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You Are My Robot: The Impact of Synchronized Motion Cues on Receivers

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Abstract

Since a telepresence robot is designed to facilitate interpersonal communication between a remote sender and a receiver at distance, the presence of a remote sender as perceived by a receiver is an important aspect of the interaction. In order to determine effective ways to increase the presence, we execute an experiment comparing a telepresence robot without motion cues, a telepresence robot with synchronized motion cues which provides synchronized motion with remote sender's motion, and a robot with unsynchronized motion cues which provides independent motion and unsynchronized with remote sender's motion (N=48). In this study, the participants engage in conversations with a remote sender through a telepresence robot. The results show that participants have a greater sense of sender presence when interacting with a telepresence robot with synchronized motion cues than when interacting with a robot with unsynchronized motion cue and a robot without motion cues. On the other hand, participants have a lesser sense of robot presence for a telepresence robot with synchronized movement compared to a robot with unsynchronized motion cues and a robot without motion cues. When interacting with a telepresence robot having either synchronized or unsynchronized motion cues, participants perceive greater sense of sender presence and robot presence than with a robot without any motion cues.

Keywords*: Co-presence, Embodied Telepresence, Social Presence, Synchronized Motion Cues, Telepresence, Telepresence Robots*

1. Introduction

Telepresence systems share the goal of realizing Minsky's vision of telepresence, the feeling of being there [1]. Since the creation of this definition, the concept of telepresence has become an important component in our understanding of how people experience mediated environments, such as television, virtual reality, and other mediated environments [2]. In one sense, the developmental progress in this field is close to Minsky's prediction; however, they are limited to audio and facial expressions [3]. Even though emotional content can be perceived from previous channels, embodied expressive communication across distance is not supported by the current technology. These are reasons that support the significance of embodied telepresence on communication. Therefore, it might be worthy to look at physical cues that can be tracked and transmitted by new media and technologies and may serve for enriching interpersonal telecommunication.

The development of embodied telepresence systems has been significantly furthered by advances in telerobotics. This system enables the remote senders of the system to embody themselves within the form of a robot in a remote environment, so that they can be immersed in the context and be felt by their interaction parties as being similarly present

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[4]. However, by combining the display of a remote sender with an articulating base, the perceived sense of the physical embodiment of the remote sender risks confusion of the receiver, which is known as proxy-in-proxy problem [5]. The remote sender has two representations in the remote place: that of the audiovisual feed, and that of the physical platform. These two distinct channels are likely to exhibit inconsistent non-verbal cues, even if this inconsistency is merely a lack of complementary actions between them. In face-to-face interactions, inconsistencies in verbal and non-verbal cues are often interpreted as a sign of a deceit [6] and mistrust, and cause increased cognitive load. Thus, we were interested how synchronization between remote sender's motions viewed on the screen and robot's motions shown in the physical space affect presence of a remote sender.

2. Related Works

2.1. The Embodied Representation of a Remote Sender

Earlier telepresence robot designs employed the metaphor of the avatar, such as the on-screen avatars in BodyChat [7] or physical avatars like Geminoid [8] as the embodied representation of a remote sender. They employed the embodied representations in one-to-one relationship between a remote sender and a receiver with human body like proportions. Recently, telepresence robot is designed with a near life size display of a remote sender's face and upper body. For example, Sun Micro-systems' Porta-Person [9] features a flat screen computer monitor system on a robotic head/neck mechanism that sits on a desk or chair. Others, like Willow Garage's Texai [10] host a live video on a large flat screen mounted on a remotely steerable base. Although each telepresence robot design which is embodied representation of a remote sender has its own unique characteristics and issues, people bring common shared expectations about how to interpret embodied social cues to each. Casting the video telepresence feed into an embodied form has significant ramifications for how a receiver perceives the telepresence robot and, in turn, the remote sender's presence. In addition, a lack of motion in the embodied platform with on-screen actions of a remote sender provides confusion to a receiver [5]. Thus, appropriate motion cues of a telepresence robot should be designed for enhancing presence of a remote sender in telecommunication.

2.2. Consistency in Robot's and Remote Sender's Motions

As we lose a lot of the information that makes communication with other people in mediated communication, researchers have been tried to supplement the message that we receive with non-verbal cues and alternate information that is provided by the medium. Unlike other previous media, a telepresence robot has its own physical embodiment which makes it able to convey non-verbal cues leading enrichment of telecommunication. Several researches demonstrated that people prefer technological counterparts, an agent or a robot, when each non-verbal cues made by their counterparts follow suit. For example, Isbister and Nass [11] demonstrated that people respond positively towards agents that display consistency in verbal and non-verbal cues compared to those with mismatched cues. In addition, people prefer agents use consistent gaze and gesture to provide contextual grounding for the agent and user's shared experience to those that do not [12]. Although several studies showed the effect of consistency in cues provided by agents in computer-mediated environments, as one cue supporting another, limited work has been done on consistency in cues provided by an agent and a remote sender in robot-mediated environments.

Since a telepresence robot is a medium intended to be used in interpersonal communication, conveying the presence of a remote sender is an important issue. In addition, the motion cues provided by a remote sender and that provided by a robot need

to be matched. Groom *et al.* [13] demonstrated that people expect robot's bodies not only to serve as decorations suggesting identity, but also as functional units intended to interact with the environment and to communicate information. In robot-mediated environment, the remote sender's on-screen actions and the robot's physical actions provide these cues. Such movements could represent either with synchronized motion cues with remote sender's motions or unsynchronized motion cues, which are independently made by a robot itself. We therefore chose to investigate individual aspects of gestural expressions, and how they contribute to positive interactions by comparing three conditions. In a telepresence robot without motion cues, a telepresence robot does not show any movement. In a telepresence robot with synchronized motion cues, a telepresence robot shows the same physical movement of remote sender's on-screen movement while in a telepresence robot with unsynchronized motion cues, a telepresence robot shows the different physical movement from that of a remote sender. Based on the previous studies [14], we assumed that consistency in a robot's and a remote sender's motion could enhance the presence of a remote sender. As Sirkin and Ju [5] have suggested that the physical embodiment of a telepresence robot itself can cause receiver confusion when appropriate nonverbal cues are not accompanied by a robot, we also anticipated that a telepresence robot that could not provide any motion cues would be evaluated as conveying a more reduced sense of the remote sender presence compared to a telepresence robot with motion cues.

H1-1. Synchrony between a remote sender and a robot movement increases co-presence of a remote sender compared to a robot with unsynchronized motion cues and a robot without motion cues.

H1-2. A telepresence robot without motion cues decreases co-presence of a remote sender compared to a robot with motion cues either with synchronized motion cues or unsynchronized motion cues.

H2-1. Synchrony between a remote sender and a robot movement increases social presence of a remote sender compared to a robot with unsynchronized motion cues and a robot without motion cues.

H2-2. A telepresence robot without motion cues decreases social presence of a remote sender compared to a robot with motion cues either with synchronized motion cues or unsynchronized motion cues.

According to Groom *et al.*'s study [13], people perceive a robot as having identity, and intended to interact with the environment and communicate by itself. Thus, when a robot shows inconsistent with remote sender's motion, it would make people perceive a robot as having intention to make an independent motion. According to a study by Sohn *et al.* [15], a robot with intention can be perceived as more sociable and intelligent. Thus, we predicted that people would perceive more co-presence and social presence toward a robot when a robot shows inconsistent motion with a remote sender. In addition, the identity of a robot and perception toward a robot is mostly determined by both appearance and behaviors of a robot. As robot's behavior is one of the key factors to build perceived presence of a robot, we also anticipated that a telepresence robot that could not provide any motion cues would be evaluated as conveying a more reduced sense of the robot presence compared to a telepresence robot with motion cues.

H3-1. Asynchrony between a remote sender and a robot movement increases co-presence of a robot compared to a robot with synchronized motion cues and a robot without motion cues.

H3-2. A telepresence robot without motion cues decreases co-presence of a robot compared to a robot with motion cues either with synchronized motion cues or unsynchronized motion cues.

H4-1. Asynchrony between a remote sender and a robot movement increases social presence of a robot compared to a robot with synchronized motion cues and a robot without motion cues.

H4-2. A telepresence robot without motion cues decreases social presence of a robot compared to a robot with motion cues either with synchronized motion cues or unsynchronized motion cues.

3. Study Design

In this study, we employed a within-participants experiment design, comparing a telepresence robot without motion cues, a telepresence robot with synchronized motion cues, and a telepresence robot with unsynchronized motion cues.

3.1. Participants

We recruited forty-eight university students having high technology acceptance as participants. Gender was balanced across conditions (24 male and 24 female). Participants were given a $1 gift certificate.

3.2. Materials

The robot used in the experiment was a home-service robot FURo-i Home [16]. This robot enables telecommunication via video calling and is composed of an iPad tablet computer with a pyramid base. We utilized three robot designs, *i.e.*, without motion cues, with synchronized, or unsynchronized motion cues with a remote sender. In the case of the robot with no physical motion cues, it did not exhibit any physical movement, and remote sender's movement was viewed on the screen only. In the case of the robot with synchronized motion cues, the remote sender moved forward to blow a kiss to the receiver on screen, and the robot performed a forward movement that was synchronized with the remote sender's forward action towards the receiver. On the other hand, in the case of the robot with unsynchronized motion cues, the remote sender waved the hand to the receiver on screen, and the robot performed not a waved movement but a forward movement, which was unsynchronized with remote sender's waving action. The other elements were identical for all examined conditions.

3.3. Procedure

The participants were welcomed into the lab by a researcher and experienced all three interaction conditions described above in a random order. The interaction between a remote sender and a participant was of 5 minutes duration, and all of the participants conversed with the same remote sender using a provided conversation script. After the participants had completed each stage of the experiment, a questionnaire for each stimulus was administered.

3.4. Measures

3.4.1. Presence of a Remote Sender

Nowak and Biocca [17] introduced a scale that can be used to evaluate presence. As explained above, presence comprises several dimensions, including co-presence and social presence. Therefore, in the post-experimental survey, the participants evaluated their experience based on 23 different Likert-type items combined into three scales: self-reported co-presence, co-presence by others, and social presence.

Co-presence Measures

Based on the dual-ecology of the setup, two separate co-presence scales were measured: self-reported co-presence, and co-presence perceived by others. Self-reported

co-presence refers to the participant's self-report of their own involvement in the interaction. The self-reported co-presence was an index of six items (*Cronbach's alpha* = 0.87), which are also used to access co-presence perceived by others, but revised to ask the participants to self-report their level of involvement in the interaction. On the other hand, the co-presence perceived by others refers to the participants' perception toward the remote sender's involvement in the interaction. The co-presence perceived by others was an index of 11 items (*Cronbach's alpha* = 0.94). All items were drawn from the study by Nowak and Biocca [17].

Social Presence Measures

The social presence evaluation, which accesses the perceived ability of the medium to connect people, was composed of six items (*Cronbach's alpha* = 0.89). All items were drawn from the study by Nowak and Biocca [17].

3.4.2. Presence of a Telepresence Robot

The presence of the robot was assessed using the above scales for co-presence and social presence. All items consisted of 12 different questions based on a 7-point Likert scale.

Co-presence Measures

The co-presence scale included the same six items (*Cronbach's alpha* = 0.81) used to assess the self-reported co-presence of the remote sender, but revised such that they asked the participants to evaluate their own level of involvement when interacting with the robot.

Social Presence Measures

The scale for social presence included the same six items (*Cronbach's alpha* = 0.86) used to assess the social presence of the remote sender, but revised such that the participants were asked about their feelings toward the robot. All items were drawn from the study by Nowak and Biocca [17].

4. Results

All statistical analyses were conducted using a repeatedly measured analysis of variance (ANOVA), with the synchronized motion cues as an independent variable.

4.1. Presence of a Remote Sender

4.1.1. Co-presence of a Remote Sender

As predicted by H1-1, participants felt that they were more involved in the interaction when communicating with a remote sender through a telepresence robot with synchronized motion cues (M=4.76, SD=0.58) than with one with unsynchronized motion cues (M=4.04, SD=0.46) and one without motion cues (M=2.81, SD=0.60, $F(2,94)=146.089$, $p<0.0005$). In addition, participants perceive less sense of self-reported co-presence of a remote sender when interacting with a telepresence robot without motion cues (M=2.81, SD=0.60) than either with synchronized (M=4.76, SD=0.58) or unsynchronized motion cues (M=4.04, SD=0.46, $F(2,94)=146.089$, $p<0.0005$), supporting H1-2.

Consistent with H1-1, the same results were revealed regarding the co-presence perceived by others ($F(2,94)=213.595$, $p<0.0005$). Participants perceived the remote sender's involvement as higher when communicating with the remote sender through a telepresence robot with synchronized motion cues (M=4.80, SD=0.58) than they did with one with unsynchronized motion cues (M=4.20, SD=0.55) and one without motion cues (M=2.72, SD=0.51). As predicted by H1-2, participants felt less co-presence perceived by

others when interacting with a telepresence robot without motion cues (*M*=2.72, *SD*=0.51) than either with synchronized (*M*=4.80, *SD*=0.58) or unsynchronized motion cues (*M*=4.20, *SD*=0.55, *F*(2,94)=213.595, *p*<0.0005).

4.1.2. Social Presence of a Remote Sender

As predicted by H2-1, participants felt more social presence of a remote sender when interacting through a telepresence robot with synchronized motion cues (*M*=4.65, *SD*=0.72) than a robot with unsynchronized motion cues (*M*=4.12, *SD*=0.40) and a robot without motion cues (*M*=2.59, *SD*=0.55, *F*(2,94)=187.605, *p*<0.0005). As predicted by H2-2, participants perceived less social presence toward a remote sender when interacting with a telepresence robot without motion cues (*M*=2.60, *SD*=0.55) than either with a synchronized motion cues (*M*=4.65, *SD*=0.72) or unsynchronized motion cues (*M*=4.13, *SD*=0.40, *F*(2,94)=187.605, *p*<0.0005).

4.2. Presence of a Robot

4.2.1. Co-presence of a Robot

Unlike the results from evaluating the co-presence of a remote sender, when a telepresence robot shows unsynchronized movements (*M*=4.77, *SD*=0.64), participants perceived more co-presence toward a robot than when a robot shows synchronized movements (*M*=4.05, *SD*=0.60), and when a robot does not show any movements (*M*=3.71, *SD*=0.81, *F*(2,94)=30.274, *p*<0.0005), supporting H3-1. As predicted by H3-2, participants perceived less sense of robot co-presence when interacting with a robot without motion cues (*M*=3.71, *SD*=0.81) than either with a synchronized motion cues (*M*=4.05, *SD*=0.60) or unsynchronized motion cues (*M*=4.77, *SD*=0.64, *F*(2,94)=30.274, *p*<0.0005).

4.2.2. Social Presence of a Robot

As predicted by H4-1, participants perceived more social presence toward a telepresence robot with unsynchronized motion cues (*M*=5.03, *SD*=0.68) than a robot with synchronized motion cues (*M*=4.16, *SD*=0.57) and a robot without motion cues (*M*=3.88, *SD*=0.89, *F*(2,94)=34.542, *p*<0.0005). As predicted by H4-2, participants felt less social presence of a robot when interacting with a robot without motion cues (*M*=3.88, *SD*=0.89) than either with synchronized motion cues (*M*=4.16, *SD*=0.57) or unsynchronized motion cues (*M*=5.03, *SD*=0.68, *F*(2,94)=34.542, *p*<0.0005).

5. Discussion

5.1. Summary and Interpretations

In this study, we examined the impact of the synchronized motion cues on presence. H1-1 predicted that a telepresence robot with synchronized motion cues would increase the co-presence of a remote sender, compared to one with unsynchronized motion cues and one without motion cues. The results of this study supported H1-1. These findings provide further evidence that people feel more involvement and connection with a remote sender, and so as their interaction partner does during the telecommunication when a telepresence robot provides synchronized motion cues with a remote sender's movement.

In addition, we also predicted that a telepresence robot without motion cues could decrease the co-presence of a remote sender than either one with synchronized motion cues or unsynchronized motion cues. The results of this study supported H1-2. The findings suggest that when a telepresence does not provide any physical motion cues, the user becomes distracted by a robot, as the telepresence robot's physical embodiment

causes receiver confusion. This implies that a telepresence robot's physical embodiment without motion cues makes the user to hardly feel as if the user and his/her interaction partner are physically together and mentally connected during the interaction.

H2-1 predicted that a telepresence robot with synchronized motion cues could increase the social presence of a remote sender more than one with unsynchronized motion cues and one without motion cues. The results of this study also supported H2-1. These findings indicate that the telecommunication with a telepresence robot with synchronized motion cues can allow the user to feel as if their interaction partners are present in the same space, and to access their interaction partners' thoughts, emotions, and physicality.

In addition, we also predicted that a telepresence robot without motion cues could decrease the social presence of a remote sender than either one with synchronized motion cues or unsynchronized motion cues. The results of this study supported H2-2. These findings can be interpreted as when a telepresence robot without motion cues is used in mediated communication, physical embodiment itself can cause increased user distraction, prevent them from accessing the interaction partners' thoughts, emotions, and physicality.

As predicted by H3-1 and H4-1, people rated a telepresence robot with unsynchronized motion cues as having more co-presence and social presence than one with synchronized motion cues. The results of this study supported H3 and H4. This implies that even though a telepresence robot with unsynchronized motion cues can engender confusion regarding the remote sender's presence, such robots are nevertheless effective at promoting their own presence.

In addition, H3-2 and H4-2 predicted that a telepresence robot without motion cues would yield decreased robot co-presence and social presence than a robot with motion cues, either with a synchronized motion cues or unsynchronized motion cues. The results of this study supported H3-2 and H4-2. This implies that providing motion cues with physical embodiment in robot-mediated communication is essentially needed for increasing presence of a robot itself.

5.2. Implications for Design

From the results of the study, we derived implications for the design of telepresence robots. The results of this study suggest that a telepresence robot with synchronized motion cues has a positive effect on perceived presence of the remote sender. The telepresence robot with synchronized motion cues can be effectively used by users who prefer to feel the emotional and physical presence of the interaction partner, such as in business where employers are using telepresence robots to stay in contact with their employees, in interactions where negotiation is a key factor, in educational settings where the teacher is using a telepresence robot to teach while maintaining control of the classroom, and in medical settings where doctors are using a telepresence robot to prescribe treatment plans for patients by providing emotional comfort.

On the other hand, the results of this study showed that even though unsynchronized movements of a robot distort presence of a remote sender, it is effective on building presence of a robot itself. The telepresence robot with unsynchronized motion cues can be effectively used in certain situations. According to Tanaka *et al.*'s study [18], Japanese children become stiff and encounter difficulties when facing a teacher who speaks a different language even in video-mediated communication. A telepresence robot with unsynchronized motion cues can alleviate tension of children through increasing presence of a robot rather than a remote sender in mediated communication.

5.3. Limitations and Future Work

Our study was subject to several limitations. Whereas our results provide a first glimpse into the effects of the synchronized motion cue facilitated by a telepresence robot

on presence, we could not examine the effects of movements across all possible gestures or scenarios. Follow up studies could compare whether larger or smaller motions, or alternative facial expressions and gestures, would be more or less effective than those we used in this study. We will also examine the further influence of mismatch cues between a remote sender and a robot. In this study, unsynchronized motion cues of a robot just shows different, independent movement from remote sender's movement. We considered inconsistency to be a lack of complementary cues. As a future study, we considered a robot design with contradictory movement cues. For example, when a remote sender nods as a sign of "yes" then, a robot actively makes shaking motion as a contradictory sign of "no."

6. Conclusions

This study investigated the effects of synchronized motion cues on the perception of presence in robot-mediated communication. Participants reported that a telepresence robot with synchronized motion cues was more effective at conveying presence of a remote sender than a robot with unsynchronized motion cues and a robot without motion cues. Unlike a telepresence robot with synchronized motion cues, a telepresence robot with unsynchronized motion cues was reported to be better at increasing presence of a robot itself. Further, a telepresence robot without motion cues generated a less sense of remote sender and robot presence than a robot with motion cues, either with synchronized motion cues or with unsynchronized motion cues. These results provide a basis for designers to determine the effect of synchronized motion cues in terms of conveying the co-presence and social presence of the remote sender or increasing the co-presence and social presence of a robot in robot-mediated communication.

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