Robotic Table and Bench Enhance Mirror Type Social Telepresence

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ABSTRACT
Current videoconferencing systems can be roughly divided into two types: a window-type where a computer display works as a window to reveal a remote partner, and a mirror-type whose display shows the mirrored reflections of both participants. While mirror-type systems enhance the feeling of togetherness by merging the two sites into one display, an inherent problem remains. Despite the mirror metaphor, the partner has no physical body in front of the display. To cope with this incongruence, we placed a partition in front of the display. Across that partition we further also placed a robotic table and a robotic bench that move based on the partner's behavior. The experiments indicated that the table and bench successfully facilitated feeling as if there were the partner's physical body was present at the opposite side of the partition.

Author Keywords
Remote haptic sensation; social telepresence; mirror-type videoconferencing; video-mediated communication; social interaction

ACM Classification Keywords
H.5.1 Information interfaces and presentation (e.g., HCI): Multimedia Information Systems -
Artificial, augmented, and virtual realities

INTRODUCTION

Mirror-type Videoconferencing
There are two types of videoconferencing schemes: window and mirror. In a window-type videoconferencing system, the display device, which stands in front of a user, functions a window and simulates a situation in which the user sees a remote scene through a window. On the other hand, in a mirror-type videoconferencing system, the display functions as a mirror and simulates a situation in which the user sees the local scene reflected in a mirror. Note however that the mirror-type videoconferencing system is different from an ordinary mirror; the system not only shows the local user in front of the display but also the remote user by superimposing her onto a shared virtual space.

Almost all of the widely used videoconferencing systems are window-type systems, e.g., FaceTime, Skype, Google Hangouts, and Polycom. Conversely, no mirror-type systems are widely used, even though they have been constantly studied [8,14,16,19,29].

Physical Inconsistency Problem
Unlike window-type systems, which show only the conversation partner's image, mirror-type systems also show the user's self-image (Figure 1). Therefore, there is an apparent problem in mirror-type videoconferencing: an inconsistency between the mirrored and physical worlds. The partner exists only in the mirrored world, but the user exists in both worlds.

Prior work on mirror-type videoconferencing suggested various applications including a shared public space [16], welcome reception [29], a dinner party [2], children's playground [8,14], a dancing studio [18], and therapeutic counseling [20]. In these applications the feeling of togetherness seems important. Although some of those previous studies have shown that mirror-type video conferencing enhances the feeling of togetherness [8, 14,19], such a feeling can only be obtained when the local

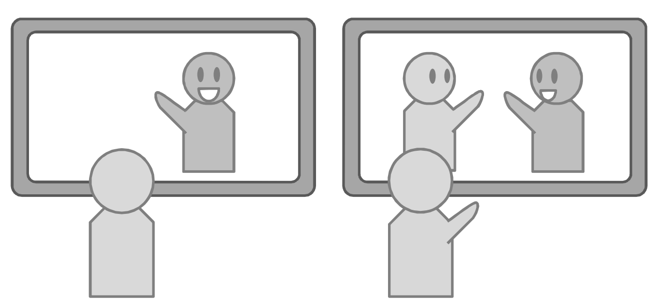

Figure 1. Two types of videoconferencing

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user is facing the display. The feeling of togetherness can easily be diminished when his/her attention moves away from the display and perceives the physical absence of the remote partner.

This physical inconsistency problem might disappear if the system could somehow reproduce the partner's physical body in front of the display. Even though this could be possible if we install a humanoid robot or a hologram, it unnecessarily complicates the system, and the mirror display would become useless after all because the local user can directly interact with the robot/3D image. Thus, the inconsistency problem of mirror-type videoconferencing systems would only make sense if it is resolved without reproducing the partner's physical body. In our study, we do this by blocking the local user's view with a partition and placing robotic apparatuses across it so that he/she can feel that a remote partner is present locally and manipulating those apparatuses.

Research Questions

The goal of our research is two-fold. We first examined whether mitigating the physical inconsistency by blocking the local user's view with a partition is effective for enhancing social telepresence (Experiment 1). Our second goal is to further enhance social telepresence by strengthening the connection between the mirrored and physical worlds. More specifically, we linked the movement of an apparatus with the remote partner's movement (i.e., something near the local user actually moves when the remote partner touches it on the screen). We ran two experiments to test the link's effects: visually showing the linkage between the two movements (Experiment 2) and allowing a user to tactually sense the movement (Experiment 3).

This paper focuses on the following three research questions:

Question 1: Effects of mitigating physical inconsistency

In an ordinary mirror-type system, a user is always aware of her partner's physical absence. If we block the user from seeing the blank space in front of the display, it might prevent her from perceiving the physical absence of her remote partner. As a result, she may feel that her partner is actually present in front of the display. In Experiment 1, we examined whether blocking the user from seeing a blank physical space with a partition increased her feeling of being with her remote partner. Note that all the participants of the experiment knew that their partners were remote and physically absent. Even though they could not see the blank space, they knew it was blank.

Question 2: Effects of visually connecting the two worlds

To further increase the feeling of togetherness, we linked the movement of a local apparatus with the remote partner's movement. When the partner moved an apparatus in the remote site, the corresponding apparatus in the local site moved in accordance with the partner's movement. The user can see the apparatus moving in the physical world. In Experiment 2, we developed a round circulating table (i.e., a lazy susan) as such an apparatus (Figure 3) and examined whether visually strengthening the connection between the physical and mirrored worlds further enhances social telepresence.

Question 3: Effects of tactually connecting the two worlds

While Question 2 addresses the effects of visually connecting the physical and mirrored worlds, Question 3 deals with the effects of tactually connecting those two worlds. When the remote partner moved an apparatus at the remote site, the corresponding apparatus in the local site moved in accordance with the partner's movement, and the user could feel the haptic sensation caused by the movement. Although haptic sensation for remote communication has been studied for a long time [13], its applications are rare to mirror-type videoconferencing. In our study, we developed a bench that vibrates when the remote partner sits down or stands up (Figure 6). The user must be able to link her remote partner's action (in the display) with the bench's vibration (in the physical world). In Experiment 3, we examined whether tactually strengthening the connection between the physical and mirrored worlds further enhances social telepresence.

RELATED WORK

Mirror-type Videoconferencing

Unlike window-type systems, mirror-type systems show a synthesized scene of local and remote sites, typically showing both local and remote participants in the display. Previous studies have proposed various methods for synthesizing both sites. A typical method cuts an image of the local participants and pastes it on the remote scene (and vice versa) with chroma key processing [19] or depth image processing [8]. In such methods, it is necessary to choose either a remote or local background as the shared background for the synthesized scene.

Other systems that avoid choosing the background use a prepared image [14], an empty background [16], or a virtual water surface [29] as a shared background. Other examples, which resemble mirror-type systems, project remote and local participants' black shadows [18] or shadow-like images [38] on floors, walls, and tables. Even though various systems have been developed and tested, the physical inconsistency problem has been basically ignored.

Social Telepresence

Various methods have strengthened the social telepresence, since its insufficiency is regarded as a bottleneck for replacing face-to-face meetings with teleconferences. A live video connection is a basic method for producing the feeling of a face-to-face meeting [9,15]. Such a feeling is strengthened if the camera and display setup allow eye contact to be established [4,24]. A past study also found that social telepresence is strengthened when the image of a conversation partner is stereoscopic or life-size [28].

Non-partitioned Partitioned

Figure 2. Mirror type system (left) vs. mirror type system with a partition (right)

Recent studies have reported that a remote camera that moves based on the position of a user's eyes [12] enhances social telepresence [21]. A conversation partner's upper body image also produces a stronger social telepresence than an image that only includes the partner's head [25]. Furthermore, a display's physical movement showing the partner's upper body image enhances social telepresence [22]. All of these methods were tested in window-type systems. Unfortunately, methods for enhancing the social telepresence of mirror-type systems have not been extensively studied.

Lazy Susan for Videoconferencing

Some previous studies developed a lazy susan table device for sharing objects between geographically distant sites [2,37]. In these studies, an identical set of table devices was installed at each site, and the table's rotation angles were adjusted to be equal to each other. The synchronous rotation of the tables produced a feeling of sharing the same table as well as the objects placed on it.

Our table device basically has the same mechanism as the tables of these studies. However, the method that synthesizes the local and remote tables is different. In previous studies, the remote table's image was either overlaid on top of the local table or shown in a window-type system's display. Our table device is the first to use a mirror-type videoconferencing system to synthesize local and remote table images (Figure 4).

Remote Haptic Sensation

Remote haptic sensations have been studied for a long time [13]. Since it is almost impossible to create a single all-purpose device that can imitate many kinds of haptic sensations, numerous studies have focused on developing a device that is tailored to transmit a specific kind of haptic sensation [5,10,11,26,35]. Since haptic sensations cannot send explicit messages by language, many studies concentrate on analyzing how they can be used as an additional nonverbal communication channel to deliver emotional states or simple reactions [1,6,7,27,33,34].

Compared to the above research topics, few have studied the effects of haptic sensations on social telepresence. Among such scant studies, one tested the effects of various haptic sensations on social telepresence without identifying any [31]. Another reported that haptic sensations increased social telepresence [3], although this result is somewhat obvious since no other communication channel (e.g., audio or video) was provided to the participants except a haptic

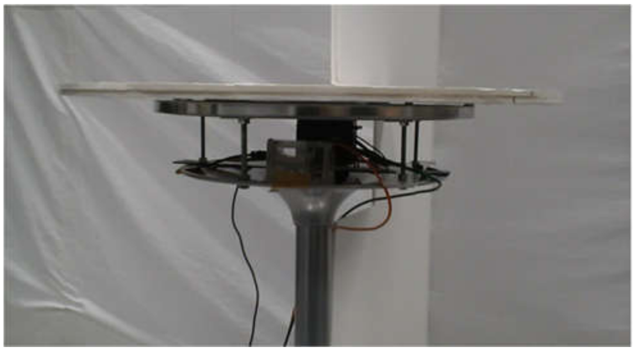

Figure 3. Round circulating table device

sensation. More recently, researchers reported that haptic sensations improved audio-mediated communication [36] and video-mediated communication [23,32]. Another study combined haptic sensations with mirror-type videoconferencing [20]. In this work, the authors address the physical inconsistency: a user can virtually touch the partner in the mirrored world, but it is impossible to do it physically. Although the authors developed a novel haptic device for mitigating the inconsistency, most of their findings are about system configuration or informal observation. Overall, it remains unclear how the combination of haptic sensations and mirror-type videoconferencing affects social telepresence.

METHODS

Our Mirror-Type System

Figure 2 (two snapshots on the left, one from behind the user and another from the front) shows our mirror-type system. In it, the left half of the display shows the user's image, and the right half shows the remote partner's image. The image on the display suggests that they are sitting in the same booth. In reality, the user is seated on the left side of the booth, and nobody is on the right side.

Two cameras were mounted above the display. The left camera captured the user, but the right one was a decoy that captured nothing. From our preliminary experiments, users seemed to assume that the decoy camera was capturing the partner, the same as the left camera.

Instead of embedding a speaker in the display, we placed a speaker on the right side of the booth so that the participant could hear the partner's voice from the place where his partner was supposed to be sitting.

Procedure

Before the experiments began, all participants were informed that since our system was a teleconferencing system, their partner in the display was at a remote site. They were also allowed to glance at the blank space on the right side of the booth.

One of the experimenters acted as the remote partner in the experiments. The participants talked with the experimenter

Figure 4. Transporting objects across a partition

for a short time. To attract the attention of participants toward the display, the experimenter played the role of a presenter and gave the participants the same presentation, in which the presenter showed objects and asked the participants several questions about the objects. The same experimenter played this role in all the experiments. He was in another room of the same building. No participant knew him.

Experiment 1

In the first experiment, we investigated whether preventing the participants from seeing the blank physical space of their remote partner (i.e., the right side of the booth) influenced social telepresence. As shown in Figure 2, the booth was partitioned into two parts, and participants were seated on its left side. The right side of the booth was empty but hidden from the participants. The left half of the figure shows the first condition: a non-partitioned system in which the remote partner's physical absence was visible to the participants. The right half shows the second condition: a partitioned system in which the remote partner's physical absence was hidden. In the experiment, the two conditions (non-partitioned and partitioned systems) were compared in terms of the participants' perceptions of being with their remote partners.

As a method to synthesize the local and remote scenes, we hung two identical shirts, one on the wall behind the participant and another on the wall behind the experimenter.

Their positions were adjusted so that their images were concatenated on the display. Similarly, two identical benches were located at both sites. We carefully adjusted the position of the two benches so that their images were precisely concatenated on the display. Note that the factor of this experiment was only the presence or absence of the partition. The experiment had a within-subject design where each participant experienced both conditions whose order was randomized.

Experiment 2

In Experiment 2, we investigated whether visually connecting the physical and mirrored worlds increases social telepresence. We developed a round table device as a method that visually connects the two worlds (Figure 3). Like the shirt and the bench in Experiment 1, we installed an identical set of tables at each site and precisely concatenated their images. In addition, a servo motor, which was embedded in the table's center pole to sense and adjust the table's rotation angle, allowed the two tables to rotate synchronously; when the experimenter rotated the table in the remote site, the table in the local site also rotated identically. By combining the concatenated images and the synchronized rotation, the table image on the display resembled a mirror image of the table at the local site. By adding two identical objects (e.g., the stuffed animal in Figure 4) in the same position on each table and rotating, both users appeared to be transporting the object across the partition (Figure 4).

In this experiment we compared three conditions (Figure 5). In the manual rotation condition, the experimenter manually turned the table. We initially placed the stuffed animal behind the partition, hiding it from the participant who could only see it through the display. As the experimenter rotated the table, the stuffed animal appeared from behind the partition. In the static condition, since the stuffed animal was already placed at the participant's side beforehand, the experimenter did not rotate the table. In the auto rotation condition, the stuffed animal was again initially placed behind the partition. Instead of the experimenter manually turning the table, it rotated automatically as the experimenter pressed a remote controller. We added the auto rotation condition to determine whether a difference between the static and manual rotation conditions emerged from the partner's manual operation or the table's rotation itself. We focused on what caused the rotation, so the table's motion was almost equal in the automatic and manual rotations. The experiment was a within-subject design where each participant experienced all three conditions whose order was randomized.

Static

Auto rotation

Manual rotation

Figure 5. Three conditions in Experiment 2

Experiment 3

In Experiment 3, we investigated whether tactually connecting the physical and mirrored worlds increased social telepresence by developing a robotic bench (Figure 6). We focused on two casual behaviors: people sitting down and getting up from a chair. When someone sits down or gets up from a bench, the person who is already sitting on it feels a vibration caused by the action. The vibration increases when the bench's four legs are not completely equal in length or the floor is not perfectly flat. In this experiment, we used the partitioned booth of Experiment 1

Electromagnetic actuators

Release

Pull

Figure 6. Robotic bench

and examined the effects of combining the partition with a bench that transmits vibrations across a distance.

As in Experiments 1 and 2, we installed an identical set of benches at each site and precisely concatenated the two benches' images. In addition, we attached electromagnetic actuators to a leg on the right side of the bench in the participant's room (Figure 6). When the experimenter sat down or got up from the bench at the remote site, the actuators pulled or released the leg to synchronize the movements of the two benches. The experimenter's sitting and standing actions were sensed by pressure sensors that were embedded under the bench's bearing surface. While the participant was sitting on the left side of the bench during the experiment, the experimenter sat on the right side of the experimenter's bench and got up after a short conversation.

As shown in Figure 6 (two snapshots at the bottom), since the actuator movements were very small, they were difficult to recognize visually. Using this robotic bench, we investigated whether haptic sensations without any visual stimulus reproduced a partner's physical presence.

We examined the effects of the robotic bench in two settings: a laboratory and an exhibition. In the laboratory setting, we compared robotic and non-robotic benches. This laboratory experiment had a within-subject design where each participant experienced both conditions whose order

Outside

Inside

Figure 7. Exhibition site

was randomized. In the exhibition setting, we observed visitors who were experiencing our robotic bench (Figure 7). As in Experiments 1 and 2, we informed both the participants and visitors that they were participating in a teleconferencing system and that they were allowed to glance at the blank space before experiencing the system. The exhibition site was crowded, noisy, and less organized than the laboratory setting. In such a distracting environment, some visitors might overlook the bench's subtle movement. We wanted to examine whether similar effects could be achieved in such a distracting environment. In the exhibition setting, after the visitors experienced the system and answered questionnaires about their feelings of being with their remote partners, we asked whether they noticed the bench movement. As we expected, about half did not. To understand how their perception of the bench movement contributed to their feelings of togetherness, we compared the questionnaire results of the visitors who noticed the bench movement with those who did not.

Participants

In the three laboratory experiments, all participants were undergraduate students from various universities, whose ages ranged from 18 to 24. They were recruited via a part-time job search site, and paid about 20 dollars. Nobody was the experimenters' acquaintance. Nobody participated in more than one experiment. Five males and two females participated in Experiment 1. Nine males and nine females participated in Experiment 2. Seven males and three females participated in the Experiment 3's laboratory setting where four males and one female noticed the bench movement.

In the Experiment 3' exhibition setting, all visitors were families who visited the exhibition site. They voluntarily participated without being paid. Nobody was the experimenters' acquaintance. We had no screening protocol and accepted everyone who wanted to experience our system. Twenty-eight males and twenty-six females participated. Five males and six females of them were children. 13 of 23 male adults, 4 of 5 male children, 6 of 20 female adults, and 3 of 6 female children noticed the bench movement (cognizant visitors).

RESULTS

Measurements

As noted earlier, we informed the participants that they were participating in a teleconferencing system and that they were also allowed to glance at the blank space beyond the partition before talking with the experimenter. After talking with the experimenter, the participants answered questionnaires about the degree of social telepresence: the feeling of being with their partner in the same room.

The experiment results are shown in Figures 8, 9, 10, and 11 in which each box represents the mean value of the responses to the degree of social telepresence. Each bar represents the standard error of the mean value. In the laboratory for Experiments 1, 2, and 3, participants responded to the following statement about the degree of social telepresence: "I felt like I was with my conversation partner in the same room." The participants rated it on a 7-point Likert scale where 1 = strongly disagree, 4 = neutral, and 7 = strongly agree.

In the exhibition of Experiment 3, we slightly changed the statement about the degree of social telepresence: "I strongly felt that I was with my conversation partner in the same room." We used a stricter expression because we were concerned that high ratings might cause ceiling effects. The visitors rated it by percentage where 0 = strongly disagree, 50 = neutral, and 100 = strongly agree. Due to the limited space and the crowd of the exhibition site, it was impossible to ask each visitor to fill out a questionnaire. Thus, an experimenter verbally asked individual visitors and recorded their scores. We used the percentage because we were concerned that some participants may get confused when we verbally explain the 7-point Likert scale. The use of percentage worked well in this exhibition experiment.

Results of Experiment 1

Figure 8 shows the Experiment 1 results and compares the participants' reactions to the non-partitioned and partitioned booths by a two-tailed paired t-test. Their feelings of being with their remote partners were significantly stronger when the physical inconsistency problem was mitigated with a partition ($t(6)=2.976, p<.05$).

Results of Experiment 2

Figure 9 shows the Experiment 2 results and compares the participants' reactions to the static, automatically rotatable, and manually rotatable tables by a repeated-measure ANOVA followed by Bonferroni's test. We found a significant difference in the participant feelings of being together ($F(2,34)=9.705, p<.001$). Multiple comparisons showed that this feeling was significantly stronger in the manual rotation condition than the auto rotation ($p<.05$) and static ($p<.05$) conditions. The comparisons also showed that this feeling was significantly stronger in the auto rotation condition than the static condition ($p<.05$).

Results of Experiment 3

Figure 10 shows the Experiment 3 results in the laboratory setting and compares the participants' reactions to the non-robotic and robotic benches by a two-tailed paired t-test. The feeling of being together was significantly stronger when the bench was robotic ($t(9)=3.284, p<.01$). Although half of the participants did not seem to recognize the bench movement, nobody rated the non-robotic bench higher.

Figure 11 shows the Experiment 3 results in the exhibition setting and compares the cognizant and incognizant visitor reactions to the robotic bench with 26 and 28 cognizant and incognizant visitors, respectively. As the laboratory setting's result suggested, the visitors who were cognizant of the bench movement felt a stronger sense of togetherness than the incognizant visitors ($t(52)=2.501, p<.05$).

DISCUSSION

Findings

The results of the first experiment, which examined the effects of mitigating the physical inconsistency problem in a mirror-type system, indicated that blocking the local user (with a partition) from seeing the blank physical space of the remote partner successfully improved the feeling of togetherness. Thus, we used "mirror-type system equipped with a partition" as a baseline in the following experiments. Experiments 2 and 3 tested our technological effort to further enhance social telepresence, i.e., the circulating table and the robotic bench. In these experiments, even though the participants were informed that their partners were not actually seated on the other side of the partition, the visual stimulus provided by the table and the haptic stimulus provided by the bench effectively reproduced their partner's physical presence.

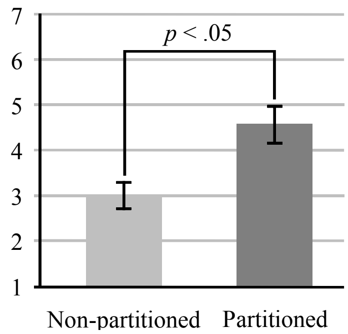

Figure 8. Feeling of being together in Experiment 1

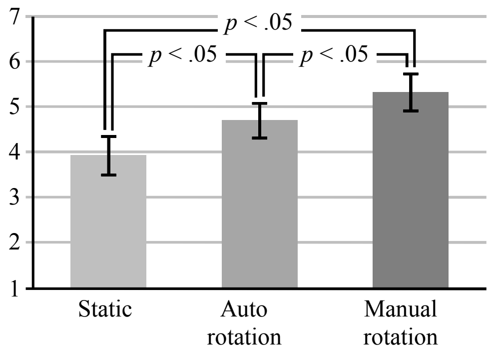

Figure 9. Feeling of being together in Experiment 2

The results show that each device (i.e., the partition, the circulating table, and the robotic bench) increased the participants' feeling of being with their remote partners at almost the same degree (between 20 and 25%). The automatically rotatable table also significantly improved the social telepresence, but its effect was almost half the amount of the manual rotation table. This means that the synchronized movement of the local and remote apparatus already effectively enhances social telepresence, but the effect increases if the movement is produced by the remote partner's body movement.

Reality or Imagination

The first experiment showed that simply placing a partition that hides the blank physical space effectively enhances social telepresence. Perhaps the most complex and expensive way to resolve the physical inconsistency problem is to develop a realistic humanoid robot that can precisely copy the motion and appearance of a remote partner [30]. The ultimate goal of this solution is to make the experience of being with a partner-like robot completely identical as the experience of being with the actual partner. In contrast to this reality-based approach, our approach is based on the user's imagination. The hidden space seemed to exploit their imagination that the partner was sitting behind the partition.

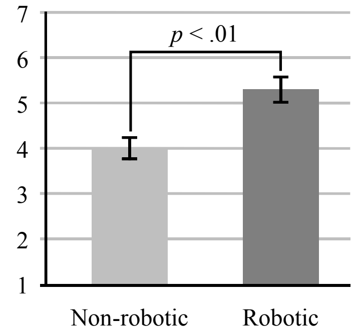

Figure 10. Feeling of being together in Experiment 3 (laboratory)

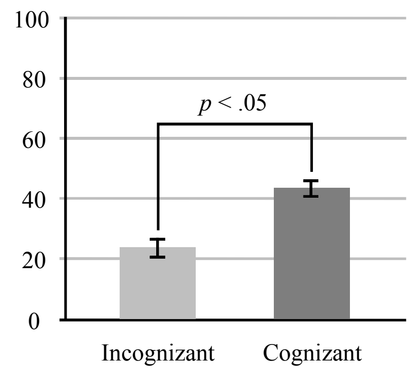

Figure 11. Feeling of being together in Experiment 3 (exhibition)

Since it is almost impossible to completely equalize the experiences of being with the robot and with the partner, we believe that a promising compromise can be found somewhere between the reality- and imagination-based approaches. An example of such an approach is a combination of mirror-type videoconferencing and a frosted glass partition that blurs the visual imperfections of a partner-like robot. In this approach, the user sees both the partner's image on the display and the robot across the semi-see-through partition. The more imperfect the robot, the more opaque the glass needs to be.

Unintentional Haptic Interaction

The haptic interaction enabled by the robotic bench is unique from the haptic interaction enabled by other systems. Prior studies on remote haptic interactions focused on interactions that had an intrinsic purpose/meaning, e.g., handshaking [23], kissing [32], touching an arm of a remote partner [36], and sharing the movement of a rocking chair [17]. However, the bench vibrations were just subsidiary movements caused by sitting down and standing up behaviors, not the purpose of the interaction. Our study successfully showed that producing unintentional haptic interaction also effectively enhances social telepresence.

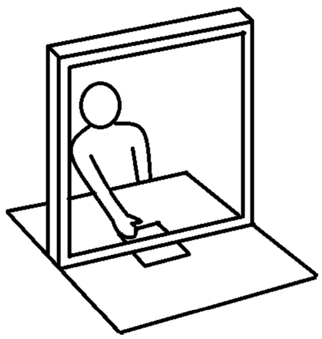

Figure 12. Document transfer system

Mutual Force Feedback
This study separately clarified the effects of visual and haptic stimuli. The bench's vibrations were too small to be visible, and the participants did not touch the table. Actually, the table can also produce haptic stimulus, since its control mechanism is bilateral. If a local user and her remote partner simultaneously rotate the table, they can feel each other's force. Future work will analyze the effects of such mutual force feedback.

Multi-sensory Integration
The third experiment showed that multi-sensory integration between haptic and visual stimuli may be a key to the reproduction of human physical presence. Although the robotic bench's vibrations were subtle and primitive, the vibrations could reproduce the remote partner's presence probably due to the accompanied video that showed the partner's sitting down and standing up behaviors. Note that the vibrations were not visible, so there was no visual stimulus that showed the vibrations directly. Interestingly, multi-sensory integration occurred by combining haptic and visual sensation generated from different things – haptic sensation generated from the bench and visual sensation generated from the partner's image. It is future work to analyze the effects of the bench vibrations that are not accompanied with any video.

Extension to More Users
We tested a simple mirror-type system that connected just two sites, each of which included only a single user. However, that simple configuration can be extended to more complex configurations where more sites are connected and more users participate at each site.

Increasing the number of users at each site requires a small modification that merely lengthens the display and the bench so that the left or right half of the display can show images of more than one user who can sit on the bench at the same time. Increasing the number of sites requires the same modification and adding partitions for dividing the space in front of the display into the number of sites. Unfortunately, a robotic table can connect only two adjacent booths.

Application to Window Type Videoconferencing
Our findings might also be applicable to window type systems. A robotic desk that moves when the partner puts a cup on the desk or rests her elbow on the desk is an example of a robotic device for transmitting vibrations, which are supposed to be caused by the remote partner shown on the display of a window type system. An example of a robotic device for transporting objects between a display's back and front sides is a document transfer system (Figure 12) in which the paper being grabbed by the partner and on the desk on the user's side synchronously moves backward and forward as if it was a single piece of paper going through the slit just under the display.

CONCLUSION
This study presented an imagination-based approach toward social telepresence. The mirror-type videoconferencing display shows the mirrored image of a remote conversation partner who is imagined to be in front of the display. We clarified three methods for facilitating such an act of imagination: 1) blocking a user from seeing a blank physical space in front of his partner's image on the display, 2) showing a user a local apparatus that moves in synchronization with the remote apparatus as if the two apparatuses constitute a single apparatus, and 3) showing a user the apparatus's movement that reflects his partner's body movement.

In our mirror-type system, we precisely put a partition at the center of an apparatus. A user can directly see half of it at the local site but not the other half on the partition's opposite side. At the same time the user can see the mirrored image of the entire apparatus on the display where the images of the half captured at the local site and the other half captured at the remote site were concatenated. These contrivances made users feel that a remote partner existed at the opposite side of the partition and was touching the apparatus when their partner was actually touching an identical apparatus located at the remote site.

We developed and tested two kinds of apparatuses: a circulating table and a robotic bench. The circulating table rotated as if a remote partner were rotating it. Actually, the remote table sensed the partner's rotating action, and the local table rotated based on the received signal. The robotic bench vibrated as if a remote partner were sitting or standing up from it. Actually, the remote bench sensed the partner's sitting and standing actions, and the local bench vibrated based on the received signals. Applying a similar technique to window type videoconferencing is future work.

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