable technology for carefully understanding and harmonizing flexible needs of personal space in the advancement of aging society.

4 Conclusion

This paper presented an experimental study that investigated the dynamic characteristics of human spatial behavior in a cooperation. We focused on how interpersonal distance varied depending on the differences of tasks, devices, and orientation of the body.

The results revealed several unique dynamic characteristics of interpersonal distance in a cooperation. First, the results indicated statistically significant simple main effects of the "task", the "device", and the "orientation of the body". In particular, there were statistically significant differences between "no particular task" > "holding a device" > "cooperative tasks"; between "face-to-face" > "side-by-side"; and between "notebook-PC" > "blackboard" or "smartphone". Second, the results revealed that the interpersonal distance was reduced by initiating a cooperative task, under the condition of either cooperative task (map or puzzle), or either orientation of the body (face-to-face or side-by-side), or either device (smartphone or notebook-PC). Also interestingly, the interpersonal distance was reduced when an evaluator held a portable device such as a smartphone, even before initiating a cooperation. This suggested that the presence of a device facilitated some change on collaborators' interactive environment. Third, the results also revealed interesting statistically significant interactions of task and orientation of the body, and the interaction of task and device. This indicated that interpersonal distance varies with a complex of multiple causes rather than a single and identifiable cause. The dynamics of social interactions seemed to influence the transformation of interpersonal spaces. Other results also involved interesting findings, for instance, the anisotropy (face-to-face > side-by-side) observed under a non-cooperative situation was transformed into the opposite during a certain cooperation.

Different age groups may have heterogeneous needs of interpersonal space. The further empirical study is needed, in order to substantiate these findings, to address this vital issue in the environmental design of human services such as nursing and care-giving, and to find feasible solutions for harmonizing flexible needs for personal space in the advancement of aging society.

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