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Facilitating Interconnectedness between Body and Space for Full-bodied Presence - Utilization of "Lazy Susan" video projection communication system -

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Abstract

A significance of a sense of togetherness or co-existence among remote communication partners has been pointed out in computer-mediated communication. In order to create such a co-existing situation, full-bodied presence of participants should be supported at each place. We devise two representation methods; representing self reflection in a shared video space, and projecting reflection of a remote partner onto the local tabletop. Then we construct "Lazy Susan" video projection communication system composed of a shared disk system and a video projection system based on this method. The results of experiments suggest our system can enhance an interconnectedness between self and a remote place, and between a remote partner and a local place, and simultaneously enhance a sense of co-existence. Based on this result we discuss and propose a novel approach focusing on duality of embodiment to facilitate interconnecting body with space for full-bodied presence.

Keywords--- **Co-existing space, Embodiment, Self reflection, Visual interaction, Tangible interaction, Interconnectedness**

1. Introduction

Many telecommunication systems have been proposed and developed in the past few decades. These systems can support remote awareness - who is participating, what they are doing, and where they are - by expressing bodily action of a remote partner such as gaze and gesture [1]. A problem of disembodiment, however, occurs in such computer-mediated communication as Dreyfus pointed out [2]. For example, even when a life-sized image of a remote partner appears on a large screen at a local place, the psychological distance to the person in the screen differs from that in a face-to-face situation [3]. We consider that image-only projection of a remote partner to create much less of a sense of presence. It is obvious to the local partner that the remote partner is not there.

In contrast, people are bodily present at the same place in face-to-face situations. This full-bodied presence is crucial to everyday human encounters [2]. We can attune ourselves to mood, when we are bodily present in a situation. The situation -we are embedded with others and things in a common setting- is called as "Ba" in Japanese [4][5]. "Ba" is not a physical place but a co-existing situation in mind. We believe that creation of a co-existing situation is fundamental before interpersonal communication takes place [4][5]. We define "co-existing space" as a common place at which people are full-bodied present.

A few communication systems have been proposed and received attention to support a sense of connectedness among remote families and a remote watching an elderly person living alone warmly in several years [6][7]. A requirement of communication technology creating a co-existing space between remote places will increase more than ever. In order to address this challenge, the first step is to enhance a sense of "interconnectedness" among remote people in a shared virtual environment. Therefore we devised a networked "Lazy Susan" communication system; integrating tangible interaction with physical disk and visual interaction in a shared virtual environment [8][9]. Consequently, we found its capability to enhance a sense of co-existence in a shared virtual space.

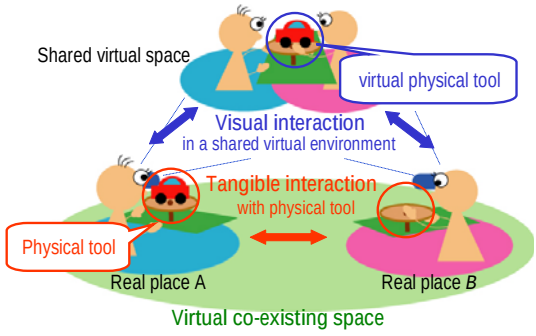
This paper describes our next step of developing this design method toward creating a virtual co-existing space in a physical place where our body exists. The paper explains two approaches and our novel "Lazy Susan" video projection communication system composed of a shared disk system and a video projection system; representing reflection of self in a common video space, and projecting reflection of a remote partner onto a local tabletop. The results of experiments suggest our system can enhance a sense of "being present in a video space of a remote place" and "a remote participant is being present at a local place", and simultaneously enhance a sense of co-existence. At the last it discusses and proposes a novel approach focusing on duality of embodiment in order to facilitate interconnecting body with space for full-bodied presence.

2. Design of a virtual co-existing space

There are few design frameworks and approaches to create a virtual co-existing space, since most communication systems discussed in current literature are intended to support primarily how to convey bodily action such as gaze awareness [10][11][12] and gesture in a shared workspace [11][13][14]. When we look at how to connect among remote people in a shared space, however, a few challenging systems are proposed. VirtualActor [15] can create a shared virtual environment where virtual reflections of remote others and self appear and act corresponding to actions of real person. Then HyperMirror [16] uses a metaphor of mirror and can create a shared video space by synthesizing reversed self reflection into a remote place. These communication systems are intended to support a sense of interconnectedness between remote partner and self, not necessarily to imitate a real face-to-face situation. In particular, a feature of these systems is to represent reflections of others and self in a common situation.

We have devised a novel communication system in order to create a virtual co-existing space in a physical place as well as in a virtual environment based on this approach representing reflections of others and self at a common place. This system is based on our "Lazy Susan" communication system we have already developed.

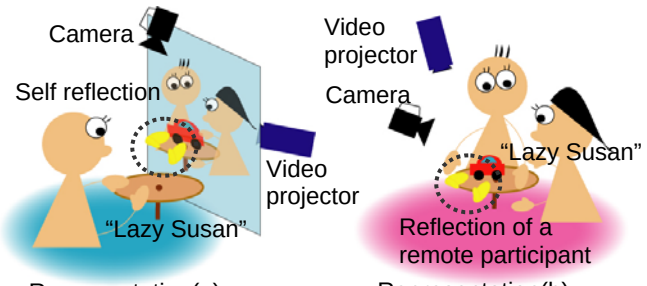
Figure1(a) illustrates a design approach of the "Lazy Susan" communication system, and Figure 1(b) shows the communication system. "Lazy Susan" is a wooden revolving disk, much like what you see in a Chinese restaurant as shown in Figure 1(b). This system supports visual interaction, -in a shared virtual space representing bodily interactions with a physical disk visually, and a virtual disk linked with the physical one-, and tangible



(a) Design of "Lazy Susan" communication system

(b) Networked "Lazy Susan" and real "Lazy Susan"

Figure 1 Networked "Lazy Susan" communication system



Representation(a): Representing reflection of self in a common video space

Representation(b): Projecting reflection of a remote participant onto a local table

Figure 2 Diagram of two ways to connect a shared video space to a real place

interaction - with a physical disk which can be rotated by hand at each site, and their rotations are synchronized with each other-. Results of communication experiments suggested that this system could enhance a sense of co-existence in a shared virtual environment [9].

In order to realize consistently representing reflections of others and self in a common space, and tangible interaction with a networked physical disk, we devise two approaches. The first one is to synthesize the reflection of self with that of others in a common video space, the second one is to project reflections of remote partners onto a local place. Figure 2(a) illustrates the first approach that a synthesized video including reflection of a remote partner and self is projected onto a screen behind a table. We call this expression as Representation(a) hereafter in this paper. Figure 2(b) illustrates the second approach that reflection of a remote partner is projected onto a local tabletop directly. We call the expression as Representation(b) in this paper.

3. "Lazy Susan" video projection communication system

The "Lazy Susan" video projection communication system is composed of a shared disk system and a video projection system as illustrated in Figure 3.

The shared disk system is packed on a wooden table (600×450×770[mm]) on the top of which a rotating wooden disk (280[mm] in diameter) is embedded as shown in Figure 4. The disk can be rotated by hand, and its rotations are synchronized with the movements of the corresponding disk on a remote table. The disk connects with one rotary encoder (NEMICON, OME-360-2MC) and with one DC servomotor (Japan Servo Co.,Ltd., DME34S36G10B) as shown in Figure 4, and its motor controller (iXs Research Corp., iMCs01) communicates with the host PC via USB. The Host PC transmits rotation angular data to the remote PC through an IP network, and then each PC applies a feedback loop to control the rotation angle of the disk according to the remote disk's rotation. When participants interact with the two networked disks, the two disks will behave as if they were coupled by a spring coil. Both disks remain motionless until one of the participants rotates his/her local disk; at that point the corresponding disk will move

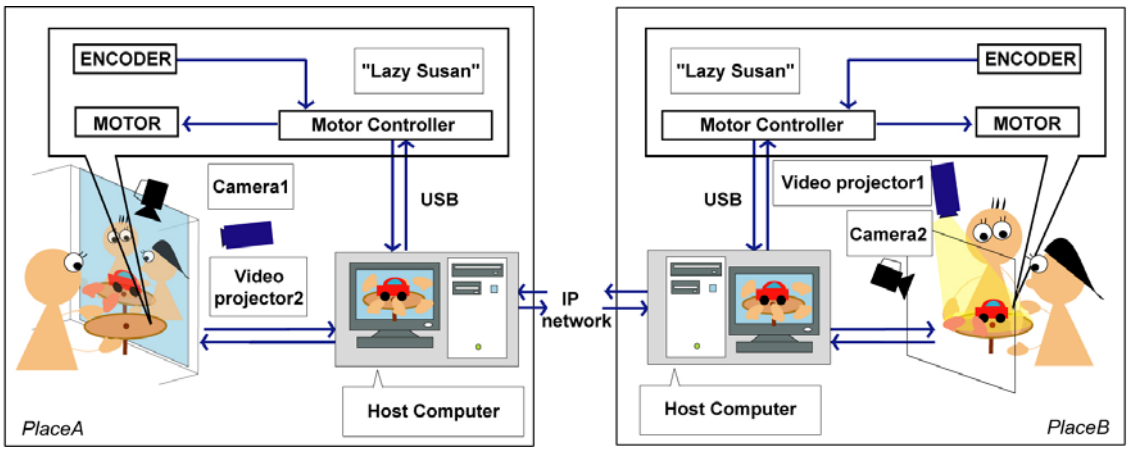


Figure 3 System configration of "Lazy Susan" video projection communication system

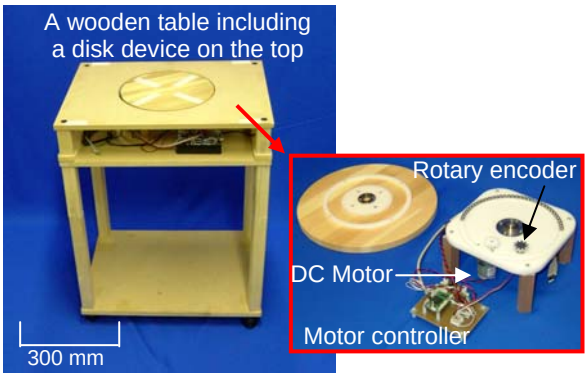
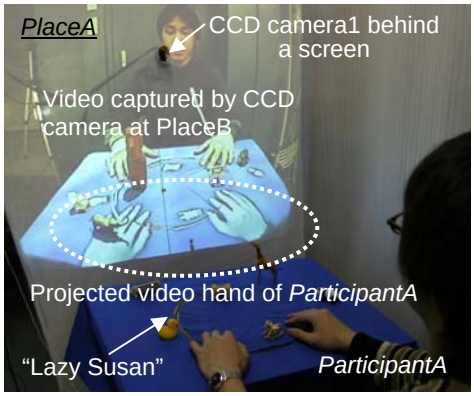


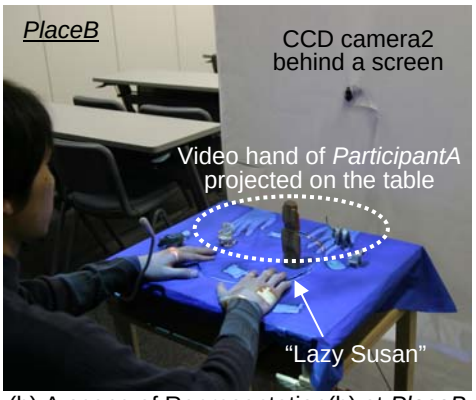
Figure 4 A shared disk system

synchronously. When one rotating disk is stopped, the other disk stops at the same time and in the same position. If there is a conflict -if, for example, one participant attempts to rotate the disk clockwise while the other participant attempts to rotate counterclockwise- then each participant will feel torque in the opposite direction.

We explain the video projection system as seen in Figure 3. This video projection system can represent reflection of participants according to Representation(a) and Representation(b) as described previous chapter. Representation(a) is installed at one site PlaceA and concurrently Representation(b) is installed at the other site PlaceB. Installing Representation(a) or Representation(b) at both sites can be available. In order to investigate the availability of those representations, each representation is installed at each site. At PlaceA, CCD camera1, which is installed over the table, captures a participant at PlaceA and physical objects on a tabletop. Simultaneously, the video is projected onto a tabletop by video projector1 at PlaceB. On the other hand, CCD camera2 at PlaceB, which is installed at the height of eye view, captures a tabletop and participants around the table. At once the video of the perspective of remote PlaceB is projected by video projector2 onto a screen behind a table at PlaceA. A participant at PlaceA can communicate with a remote participant at PlaceB by viewing reflection of the other and self in a video of a remote place and by rotating the physical disk linked with remote one. On the other hand, the participant at PlaceB can communicate with the remote participant at



(a) A scene of Representation(a) at *PlaceA*



(b) A scene of Representation(b) at *PlaceB*

Figure 5 "Lazy Susan" in use between remote places

PlaceA, whose reflection is projected on the local tabletop while rotating the remote linked disk. Figure 5 shows a scene of employing our communication system at both sites.

4. Design of Experiments

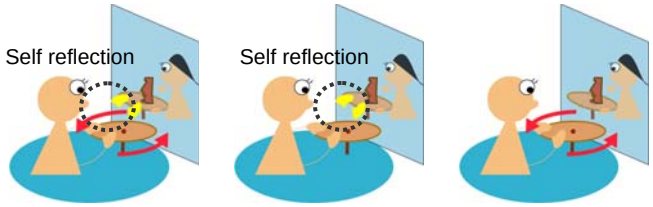
Our experiments are designed to investigate the extent of connectedness between self and remote things -participant, disk, table and object-, and between a remote participant and local things with or without self reflection in a synthesized video, projecting a reflection of the remote participant on a real table, and tangible

interaction with remote-linked disk on Representation(a) and Representation(b).

The experiments were conducted under the three conditions on Representation(a) as displayed in Table 1 and Figure 6, and under the three conditions on Representation(b) as displayed in Table 2 and Figure 7. Eleven pairs of adult students (aged 20-24) participated in the experiments. One of the pairs experienced Representation(a) in one place and simultaneously the other experienced Representation(b) in another remote place. Experimental participants were required to rotate the disk alternately while making sure that an object on the disk wasn't going to fall down. They spent three minutes experiencing each condition. Figure 5 shows a scene of communication experiment under Condition1. After three conditions, each participant answered a questionnaire and wrote down some comments on a

Table 1 Three conditions of communication experiments on Representation(a)

	Reflection of self appears in a video of remote place.	Video disk can be operated by rotating a physical disk.
Condition1	Yes	Yes
Condition2	Yes	No
Condition3	No	Yes



Condition1: Visual interaction and tangible interaction

Condition2: Only Visual interaction

Condition3: Tangible interaction without self reflection

Figure 6 Three conditions of communication experiments on Representation(a)

Table 2 Three conditions of communication experiments on Representation(b)

	Reflection of remote partner is projected on a table.	Remote partner can operate a physical disk networked with a local disk.
Condition1	Yes	Yes
Condition2	Yes	No
Condition3	No	Yes

Condition1: Visual interaction and tangible interaction

Condition2: Only Visual interaction

Condition3: Only tangible interaction

Figure 7 Three conditions of communication experiments on Representation(b)

sense of co-existence and interaction with the rotating disk under each of the three conditions. The questionnaire includes 12 items for Representation(a) as displayed in Table 3 and for Representation(b) as displayed in Table 5, and each item is rated on a scale from –3 to +3 (0 neutral). After one experiment, the same pair changed the place with each other, and experienced three conditions in the other representation again. Each participant experienced Representation(a) and Representation(b) with the same partner. The order of these conditions was shuffled to each pair. Figure 8 and 11 illustrate the results of average and standard deviation under 12 items of the questionnaire. A Wilcoxon signed-rank test is executed to calculate a significant difference. Table 4 and Table 6 sum up comments obtained from participants under each condition on both representations.

We call condition1 “dual” interaction mode, condition2 “visual” interaction mode and condition3 “tangible” interaction mode.

5. Result

5.1. Results of Representation(a)

In Representation(a), a questionnaire including 12 items in Table 3 is designed to investigate to what extent connectedness between self and a remote place, and also between self and a remote participant, are influenced with or without self reflection in a synthesized video, and with or without the subject’s operating a video disk by physically rotating it. Table 4 sums up comments from all participants.

Questions 1 through 6 ask about the connectedness between self and remote things in a video - a rotating disk that can be connected with physical one, a fixed table, physical objects, and communication partner. Questions 7 and 8 ask about the connectedness between a physical object actually located in front of the subject and its video in a remote place. Questions 9 through 12 ask about a sense of “being co-located” and closeness.

Figure 8 shows most of the participants rated positively all items under “dual” interaction mode. Additionally a highly significant difference can be found between “dual” interaction mode and visual interaction mode, and between “dual” interaction mode and tangible interaction mode. Comments from participants in Table 4 also suggest superiority of “dual” interaction mode over visual interaction mode and tangible interaction mode. Most of the participants reported a sense of connectedness between self and a remote place and between self and remote partner was enhanced. Additionally, we observed an interesting situation in which a participant at PlaceA almost stretched out to a falling statue on a remote disk when he/she rotated the local physical disk by his/her hand or when he/she touched the local physical disk a remote partner controlled at PlaceB as shown in Figure 9. Another situation is that when a remote statue was falling down toward reflection of own hand, he/she moved his/her hand away at once as shown in Figure 10. Afterwards,

most of them reported that they felt as if their hands expanded to the remote place. These results indicate a connectedness between self and remote things is enhanced in "dual" interaction mode over in visual interaction mode and in tangible interaction mode.

In visual interaction mode without tangible interaction with video disk, Figure 8 shows participants rated positively Q1 and Q2 inquiring a connectedness between self and a remote disk, and between self and a remote table. However, they didn't necessarily rate positively Q3,4,5 and Q6 inquiring a connectedness between self and remote objects, and between self and remote partner, since each average of those scores indicates near neutral zero. In view of all comments, these results suggest a connectedness between self and remote things is weak only in visual interaction mode.

In tangible interaction mode without self reflection, Figure 8 shows participants rated positively only Q1 inquiring a connectedness between self and a remote disk. However, each average of the other items' scores indicates around or below neutral zero. In view of all comments, these results suggest a connectedness between self and remote things is also weak only in tangible interaction mode.

Table 3 Items of questionnaire on Representation(a)

Q1. To what extent if they sensed as if they touched a remote disk.
Q2. To what extent if they sensed as if they touched a remote table.
Q3. To what extent if they sensed as if they touched an object on a remote disk.
Q4. To what extent if they sensed as if they touched an object on a remote table.
Q5. To what extent if they sensed as if they touched a participant on a remote disk.
Q6. To what extent if they sensed as if they touched a participant on a remote table.
Q7. To what extent if they sensed as if a local object were on a remote disk.
Q8. To what extent if they sensed as if a local object were on a remote table.
Q9. To what extent if they sensed as if they were in a remote place.
Q10.To what extent if they sensed as if a remote participant were here in a local place.
Q11.To what extent if they sensed as if they were co-located in the same place.
Q12.To what extent if they felt a closeness of a remote participant.

Table 4 Summary of comments on communication experiments

Condition1 **"Dual" interaction mode**	They felt as if their bodies expanded toward a remote space. They turned aside their hands not to put their hands on a video of remote objects. They were surprised that they turned over an object on a remote disk when they rotated the disk. They felt as if they touched a remote participant while rotating the disk. They felt a sense of disconnectedness between a local table and a video when a remote participant rotated the disk.
Condition2 **Visual interaction mode**	They felt a sense of connectedness was weak between self and video of remote table. They didn't feel well as if they touched a remote object. They felt their hands passed through an object.
Condition3 **Tangible interaction mode**	They felt they rotated the remote disk through a controller device indirectly. They felt a sense of connectedness was weak. They felt it was obscure a remote participant rotated the local disk or the disk rotated automatically. They didn't feel they rotate the remote disk even when they rotated the disk. They felt their timing was off.

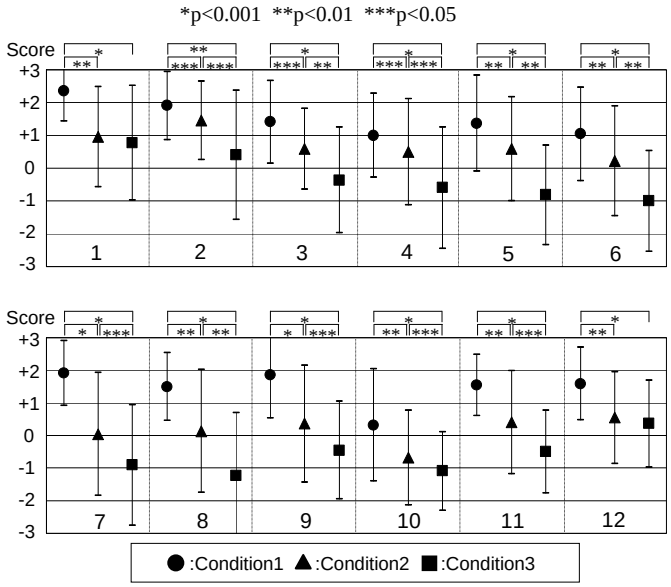


Figure 8 Result of questionnaire on Representation(a)

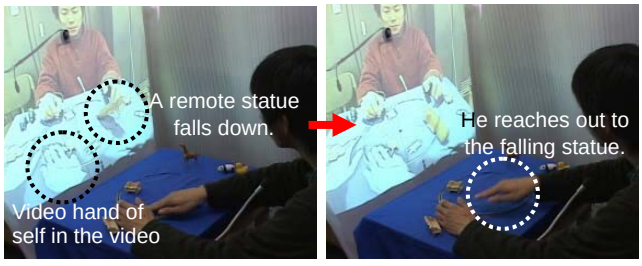


Figure 9 A scene of reaching out to a remote object that is going to fall down

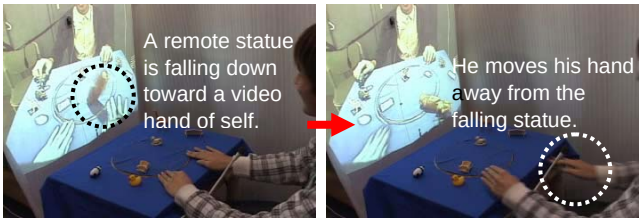


Figure 10 A scene of moving own hand away from a falling down statue

5.2. Results of Representation(b)

In Representation(b), a questionnaire including 12 items in Table 5 is designed to investigate to what extent connectedness between a remote participant and a local place, and also between remote participant and self are influenced with or without projecting reflection of remote participant on a real table, and with or without remote partner's rotating a physical disk networked with a local disk. Table 6 sums up comments of all participants.

Table 5 Items of questionnaire on Representation(b)

Q1. To what extent if they sensed as if a remote participant touched a local disk.
Q2. To what extent if they sensed as if a remote participant touched a local table.
Q3. To what extent if they sensed as if a remote participant touched an object on a local disk.
Q4. To what extent if they sensed as if a remote participant touched an object on a local table.
Q5. To what extent if they sensed as if a remote participant touched their hands on a local disk.
Q6. To what extent if they sensed as if a remote participant touched their hands on a local table.
Q7. To what extent if they sensed as if a remote object were on a local disk.
Q8. To what extent if they sensed as if a remote object were on a local table.
Q9. To what extent if they sensed as if they were in a remote place.
Q10. To what extent if they sensed as if a remote participant were here in a local place.
Q11. To what extent if they sensed as if they were co-located in the same place.
Q12. To what extent if they felt a closeness of a remote participant.

Table 6 Summary of comments on communication experiments

Condition1 **"Dual" interaction mode**	They felt as if a remote participant rotated the disk actually.
	They felt as if a remote participant touched an object on a local table.
	They felt as if a remote participant touched on hands of their own.
	They felt as if they rotated disk in face-to-face.
	They felt as if a remote hand came in.
	They felt a sense of discomfort to a two dimensional video object especially when the object was tall.
Condition2 **Visual interaction mode**	They felt video hands of a remote participant was just an image.
	They felt a sense of connectedness with a remote participant was weak.
	They felt it was weird that a local object didn't move even when a remote participant touched it.
	They didn't feel well as if they were co-located in the same place.
	They felt a sense of discomfort to a two dimensional remote object.
Condition3 **Tangible interaction mode**	They felt as if a remote participant rotated the disk actually.
	They felt it was weird that the disk rotated automatically.
	They couldn't guess when a remote participant rotated the disk.
	They didn't feel they rotated the same disk together.
	They felt uneasy when the disk was still because they didn't understand where a remote participant was.

Questions 1 through 6 ask about the connectedness between a remote participant and physical things at a local place - a disk that can be rotated, a fixed table, physical objects, and self. Questions 7 and 8 ask about the connectedness between a physical object at a remote place and its video projected in front of the participant. Questions 9 through 12 ask about the sense of "being co-located" and closeness.

Figure 11 shows most of the participants rated positively all items under "dual" interaction mode. Additionally a highly significant difference can be found between "dual" interaction mode and visual interaction mode, and between "dual" interaction mode and tangible interaction mode. Comments from participants in Table 6 also suggest superiority of "dual" interaction mode over visual interaction mode and tangible interaction mode. Additionally, we observed an interesting situation during which a participant at PlaceB was going to touch a video hand, but moved his hand away from the video hand when the video hand was going to hit his own hand. These results suggest a connectedness between remote partner and local things is enhanced in "dual" interaction mode over in visual interaction mode and in tangible interaction mode. However, some participants in visual interaction mode pointed out that they felt a sense of discomfort viewing a two-dimensional video object especially when the object was tall.

In visual interaction mode without remote partner's rotating a physical disk networked with a local disk, Figure 11 shows participants didn't rate positively all items, since each average of all items' scores indicates around or below neutral zero. In view of all comments, these results suggest a connectedness between remote

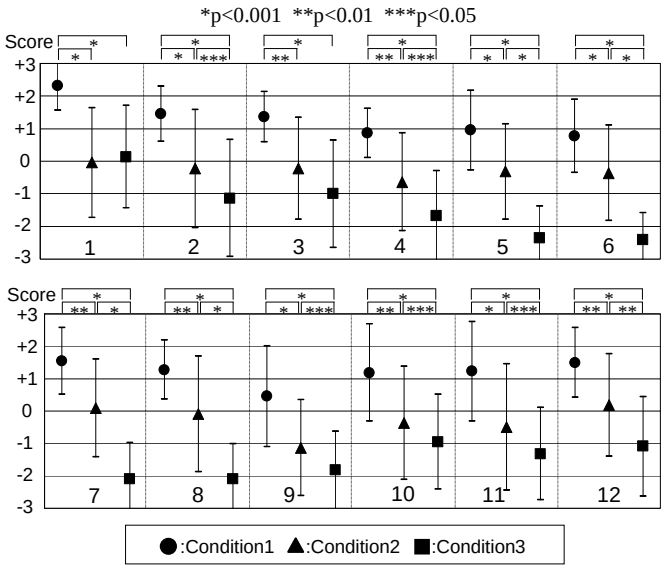


Figure 11 Result of questionnaire on Representation(b)

partner and local things is weak only in visual interaction mode.

In tangible interaction mode without reflection of a remote partner, Figure 11 shows participants didn't rate positively all items, since an average of only Q1 item's score indicate around neutral zero, and each average of the other items' scores indicates substantially below neutral zero. We can find two opposite standpoints in comments. Some of the participants reported that they felt as if a remote participant actually rotated the disk, the others reported that they felt it was weird that the disk rotated automatically. In view of all comments, these results suggest a connectedness between remote partner and local things is also weak only in tangible interaction mode.

5.3. Results of Representation(a) and (b)

The results described in the previous section indicate in "dual" embodied interaction mode that Representation(a) can enhance a connectedness between self and a remote place, and simultaneously Representation(b) can enhance a connectedness between a remote participant and a local place. In other words, Representation(a) can create a situation of "being present at a remote place", and Representation(b) can create a situation of "a remote participant is being present at a local place". From this view, we consider the result of common items Q9, Q10, Q11, and Q12 in both representation methods. At Q9 inquiring as if they were in a remote place, Representation(a) is evaluated more highly than Representation(b), and a highly significant difference can be found ($p<.001$) between them. On the other hand, at Q10 inquiring as if a remote participant were here in a local place, Representation(b) is evaluated more highly than Representation(a), and a highly significant difference can be found ($p<.01$) between them. Additionally both Representation(a) and Representation(b) are highly rated at Q11 as if they were co-located in the same place , and at Q12 on a closeness of a remote participant. These results mean each representation method proposes two approaches where a co-existing space is created.

6. Discussion

We discuss our two representations to create a virtual co-existing space and its fundamental design approach.

First, we consider a method of representing reflection of others and self in a common space. VirtualActor [15] and HyperMirror [16] are constructed based on this approach. A CG avatar appears in VirtualActor [15], and life-sized reversed reflection of an upper body or full body appears in Hyper Mirror [16]. These systems can support a connectedness between others and self by representing their reflections at a common space. In our "Lazy Susan" system, a reflection of one's own hand and arm appears in a video from the perspective of viewing a table, and in addition the participant can interact with the physical disk. Our experiment results indicate a sense of "as if own body expanded toward a remote place" is enhanced in "dual" interaction mode more than that in only visual interaction and that in tangible interaction. Recent studies in brain science report interesting discoveries on expansion of body image by measuring brain activity when a monkey sees himself reflected in video monitor and when the monkey is using a tool [17]. It is significant to consider a fundamental design method of interface system expanding embodiment and its evaluation from the knowledge on body image in brain science.

Second, we consider a method of representing reflection of a remote communication partner at a local place. Plenty of communication systems have been proposed based on this idea. Hydra [10] and MAJIC [12] can support gaze awareness during conversation. AGORA [14] can support remote collaborative work with physical objects. Clearboard [11] can support gaze awareness during collaborative drawing on a shared board. These systems report availability of video conference and remote collaborative work; however, they hardly evaluate at all a sense of connectedness among participants and common space. Additionally, inTouch [18] proposes to arouse a sense of presence of a remote participant by rotating wooden rollers with each other without representing reflection of participants visually. Our experiment results indicate a sense of "as if a remote participant were present at a local place" is enhanced in "dual" interaction mode more than that in only visual interaction and that in tangible interaction.

It's interesting that experiment results suggest presence of a remote partner is enhanced even when both participants don't touch each physical disk concurrently. Additionally, the results also suggest presence of a remote object is enhanced even when it is projected on a fixed table as well as projected on a rotating disk. Experiment results in an approach representing reflection of self in a video space also indicate, although participants can only operate the disk that is one small part of common video space, a sense of remote presence is enhanced when one's own hand and objects are located on the fixed table as well as when they are on the rotating disk. In our opinion, these results propose a design approach that participants shouldn't necessarily touch a shared tool all the time, and all of things they can touch shouldn't necessarily be tele-operated in order to enhance connectedness between a remote place and self, and between remote participants and a local place. This method for connecting a physical tool with a remote space or a virtual environment has also been applied in other domains, for example Tactile Augmentation for conducting virtual therapy for arachnophobia and the reduction of pain during treatment for burns [19].

At the last we propose a fundamental design approach in order to create a virtual co-existing space between remote places. We believe embodied interaction has two roles [4][5]; one is a function to convey intentions with each other by explicitly expressing bodily action such as gaze, facial expression and gesture, another is a function to interconnect self with others,

things and situation implicitly in the background by representing reflections of others and self in a common space or by interacting with a shared tool. Most of previous communication systems are intended to support the former function for remote collaborative work. In contrast, our system, VirtualActor [15] and HyperMirror [16] are intended to enhance an interconnectedness between others and self. Our system has the special ability to enhance an interconnectedness between self and a remote place not only by representing reflection of self but also by the participant's ability to operate a video disk by rotating a corresponding physical one: and between a remote partner and a local place not only by representing reflection of a remote participant but also by that remote participant rotating a local disk. Tangible interface framework also proposes "duality" expressing information in foreground and background, however, there has been proposed and evaluated few communication systems yet. We propose that "duality" of explicit and implicit embodied interaction should be supported for creating a virtual co-existing space at which people are full-bodied present.

7. Conclusions

A significance of a sense of co-existence and connectedness among remote participants has increased in computer-mediated communication. Therefore a design approach to create a co-existing space at which remote participants are bodily present is necessary. However, previous communication systems have not been developed in the view of creating such a co-existing situation. Therefore, we devise two representation methods; representing a self reflection in a shared video space, and projecting reflection of a remote partner onto the local tabletop. Then based on these approaches we construct a "Lazy Susan" video projection communication system composed of a shared disk system and a video projection system. The results of experiments suggest that our system can enhance an interconnectedness between self and a remote place, and between a remote partner and a local place. We introduce the concept of "duality" of embodied interaction - conveying intentions by expressing explicitly bodily action, and interconnecting self and others implicitly. We believe our system can support this "duality" of embodied interaction and propose an approach based on "duality" of embodied interaction for creating a virtual co-existing space. The direction of our future work will be that we construct and evaluate the design framework by referring to knowledge on extension of body image when using a tool in brain science [17].

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